Carnegie Mellon University

Undergraduate Catalog
2019 – 2020

College of Engineering

College of Fine Arts

Dietrich College of Humanities and Social Sciences

Heinz College of Information Systems and Public Policy

Mellon College of Science

School of Computer Science

Tepper School of Business

Carnegie Mellon University in Qatar

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About CMU

Carnegie Mellon is a private, internationally ranked (https://www.cmu.edu/about/rankings.html) research university with programs in areas ranging from science, technology and business, to public policy, the humanities and the arts. More than 14,000 students in the university’s seven schools and colleges benefit from a small student-to-faculty ratio and an education characterized by its focus on creating and implementing solutions for real problems, interdisciplinary collaboration and innovation.

Undergraduate students can pursue majors in six of the university's seven colleges: the College of Engineering, the College of Fine Arts, the Tepper School's business administration program, the Dietrich College of Humanities and Social Sciences, the Mellon College of Science, and the School of Computer Science.

CMU is positioned like never before to meet the challenges of the 21st century. At the intersection of technology and humanity, CMU research, innovation and creativity will continue to guide our future as a world-class university.

As outlined in the Strategic Plan 2025 (http://www.cmu.edu/strategic-plan), the university will focus on advancing the individual student experience, the broader Carnegie Mellon community experience, and the social impact of Carnegie Mellon throughout the world.

Take a closer look at CMU (p. 5).

Vision & Mission

Vision

Carnegie Mellon University will have a transformative impact on society through continual innovation in education, research, creativity, and entrepreneurship.

Mission

To create a transformative educational experience for students focused on deep disciplinary knowledge; problem solving; leadership, communication, and interpersonal skills; and personal health and well-being.

To cultivate a transformative university community committed to (a) attracting and retaining diverse, world-class talent; (b) creating a collaborative environment open to the free exchange of ideas, where research, creativity, innovation, and entrepreneurship can flourish; and (c) ensuring individuals can achieve their full potential.

To impact society in a transformative way — regionally, nationally, and globally — by engaging with partners outside the traditional borders of the university campus.

Look at Carnegie Mellon

CMU's History

In a letter written in 1900, industrialist and philanthropist Andrew Carnegie offered to give the city of Pittsburgh $1 million in bonds to found a technical institute. The city provided 32 acres of land near Schenley Park, and the institution became known as the Carnegie Technical Schools. According to Carnegie's plans, the institution would train the sons and daughters of working-class families in five schools: Science and Technology, to train draftsmen and engineer's assistants; Fine and Applied Arts, for designers and art workers; Apprentices and Journeymen, for mechanics in manufacturing and construction; and Margaret Morrison Carnegie College, for home economists or secretaries. Within two decades, the Carnegie Technical Schools offered bachelor's, master's and doctoral programs, and fittingly changed its name to the Carnegie Institute of Technology.

In 1967, the trustees of the Mellon Institute and the Carnegie Institute of Technology merged the two institutions and adopted the name Carnegie Mellon University. In 1968, Margaret Morrison Carnegie College closed and the university organized a new College of Humanities and Social Sciences. New graduate-level colleges and schools also flourished, including the Graduate School of Industrial Administration (GSIA), the Heinz College of Public Policy and Management, and the School of Computer Science. As time progressed, new research centers and institutes developed on and off campus in specialties ranging from art conservation to sustainable computing. In 2004, GSIA was renamed the Tepper School of Business after alumnus David A. Tepper.

Over time, the Carnegie Institute of Technology has developed from a regional, technical college into Carnegie Mellon University, a selective, international research university that ranks among the nation's best colleges.

A Unique Educational Experience

The university's diverse community, focus on strong student-faculty ties and commitment to education outside the classroom combine to create a learning environment that is as uniquely Carnegie Mellon as the Tartan plaid on the kilts of its bagpipers.

Carnegie Mellon strives for a campus culture that reflects a fundamental respect for different ways of living, working, and learning so every student has the opportunity to reach their potential.

A Carnegie Mellon education is marked by its strong focus on fundamental and versatile problem-solving skills in a specific discipline, but the university respects and values students' varied talents and interests that often span many specialties. Students can explore more than one field of study while developing the strong professional core that is the hallmark of a Carnegie Mellon education. The university encourages students to expand their thinking in new and exciting dimensions.

CMU's faculty conduct groundbreaking research, create new and exciting art, and contribute to a growing global scholastic community. They are continuously innovating, and the new knowledge they create and the methods they discover routinely benefit classroom learning. Research is a vital component of undergraduate education at Carnegie Mellon. Students can initiate projects of their own or become involved with existing ones on campus.

A Global Impact

In its 115 years, Carnegie Mellon has soared to national and international leadership in higher education and research. A birthplace of innovation since its founding, it continues to be known for innovation, for solving real-world problems and for interdisciplinary collaboration.

Its alumni can be found across the globe — from Tony Award winners to Nobel Prize and Turing Award winners, from CEOs to entrepreneurs, from professors to artists.

In the 2000s, in response to demand for expanded international educational opportunities, Carnegie Mellon began offering degree programs outside of Pittsburgh. Today its global presence includes campuses in Qatar and Silicon Valley, California, more than a dozen degree-granting locations, and more than 20 research partnerships such as Los Angeles, New York City, Washington, D.C., Australia, Portugal, and Africa.

Undergraduate Admission

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Gregory Edleman, Director of Admission
Location: Warner Hall, 2nd Floor, 5000 Forbes Ave., Pittsburgh, PA 15213
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www.cmu.edu/admission

Admission Philosophy

At Carnegie Mellon, we select our freshman class from a large group of very qualified candidates. We don't use a calculation to arrive at our admitted class. Calculations can't take into account all of the factors we consider when making admission decisions. No single grade, factor, score or activity will automatically gain or deny you admission to Carnegie Mellon. We treat every applicant as an individual and take great care to make our admission decisions fair, thorough, and sensitive. We're interested in students who can be successful at Carnegie Mellon, while taking full advantage of all the university has to offer and enriching our campus community.

Admission Criteria

The majority of our applicants are admissible and could be successful at Carnegie Mellon. We use a variety of factors (https://admission.enrollment.cmu.edu/pages/admission-consideration) to select our first-year class from those admissible candidates.

Our admission process is designed to select a highly talented, diverse undergraduate population with high aspirations, who will succeed at Carnegie Mellon. If you’re applying to academic programs, your high school performance will be a significant factor in our admission decision because it’s the most meaningful indication of your motivation and abilities. We pay close attention to your curriculum rigor, the grades you’ve earned and the work you’ve accomplished. We’re interested in seeing that you’ve challenged yourself within your secondary school environment. If you’re applying to programs in the arts, your artistic performance will be either the main factor or a significant factor (depending on the program) in our admission decision.

Standardized test scores add to our knowledge of a student's ability, but we don't make decisions on the basis of test scores alone. The high school record and standardized test scores (SAT or ACT and, if applicable, recommended SAT Subject Tests) work together to make up the academic portion of a student's evaluation.

Your non-academic activities, including extracurricular accomplishments, part-time jobs, hobbies and community service also play a very important role in the admission process. We also consider leadership, motivation, out-of-class recognition, community and volunteer service and other experiences when making admission decisions. Our students make Carnegie Mellon an exciting campus. The positive qualities and diverse experiences you bring with you will enrich our community. By looking at this non-academic information, we develop a sense of your personality, motivation and responsibility.

Because we want to have a sense of who the applicant is as a person, we look closely at your Common Application essay, your short answer questions, the secondary school counselor's evaluation and the teacher's recommendation.

We do not consider demonstrated interest in our admission paradigm. Demonstrated interest is a term used in undergraduate admission that describes the ways in which a prospective student shows a college that they’re interested by visiting campus and submitting additional materials that aren’t required in the application. As a result, we do not consider a campus visit or communication with the Office of Admission or other members of the Carnegie Mellon community when making admission decisions.

Learn how Carnegie Mellon considers criminal justice information in the admission review process here (https://admission.enrollment.cmu.edu/pages/criminal-justice-information).

Different Criteria for Different Colleges

Each college/program at Carnegie Mellon has admission criteria specifically related to each course of study.

Admission to the Schools of Drama and Music is based primarily on a pre-screen, audition or portfolio review (http://cmu.edu/admission/finearts). Applicants to the Schools of Architecture, Art and Design will be evaluated not only on the basis of their portfolio review (http://cmu.edu/admission/finearts) but also on their academic performance.

Applicants to the College of Engineering, Mellon College of Science, and School of Computer Science will be evaluated on the basis of academic performance, and we'll look additionally for strength in mathematics and science. Academic performance is also the main criteria we use to evaluate applicants to the Dietrich College of Humanities and Social Sciences, Information Systems program and Tepper School of Business' undergraduate program. With these programs, we emphasize reading and comprehension abilities as well as mathematics courses.

Applicants should be aware of our admission requirements (http://admission.enrollment.cmu.edu/pages/admission) (secondary school preparation, standardized test requirements, nonacademic information, counselor, teacher and interview recommendations) when submitting applications.

Application Instructions

The following instructions are applicable to first-year, incoming undergraduate students. Graduate students should refer to the Graduate Education website (https://www.cmu.edu/graduate/admissions) for application instructions.

1. Applicants must apply online by completing the Common Application (http://www.commonapp.org) and submitting the $75 application fee. We require this fee of all applicants except in extenuating financial circumstances.
2. Request that your secondary school counselor submit all high school transcripts, including senior year courses, mid-year grades and a school profile to the Office of Admission (preferably online) as close to the deadline as possible. Visit our website (https://admission.enrollment.cmu.edu/pages/application-plans-deadlines) for Early and Regular Decision deadlines.
3. Apply for admission only to the specific college(s) or programs in which you’re interested.
    a. Rank your program and/or major preference; applicants may apply to a maximum of two colleges/programs. Applicants are typically considered for their highest preference academic program.
    b. If you’re applying to more than one college/program, there’s no need to submit multiple applications and no additional application fee. However, you should describe your interest in each program in your Carnegie Mellon essay.
    c. Be sure to review the academic requirements (https://admission.enrollment.cmu.edu/pages/academic-requirements) for each college/program.
    d. Early Decision and transfer candidates will only be considered for their first choice college/program.
4. If you’re applying to the College of Engineering, Dietrich College of Humanities and Social Sciences, Information Systems, Mellon College of Science, School of Computer Science, or Tepper School of Business, we strongly urge you to indicate a program and/or major preference at the time you apply. Although you might not declare a major until the end of your freshman or sophomore year, we do limit access to certain majors, such as electrical and computer engineering, computer science and business.
5. If you’re applying to the College of Fine Arts, you must apply specifically to one of the following schools: Architecture, Art, Design, Drama or Music. (See specific instructions to follow.)
6. If you're applying to the School of Music, an additional pre-screen/audition/portfolio review fee of $50 is required. If you're applying to the School of Drama, an additional pre-screen/audition/portfolio review fee is $115 is required. If you're applying to the School of Art, Architecture, or Design, an additional portfolio review fee of $15 is required. These fees must be paid at the time of registration (http://cmu.edu/admission/finearts).
7. Take the SAT or ACT and recommended SAT Subject Tests, preferably by November but no later than December. Review our standardized test requirements (http://admission.enrollment.cmu.edu/pages/standardized-test-requirements) for more details.
    a. You must submit all official scores electronically through College Board, ACT or the Educational Testing Service (ETS). When you register for the test, request that an official score report be sent directly to Carnegie Mellon. Make sure your name, address and birthdate on your application matches the information used to register for these tests. The Carnegie Mellon code number is 2074.
8. The Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS) is required if your native language is not English. Carnegie Mellon requires (http://admission.enrollment.cmu.edu/pages/standardized-test-requirements)

102 or higher on the IBT TOEFL, and an IELTS scores of 7.5 or above. Please arrange to have these scores sent by the appropriate deadline (https://admission.enrollment.cmu.edu/pages/application-plans-deadlines).

9. If you are applying to the College of Fine Arts, you must complete pre-screen, audition or portfolio review requirements (http://admission.enrollment.cmu.edu/pages/fine-arts-admission). The Schools of Art, Architecture, Design, Drama and Music require that students apply to the university before registering for a pre-screen, audition or portfolio review. There is no Early Decision consideration given for acting, directing, dramaturgy, music theater or the School of Music.
10. You must sign the "Confidentiality Statement" on the Common Application School Report Form and give it to your secondary school counselor for completion. Your counselor should return this form, along with the school profile and your transcript.
11. Choose a teacher to complete the Common Application Teacher Recommendation Form and make sure it is submitted to the Office of Admission by the application deadline (https://admission.enrollment.cmu.edu/pages/application-plans-deadlines).
12. Our Regular Decision application deadline is January 1. The Schools of Drama and Music's Regular Decision deadline is December 1.
13. If you are applying for financial aid, please visit the Applying for Aid section of our website (http://admission.enrollment.cmu.edu/pages/applying-for-aid). We require financial aid applicants to complete the Free Application for Federal Student Aid (FAFSA) (http://www.fafsa.gov). Carnegie Mellon's federal code is 003242. You must also complete the CSS PROFILE (https://profileonline.collegeboard.com) and submit signed copies of parent and student tax documents.

Application Notification

- Students applying under the Early Decision Plan will be notified of our decision no later than December 15.
- Students applying under the Regular Decision Plan will be notified of our decisions no later than April 15.
- Students who are applying for financial aid will also receive financial aid decisions no later than April 15 provided they submitted their financial aid forms by the February 15 financial aid deadline.

If you are offered admission and wish to enroll at Carnegie Mellon, you are required to pay an $800 non-refundable enrollment deposit by May 1 in order to reserve your place in the freshman class and in university housing. This deposit will be credited to your first semester's charges. The admission staff assumes that a student's deposit to Carnegie Mellon is their only deposit. We reserve the right to cancel our offer of admission if a student also posts a tuition deposit at another university. During the summer, information concerning registration, enrollment, insurance, orientation, housing and dining services, etc., will be communicated to all incoming students.

Deferred Admission

If you are admitted to Carnegie Mellon and wish to defer your admission for one year, you must submit a written request to the Office of Admission. If permission is granted, your enrollment deposit must be paid in order to confirm enrollment for the following year. You cannot enroll in a degree program at another institution in the interim.

Application Plans

Early Decision Plan (http://admission.enrollment.cmu.edu/pages/application-plans-deadlines)

If Carnegie Mellon is your first choice, you may want to consider applying Early Decision. Under this plan, applicants are notified of their admission decision early in their senior year. If you're accepted Early Decision, you're in a binding agreement to enroll at Carnegie Mellon. When applying under the Early Decision plan, we encourage you to submit non-binding applications to other schools. However, if you're accepted to Carnegie Mellon, we require you to withdraw your applications from other schools. Early Decision is available to all programs, with the exception of acting, directing, dramaturgy, music theater and the School of Music.

Early Decision applications are due November 1, and students will be notified of an admission decision no later than December 15. If you are admitted under Early Decision, you are required to withdraw all admission applications to other colleges or universities and post a non-refundable enrollment deposit of $800 by February 1.

Regular Decision Plan (http://admission.enrollment.cmu.edu/pages/application-plans-deadlines)

Regular Decision is our most popular application option. The deadline is January 1 (December 1 for Drama and Music applicants). You will be notified of your decision no later than April 15. Admitted students will have until May 1 to accept our offer of admission.

Early Admission (http://admission.enrollment.cmu.edu/pages/application-plans-deadlines)

Through the process of Early Admission, the university admits certain highly qualified applicants at the end of their junior year in high school. In general, Early Admission candidates are highly mature and responsible students who have usually exhausted the courses offered at their high schools without receiving a high school diploma. Early Admission applicants must follow the same procedures as regular freshman applicants. We also strongly encourage these applicants to have a discussion with a member of the Office of Admission staff. It's important to note that the College of Fine Arts very rarely accepts Early Admission applicants.

Transfer Applicants

Transfer students are admitted to Carnegie Mellon under policies that vary from college to college (http://admission.enrollment.cmu.edu/pages/transfer-admission). If there is space in the requested program, we'll base our decision on your college grades, college recommendations, high school grades and test scores (SAT or ACT and SAT Subject Tests, if previously taken). In the College of Fine Arts, most transfer applicants compete with freshman applicants for a place in the entering class and are required to complete a pre-screen, audition or portfolio review (http://cmu.edu/admission/finearts).

Transfer Application Instructions

1. Apply for admission to your specific college of interest, noting departmental preference if applicable. Transfer students will only be considered for one college.

   Engineering, DC, IS, MCS, SCS or Tepper:
   • Fall transfer possible if space is available
   • Spring transfer is extremely limited due to space constraints
   • No external transfers accepted into BHA/BSA/BCSA

   CFA:
   • Only fall transfer is available for fine arts applicants
   • Transfer applicants are considered alongside freshman applicants and are likely to be given first-year status
   • No external transfers accepted into BHA/BSA/BCSA

2. A $75 application fee is required.

3. Send all secondary/high school and college/university transcripts to the Office of Admission. We also require a copy of course descriptions from a college catalog from each college/university you attended. Course descriptions should be sent by email to admission@andrew.cmu.edu with the subject line "Transfer Course Descriptions." Course descriptions should be copied and pasted into a single .pdf document and must have your name and address on the first page.

4. If you are applying to the College of Fine Arts, you must complete any pre-screen, portfolio or audition requirements (http://cmu.edu/admission/finearts) by the appropriate fine arts application deadline.

5. A recommendation from a professor or advisor should be submitted in place of a college counselor recommendation. The College Report (a Common Application form) is also required from your current academic institution. This form should be completed by your college/university registrar or appropriate dean/college official who can verify your enrollment and academic standing.

6. Transfer application deadlines are as follows:

   • Spring transfer: October 15
   • Fall transfer: February 15 (December 1 for performing arts, January 1 for visual arts)

7. If you are applying for financial aid, please visit the Applying for Aid (http://admission.enrollment.cmu.edu/pages/applying-for-aid) section of our website. We require financial aid applicants to complete the Free Application for Federal Student Aid (FAFSA) (http://www.fafsa.gov). Carnegie Mellon's federal code is 003242. You must also complete

the CSS PROFILE (https://profileonline.collegeboard.com) and submit signed copies of parent and student tax documents.

If planning on:	**File FAFSA by this date:**
Spring transfer	**November 1**
Fall transfer (CFA)	**February 15**
Fall transfer (all other colleges)	**March 1**

Admission and financial aid award notification dates for transfer students:

Spring transfer:	**December 15 or soon after**
Fall transfer (CFA):	**April 15**
Fall transfer (all other colleges):	**May 15**

If admitted, you will need to make arrangements to have a final copy of your college transcript(s) sent to Carnegie Mellon.

Deposit Information for Transfers

If you are offered admission for the spring semester, Carnegie Mellon does not require a tuition deposit due to the short time interval between December 15 and the start of the spring semester. If you are offered admission to the College of Fine Arts for the fall semester, you must pay a non-refundable deposit of $800 by May 1. If you are offered admission to Engineering, DC, IS, MCS, SCS, or Tepper for the Fall semester, you must pay a non-refundable $800 deposit by June 15, even if you are receiving financial aid. The enrollment deposit will reserve your place at the university and a place in university housing if available. It will be credited to the first semester charges.

IMPORTANT: If you accept our offer of admission, Carnegie Mellon assumes that the tuition deposit to Carnegie Mellon is your only tuition deposit. We reserve the right to cancel our offer of admission if you post a tuition deposit at more than one university. Enrollment deposits received after the deadline may be returned if space is no longer available.

University Housing for Transfers

Carnegie Mellon expects to accommodate most transfer students who request university housing, but it is not guaranteed. The Off-campus Housing Advisory and Referral Service is available to help you locate housing accommodations in the local area.

Transfer Credit Evaluated on Individual Basis

Carnegie Mellon's departmental faculty will determine transfer credit for courses you've taken at other universities. Transfer credit is considered on an individual basis. We may award elective credit for courses with no Carnegie Mellon equivalent. In some instances, the College Council may recommend a special program of study for you to meet the university's graduation requirements.

Transfer credit for courses you are taking while we review your existing college record depends upon successful completion of each course. Grades are not transferred - only credit is. You may receive transfer credit for elective courses you've taken but will still have to take Carnegie Mellon courses to fulfill the elective space in your chosen degree program. Sometimes transfer students have to take specific courses and accumulate a larger total number of credits than the normal amount required for graduation. The time it takes for you to graduate will depend on the time you need to complete the full university degree requirements, not on class standing at a previous institution.

If you transfer into Engineering, IS, MCS, SCS or Tepper in the Fall semester, you will receive an estimate of the additional academic work that you must complete in order to fulfill the university degree requirements. If you transfer into Engineering, IS, MCS or SCS in the Spring semester, you will have the opportunity to meet with a dean or department head in order to outline the additional academic work that you must complete in order to meet the university degree requirements. If you transfer into DC in the fall or spring semester, you'll receive a credit and requirement review of the work you've completed at your previous institution(s). It is best for transfer students in CFA to assume that they'll receive freshman status. Occasionally advanced standing is awarded based on review of previous college courses.

Application as an International Student

International students should apply to Carnegie Mellon using the same procedures outlined for either freshmen or transfer students. Also note this additional information (http://admission.enrollment.cmu.edu/pages/undergraduate-international-students):

- Carnegie Mellon does not offer financial aid or installment plans to international students. International students are not eligible for application fee waivers.
- If your native language is not English, you are required (https://admission.enrollment.cmu.edu/pages/international-admission-requirements) to take the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS). Carnegie Mellon requires 102 or higher on the IBT TOEFL or an IELTS score of 7.5 and above. Please arrange to have these scores sent by the appropriate deadline (https://admission.enrollment.cmu.edu/pages/application-plans-deadlines).
- InitialView interviews are recommended for non-native English speakers but are not required. Often these interviews can measure readiness for engagement in the classroom and also showcase a student's personality, likes and dislikes, as well as the area of intended major. InitialView interviews can show English language proficiency while also corroborating the application with more details about the student.

Advanced Placement Consideration

Advanced Placement Program

Carnegie Mellon recognizes the Advanced Placement program and may grant advanced placement and credit for test scores of four or five (http://admission.enrollment.cmu.edu/pages/standardized-test-requirements). We encourage eligible students to take the AP examinations. We will receive the test scores in early summer for those students who have requested that their results be sent to Carnegie Mellon. The appropriate academic deans will evaluate your scores, and in late summer, you will be informed of the AP credit awarded.

College Level Course Work

The university may also award placement and credit for college work completed during high school. Applicants who have taken college courses should arrange to have their college transcripts along with course catalogs or descriptions sent to the Carnegie Mellon Office of Admission for transfer credit evaluation and advanced placement.

International Baccalaureate Program

Carnegie Mellon also recognizes the International Baccalaureate Examination and may grant advanced standing and/or credit in various fields if scores on the higher level examination range from six and seven. (http://admission.enrollment.cmu.edu/pages/standardized-test-requirements) The results of the IB exams should be sent to Carnegie Mellon, where the appropriate dean will evaluate the scores. In late summer, you will be notified of the credit that has been awarded.

Cambridge General Certificate of Education

Carnegie Mellon recognizes the Cambridge GCE A-Level (advanced level) examinations in various higher-level subjects and may grant advanced placement and/or credit for exemplary grades (http://admission.enrollment.cmu.edu/pages/standardized-test-requirements). Please note that we don't accept GCE "O" level examinations for placement.

BXA Intercollege Degree Programs

The BXA programs are intercollege degree-granting programs designed for students who'd like to combine and blend their interests in the fine arts and one of the following academic areas: computer science (BCSA), humanities/social sciences (BHA), natural sciences/mathematics (BSA). To apply for a BXA program, select the College of Fine Arts school you wish to apply for and then you'll be asked if you'd like to be considered for a BXA program.

Bachelor of Computer Science and Arts (BCSA)

To be considered for the BCSA program, you must apply and be admitted to both CFA and SCS (you must select a CFA school and SCS major on the Common Application). This program is not open to design, music theater, or acting majors. Not all students admitted to both colleges are selected for the BCSA program.

Bachelor of Humanities and Arts (BHA)

To be considered for the BHA program, a student must apply and be admitted to both CFA and DC (you must select a CFA school and DC major on the Common Application). This program is not open to design, music theater, or acting majors. Not all students admitted to both colleges are selected for the BHA program.

Bachelor of Science and Arts (BSA)

To be considered for the BSA program, a student must apply and be admitted to both CFA and MCS (you must select a CFA school and MCS major on the Common Application). This program is not open to design, music theater, or acting majors. Not all students admitted to both colleges are selected for the BSA program.

In your accompanying application essay, please describe your interdisciplinary goals in both areas and how the BXA program would provide the opportunity and framework for you to accomplish these objectives. This essay is a central component in the selection process. You do not need to complete another essay. If you are selected for this program, you will be notified in your admission decision letter. These programs are not available for external transfers; selected program options are not available under Early Decision.

College of Fine Arts Requirements

Detailed information may be found on the Office of Admission website (http://cmu.edu/admission/finearts).

Deadlines

- Early Decision applicants must submit a complete admission application, including any required artistic evaluation, by November 1.
- Regular Decision applicants to Drama and Music must apply and make all pre-screen, audition or portfolio review reservations (http://cmu.edu/admission/finearts) by December 1.
- Regular Decision applicants to Art, Architecture and Design must apply by January 1 and submit their portfolio (http://cmu.edu/admission/finearts) no later than January 15.
- We recommend that you apply for admission as early as possible in order to register for a pre-screen, audition or portfolio review (http://cmu.edu/admission/finearts), which fill on a first-come, first-served basis.

Communication of Information and Admissions Decisions

- Final admission decisions are not made at the time of your audition or portfolio review. We will consider the artistic evaluation as part of your application along with your other credentials and notify you of your admission decision no later than April 15 (December 15 for Early Decision applicants).

Visit our fine arts admission procedures website (http://cmu.edu/admission/finearts) for details regarding the specific requirements for fine arts auditions and portfolio reviews.

Exploring Carnegie Mellon

Visiting a campus is one of the best ways for you to discover which school is right for you. You are welcome to attend an information session or admission counseling session (http://admission.enrollment.cmu.edu/pages/visit) while on campus.

Campus Tours

Campus tours (http://admission.enrollment.cmu.edu/pages/visit) are conducted by Andrew Ambassadors. We offer tours most weekdays and weekends during the academic year.

Hometown Counseling Sessions

We realize that it's not always possible for you to come to campus. The Admission staff does travel to different parts of the country and may offer Admission Counseling Sessions in your hometown (https://admission.enrollment.cmu.edu/pages/visit-carnegie-mellon-in-a-city-near-you).

Turn Tartan Overnight Weekends

The more information you have, the better decisions about college you'll make! The Admission staff invites you to learn more about Carnegie Mellon by living like a university student for a day and a half in our Turn Tartan Overnight (http://admission.enrollment.cmu.edu/pages/turn-tartan-overnight) program. Visits begin on Sunday morning and last through Monday afternoon.

Information Sessions

The Office of Admission offers information sessions (http://admission.enrollment.cmu.edu/pages/visit) throughout the year, both on and off campus. The session offers an experiential look at the university through student and faculty stories. You'll have the opportunity to learn more about Carnegie Mellon's areas of study, admission, financial aid, and the city of Pittsburgh.

Contact Carnegie Mellon for Assistance

If a student will need assistance while visiting the campus, due to a physical or learning disability, they should contact us at admission@andrew.cmu.edu or 412-268-2082, and we will help meet the student's needs during his/her visit at Carnegie Mellon.

Getting to Campus

Plan your visit to Carnegie Mellon using our Maps & Directions webpage (http://admission.enrollment.cmu.edu/pages/maps-directions). We also provide information on Travel and Accommodations (http://admission.enrollment.cmu.edu/pages/pittsburgh-travel-accommodations) to assist you in your planning.

Summer Pre-College Programs

Our Summer Pre-College Programs (https://www.cmu.edu/student-affairs/pre-college) are designed to preview an actual college experience. Our programs afford high school students many opportunities for personal growth and development within a university setting. A wide range of social, cultural, and recreational activities are planned by a staff of resident counselors to fully integrate the students' lives on campus and in Pittsburgh. Movies, dances, museum and gallery visits, field excursions or attendance at professional theater productions, concerts, and Pittsburgh Pirates games are just a few of the sponsored activities. Please visit the Office of Admisson Pre-College website (http://admission.enrollment.cmu.edu/pages/pre-college) for information about applying to the program.

Summer Academy for Mathematics and Science (http://admission.enrollment.cmu.edu/pages/summer-programs-for-diversity)

Students from underserved and underrepresented backgrounds who are entering their senior year and considering careers in computer science, engineering, science and other math-based disciplines are eligible to participate in this rigorous program. Traditional classroom instruction, along with creative "hands-on" projects will allow students to apply concepts and principles.

Advanced Placement Early Admission Program (http://admission.enrollment.cmu.edu/pages/pre-college)

The main purpose of the Advanced Placement Early Admission (AP/EA) Program is to provide the opportunity to take university courses at Carnegie Mellon for talented, motivated high school students. Students earn college credit while working in an academic environment mirroring that which the student would encounter during the first year of college.

Students who complete two courses in the AP/EA Program and who can graduate early from high school have the unique opportunity to apply Early Admission. All AP/EA students may also apply to Carnegie Mellon during their senior year, through Early Decision or Regular Decision.

Regardless of whether students choose to apply to Carnegie Mellon, successful AP/EA students can leverage their experiences here as demonstration of their ability to succeed in college. AP/EA courses are college courses, not AP classes, and as such they count toward graduation requirements here and are widely accepted elsewhere. Students applying to another college or university can request an official Carnegie Mellon transcript be sent to that institution. Any use of AP/EA courses to satisfy high school requirements should be approved ahead of time by an appropriate high school official.

Pre-College Architecture Program (http://admission.enrollment.cmu.edu/pages/pre-college-architecture)

The study of architecture is an exciting multidisciplinary activity that combines design creativity, historical perspective, technical excellence, social responsibility, and global and environmental leadership. The Pre-College Architecture Program is structured to introduce you to each of these areas and for you to experience studying architecture in a university setting.

Pre-College Art Program (http://admission.enrollment.cmu.edu/pages/pre-college-art)

The Summer Pre-College Art program motivates, stimulates, and prepares you as an emerging artist. Exploring traditional tools and new technologies in a variety of media leads you to develop conceptual and technical skills, excellent preparation for applying to and succeeding in a competitive college-level art program. You'll be introduced to the spirit and substance of the Carnegie Mellon School of Art culture through challenging courses, critique, stimulating workshops, portfolio development, and energetic interaction with dedicated faculty and talented peers.

Pre-College Design Program (http://admission.enrollment.cmu.edu/pages/pre-college-design)

Designers help create the artifacts and environments of our everyday experiences. Designers are responsible for creating the things we interact with -- from software applications, to magazines and books, to automobiles, to toothbrushes. Beyond products and communications, some designers are now responsible for re-thinking the environments that we live and work in, from retail spaces to the studios of the future. Over six weeks, the Pre-College Design program provides core experiences in the communication, product, and environment design processes led by experienced design faculty and design practitioners.

Pre-College Drama Program (http://admission.enrollment.cmu.edu/pages/pre-college-drama)

The Pre-College program in Drama allows talented high school students to experience professional theater training. The program provides an opportunity for aspiring artists to experience the rigorous demands of college-level theater programs options, including Acting, Music Theater, and Design/Production.

Pre-College Music Program (http://admission.enrollment.cmu.edu/pages/pre-college-music)

The summer Pre-College Music program offers a unique view of the life of a music student at Carnegie Mellon in a supportive environment of study and performance. It is an ideal opportunity to experience a world-class conservatory program and discover your potential for a career in music. Coupled with the rich cultural life of the city of Pittsburgh and varied campus activities, the summer Pre-College Music program is an extraordinary way for young musicians to spend their summer.

National High School Game Academy (http://admission.enrollment.cmu.edu/pages/pre-college-nhsga)

The National High School Game Academy (NHSGA) explores the video game industry and the skills needed to be successful in it. The program includes an exciting blend of hands-on exercises combined with traditional lecture and discussion. Students are encouraged to expand their own creative possibilities in a unique blend of left- and right-brain college-level work.

Cost of Attendance

The cost of attendance listed below references typical resident, commuter and off-campus undergraduate students. The academic year tuition charges are for full-time undergraduate students. A full-time student is one registered in a degree program and carrying a schedule of at least 36 units per semester. A student enrolled for less than 36 units per semester will be charged tuition on a per-unit basis. The university reserves the right to change its charges without notice.

Freshmen Entering Fall 2019

Per-unit tuition rate: $776

	Resident	Commuter
Tuition	55,816	**55,816**
Orientation Fee (Fall semester only)	375	**375**
Activity Fee	264	**264**
Transportation Fee	224	**224**
Media Fee	10	**10**
Technology Fee	430	**430**
Room & Fees (1)	8,822	**0**
Dining (2)	6,150	**3,075**
Books/Supplies & Miscellaneous (3)	2,400	**2,400**
Travel Allowance (3, 4)	0	**680**
Totals	**$74,491**	**$63,274**

Undergraduate Students Who Entered Fall 2015-2018

Per-unit tuition rate: $776

	Resident	Commuter	Off-Campus
Tuition	55,816	55,816	**55,816**
Activity Fee	264	264	**264**
Transportation Fee	224	224	**224**
Media Fee	10	10	**10**
Technology Fee	430	430	**430**
Room & Fees (1)	8,822	0	**8,322**
Dining (2)	6,150	3,075	**6,150**
Books/Supplies & Miscellaneous (3)	2,400	2,400	**2,400**
Travel Allowance (3, 4)	0	680	**0**
Totals	**$74,116**	**$62,899**	**$73,616**

Footnotes:

[1] All incoming freshmen are required to live on campus. Permission for freshmen to commute must be granted by Student Affairs. Off-campus room rate is estimated at resident room minus $500.

[2] The commuter dining amount is based upon 14 meals per two weeks. Upperclass resident and off-campus dining is estimated; however, dining costs vary according to the plan chosen.

[3] These expenses do not appear on the student account.

[4] Travel allowance for resident and off-campus students varies based on home state.

Health Insurance

In addition, health insurance coverage is required at an estimated cost of $2,685/year. If a student is covered under a family's health plan, a waiver may be submitted to University Health Services for approval. View more details at www.cmu.edu/health-services/student-insurance.

Division of Enrollment Services

Lisa Krieg, Associate Vice President & Director of Enrollment Services and International Programs
Location: Warner Hall A19, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-8084
thehub@andrew.cmu.edu
www.cmu.edu/hub

The Division of Enrollment Services (https://www.cmu.edu/es) includes seven administrative departments: The HUB (https://www.cmu.edu/hub), University Registrar's Office (https://www.cmu.edu/hub/registrar), Student Financial Aid (https://www.cmu.edu/sfs/financial-aid), Student Accounts Office (https://www.cmu.edu/sfs/billing), Summer Studies (https://www.cmu.edu/summer), Enrollment Systems (https://www.cmu.edu/es/enrollment-systems), and the Office of International Education & Study Abroad (https://www.cmu.edu/oie).

The division leads and delivers integrated services that support students' academic goals from enrollment through graduation. Our staff strives to champion collaborative administrative services and counsel for all CMU campuses and programs in alignment with the university's strengths in technology and effectiveness.

VISION

Actively contribute to the attainment of educational goals for all CMU students across the globe.

MISSION

Our staff and services support student success daily and through each stage of enrollment.

The HUB & ID Card Services

Maggie Sikora, *Director of The HUB & Associate Director of Enrollment Services*
Location: Warner Hall A12, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-8084
thehub@andrew.cmu.edu
www.cmu.edu/hub

The HUB Student Service Center

The HUB staff delivers comprehensive service and counsel to students and families regarding financial aid, billing and payment, registration, academic records, and ID Card services. In direct support of student enrollment and persistence, The HUB offers students and families highly integrated information through personal attention and technologically responsive tools in a professional, forward-thinking, and accessible environment.

The Assistant Directors in The HUB serve as liaisons for specific colleges and support enrolled students with key aspects of the enrollment process – financial aid, billing and registration. Contact information for assigned HUB Liaisons can be found on The HUB website (https://www.cmu.edu/hub/contact) or the student's personalized Student Information Online (SIO) account.

Regular office hours for The HUB are: Monday, Wednesday, and Friday (8:30 a.m. to 4:30 p.m.) or Tuesday and Thursday (10:30 a.m. to 4:30 p.m.).

ID Card Services in The HUB

One of the most important items students will need at Carnegie Mellon is their official identification card. The CMU ID Card, administered through The HUB, classifies you as a member of the Carnegie Mellon community and is a part of everyday campus life. From bus access and Plaid Cash to campus events and museum entry, the ID Card is an essential tool for on and off campus.

View more information at www.cmu.edu/idplus.

Student Financial Services

Brian Hill, *Director of Student Financial Services*
Location: Warner Hall A12, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-6651
thehub@andrew.cmu.edu
www.cmu.edu/sfs

Student Financial Aid Office

In alignment with the university's enrollment goals, Student Financial Aid consistently optimizes the utilization of all financial aid resources in order to recruit and retain a high quality and diverse student population. Student Financial Aid strives to deliver superior services that exceed the expectations of students, parents, and internal and external constituencies. Student Financial Aid identifies, creates and delivers strategies that facilitate the integration of financial aid policies. These policies align with current and future university recruitment, retention and enrollment priorities.

How Aid Works

Our financial aid program is need-based, meaning that all aid eligibility is determined by a student's family's financial circumstances. While student's and families have the primary responsibility for paying for college, financial aid can bridge the gap between the total costs and ability to pay.

Nearly half of our undergraduate students rely on some type of financial aid to pay for educational expenses. While many of our graduate students are offered departmental scholarships, grants, stipends, assistantships and fellowships, some rely on other resources, like federal loans, available through the Student Financial Aid Office.

Student financial aid packages may be comprised of scholarships and grants, student employment, and loans. In addition, options like the monthly payment plan may be suggested as a way to help budget payments of educational expenses and to limit debt. Like any major investment, most families pay for education with a mix of current income, savings and borrowing. Finding the right balance among these resources can save money.

For more information or complete steps for applying for financial aid at CMU, visit www.cmu.edu/sfs/financial-aid.

Types of Financial Aid

There are several types of financial aid available to students, such as federal and private loans, university scholarships, outside scholarships, federal and state grants, and student employment. A full listing and explanation of these types of aid may be found at www.cmu.edu/sfs/financial-aid/types.

Student Financial Aid Terms and Conditions

All students, regardless of whether they are financial aid recipients, are required to confirm agreement to the university's student financial aid terms and conditions upon their initial log-in to Student Information Online (SIO) and before any financial aid disburses to their account. The terms and conditions apply to all student financial aid, regardless of source (e.g., federal, state or institutional), including grants, scholarships, fellowships, loans and work-study awards.

Learn more at www.cmu.edu/sfs/financial-aid/terms.html.

Undergraduate International Students

Only U.S. Citizens or Eligible Noncitizens are eligible to receive federal student aid. U.S. Citizens who were not born in the United States will need to send documentation of citizenship (i.e., a copy of passport or naturalization certificate). Verification is required for Eligible Noncitizens or refugees. Acceptable forms of verification include a photocopy of both sides of the student's I-551 or I-551C card.

Undergraduate international students are not eligible to receive federal or state student financial aid. Additionally, Carnegie Mellon does not award any institutional financial aid funds to undergraduate international students.

Student Accounts Office

The Student Accounts Office serves the university's various academic and administrative departments by processing and invoicing all student-related financial activity and managing the corresponding student financial obligations resulting from this activity. The office strives to serve students by accurately reflecting and communicating these financial obligations, providing timely and consistent responses to inquiries, and instilling financial responsibility and accountability with clear and concise guidance.

Student Financial Obligation Terms

Carnegie Mellon University wishes to be transparent about the financial expectations of students to the university. All students must acknowledge their agreement to the financial obligation terms only one time during their career at the university before access to Student Information Online (SIO) can be granted.

The student financial obligation terms (https://www.cmu.edu/sfs/docs/sfo-terms.pdf) (pdf) detail the student's responsibility to remit payment for charges incurred at the university as well as repercussions of non-payment.

UNIVERSITY CHARGES

All charges incurred at the university are reflected on your student account. Charges include tuition and fees and may include housing, dining, sorority or fraternity charges, health insurance, Plaid Cash, DineXtra, and other miscellaneous charges incurred. Miscellaneous charges may include, but are not limited to, music lessons, library fines, parking fines, or emergency loans.

STUDENT ACCOUNT INVOICES

Student account invoices are produced on the last day of each month. Invoices detail all transactions processed in the month, as well as any charges due in the future. Students receive an email notification to their Andrew email account when an invoice is ready for viewing on Student Information Online (SIO) (https://www.cmu.edu/hub/sio/about.html). Payments for amounts due from a monthly invoice must be received by the 15th of the next calendar month. Any amounts not paid by the stated due date are subject to a 1.5% interest charge each month until the balance is paid in full.

Carnegie Mellon does not print and mail student account invoices.

BILLING AUTHORIZATIONS & MY PLAID STUDENT

Students may authorize Carnegie Mellon to send a PDF copy of their invoice to another individual's (parent, spouse, etc.) email address. After completing the authorization process, designated recipients will receive an email with a PDF attachment of the invoice and any related billing messages.

Students can also invite a bill payer or other individual to use My Plaid Student (MPS) (https://www.cmu.edu/hub/MyPlaidStudent), which gives authorized users access to a student's invoices and student account activity, as well as the ability to make payments to the student's account. Students may also authorize their users to request enrollment verifications, and view grades and course schedules, via MPS. .

View more information at www.cmu.edu/hub/parents-and-family.

Tuition Assessment

The tuition charged to each student will be automatically adjusted on the 10th regularly scheduled class day (refer to the specific date noted in the Official Academic Calendar (http://www.cmu.edu/hub/calendar.html) as the “last day to add courses”) based upon each student's schedule at that time. The tuition charged will be increased whenever the number of units added justifies tuition charges greater than those paid by the student at the time of fee settlement. After that time, no tuition adjustments will be made, with the exception of second minis for that particular semester.

For additional information, view www.cmu.edu/sfs/tuition/adjustment.

Payment Options

Carnegie Mellon University is pleased to offer a wide variety of payment options for students and families. A full listing of these, as well as more information on each type, is available at www.cmu.edu/sfs/billing/payments.

We recommend that students enroll in Online Banking by linking a U.S. bank account to their student account via SIO. This is the fastest, easiest, and most convenient way to make a payment to or receive a refund from the university. The university does not initiate a withdrawal from a student's bank account; funds are only withdrawn when a student schedules a payment through SIO.

Refunds

If a student account has a negative balance resulting from an overpayment, financial aid, or a reduction of charges, the Student Accounts Office will review the account and issue a refund.

All students are encouraged to authorize electronic deposit of their student account refunds directly into their U.S. checking or savings accounts. Taking advantage of this opportunity eliminates the need to stand in line at The HUB to pick up a refund check and makes the funds available to the student within two business days.

If electronic refunding is not selected, the refund will be generated as a paper check that must be picked up in The HUB. Students who are issued a paper check for a student account refund have six months to cash the check. If the check is not cashed within six months, it will be voided and credited back to the student account and applied to any outstanding charges.

View more details about refunds at www.cmu.edu/sfs/billing/refunds.

University Registrar's Office

John Papinchak, *University Registrar*
Location: Warner Hall A19, 5000 Forbes Avenue, Pittsburgh, PA 15213
Fax: 412-268-6651
cmuregistrar@andrew.cmu.edu (university-registrars-office@andrew.cmu.edu)
www.cmu.edu/hub/registrar

The University Registrar's Office performs the essential roles of administering the collection and maintenance of student records, ensuring their accuracy and integrity, and enforcing academic policies while providing the best possible services. The University Registrar's Office aspires to provide exceptional, environmentally-conscious services, while anticipating and meeting growing customer requirements with innovative processes, training and self-service applications. The office strives to foster and promote an environment of professional development and appreciation.

The University Registrar's Office produces the Academic Calendar (www.cmu.edu/hub/calendar).

Undergraduate Enrollment

Enrollment is the process whereby eligible students notify Enrollment Services that they will be attending the university by registering for courses and settling their student accounts. Enrollment must be completed before students may begin classes and before they may utilize university facilities.

Registration

Registration is the process of selecting courses for the upcoming semester and discussing those selections with an academic advisor. We strongly encourage students to meet with their academic advisor before finalizing selections and registering for courses. Registration is completed within Student Information Online (SIO) (https://www.cmu.edu/hub/sio/about.html).

For most entering freshmen, registration is accomplished during the summer, with the assistance of associate deans and department heads. Academic placement and elective choice information is collected through mailed questionnaires during June and July. Most freshmen receive their schedules and enrollment information prior to the first day of classes.

Currently enrolled students select their courses for the upcoming semester during Registration Week, prior to the end of each semester. The Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) is available online prior to Registration Week, listing available courses along with general enrollment information. The university reserves the right to make changes to hours, units or instructional staff when such changes seem necessary or advisable.

Students are not permitted to register for courses in which the prerequisites have not been satisfied. Exceptions to the rule may be granted only upon the recommendation of the teaching department concerned. Unless the prerequisites are satisfied or special approval is obtained when the student enters the course, no credit can be allowed for the course.

PCHE Cross-Registration

Cross-registration provides opportunities for enriched educational programs by permitting full-time paying undergraduate and graduate students to cross register for one course at a Pittsburgh Council on Higher Education (PCHE) Institution. Students who are paying full-time Carnegie Mellon tuition (per the requirements of their home college) are eligible. The PCHE course may not count towards full-time status. There is no additional tuition charge, except for special course or laboratory fees. Carnegie Mellon students do not acquire status at the Host Institution, but are given library and bookstore privileges. Credit and grades are transferred directly to the home institution. Cross-registration is not applicable during the Summer Session or during intersessions.

For more information, visit www.cmu.edu/hub/registrar/registration/cross (https://www.cmu.edu/hub/registrar/registration/cross).

Faculty Course Evaluations (FCEs)

Students play an integral role in the academic life of the university when they participate in the evaluation of the faculty through the Faculty Course Evaluation process. FCE data is important in the evaluation of teaching and learning, as an important piece of the promotion and tenure process and as part of the process of course design and improvement. Student participation in the FCE process is critical to the university's commitment to quality teaching and academic excellence. Students are strongly encouraged to participate in the process with constructive feedback that is relevant to teaching and course content. More information on the Faculty Course Assessment process and results from previous years may be found at www.cmu.edu/hub/fce.

Office of International Education & Study Abroad

Linda Gentile, *Director of OIE*
Location: Posner Hall (3rd Floor), 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-5231
o (thehub@andrew.cmu.edu)ie@andrew.cmu.edu (oie@andrew.cmu.edu)
w (https://www.cmu.edu/hub)ww.cmu.edu/oie

The Office of International Education (OIE) is committed to supporting, promoting and celebrating individuals in an intercultural environment. We advocate for and facilitate international and cross cultural experiences, perspectives, and initiatives. OIE is the primary contact for study abroad programs and non-immigrant matters for all students and scholars (foreign professors and researchers) who are not United States citizens or permanent residents. OIE encourages both U.S. and international students to participate in international programs and events on campus, and we also welcome volunteers to participate and assist with programs sponsored by the office.

Foreign Students & Scholars

OIE serves as the liaison to the university for all non-immigrant students and scholars. The foreign student and scholar advisors provide many services including advising on immigration, academic, social and acculturation issues; presenting programs of interest such as international career workshops, tax workshops, and cross-cultural and immigration workshops; supporting international and cultural student groups such as the International Student Union and the International Spouses and Partners Organization; maintaining a foreign student resource library that includes information on cultural adjustment, international education and statistics on foreign students in the United States; posting pertinent information to students through email and our website; and conducting orientation programs.

Study Abroad

Carnegie Mellon students in every major can spend a summer, semester, or year abroad. Over 400 students go to all corners of the globe each year and receive credit for pre-approved study abroad. There is a wide range of funding options. The study abroad office assists students in all stages of the process of going abroad. The advisors promote study abroad, advise students, work with the academic departments and conduct information sessions, pre-departure orientations and welcome back workshops.
For more detailed information about Carnegie Mellon's study abroad program, see the Undergraduate Options (p. 27) section of this catalog or visit www.cmu.edu/studyabroad.

Summer Studies

Amy Yearwood, *Director of Summer Studies & Divisional Strategic Initiatives*
Location: Warner Hall A19, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-9796
summer-studies@andrew.cmu.edu
www.cmu.edu/summer

The university continues to offer outstanding, innovative, and educational programming throughout the summer. All university resources and offices are still available to assist students with academic support, health and wellness, career exploration, and more. Students have the opportunity to take exciting and enriching coursework, participate in research, work on campus or in the city, and attend a variety of local events/activities.

Visit the w (https://www.cmu.edu/summer)ww.cmu.edu/summer to learn more about summer at CMU.

SUMMER COURSEWORK

Summer semester offers a great opportunity to enroll in Carnegie Mellon's innovative courses and programs in fine arts, business, engineering, technology, liberal arts, and more. Summer classes allow more flexibility to focus on studies outside the typical fast-paced campus environment, and more interactive learning with a smaller class size. Our visiting and non-degree program (https://www.cmu.edu/hub/registrar/registration/visiting-non-degree.html) also allows professionals and non-CMU students to expand their education, and to learn from award-winning faculty. Summer courses are offered via three sessions: Summer All, Summer One and Summer Two.

SUMMER RESEARCH AND PROGRAMS

Carnegie Mellon offers many opportunities for academic enrichment and research during the summer months. These programs (https://www.cmu.edu/summer/research-and-programs) are designed to meet the academic needs of CMU students and visiting students by providing a wealth of services dedicated to academic achievement. Students have the opportunity to have a seamless educational experience that does not end in the classroom. In collaboration with other departments and organizations, these opportunities facilitate students' individual growth and development, helping them to reach and often surpass their academic goals.

SUMMER (RE)CHARGE PROGRAM

Summer (re)CHARGE (https://www.cmu.edu/summer/research-and-programs/recharge) is a collaborative, campus-wide initiative designed to ensure that all students are able to maximize their opportunities and take advantage of all that Carnegie Mellon University has to offer. This program is the perfect option for rising sophomores and juniors who are needing to enhance their academic profile, longing for a greater connection with the university community, interested in re-taking a pre-requisite course, planning a return to the university after a leave of absence, or exploring a new major that might be a better fit.

Division of Student Affairs

Gina Casalegno, Vice President for Student Affairs & Dean of Students
Location: Warner Hall 321, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-2075
www.cmu.edu/student-affairs

The Division of Student Affairs is available to support and foster student intellectual and personal growth and help students explore and experience the different aspects of college life. We care about you, your studies, your social growth, your well-being and your future and want to help you enjoy a great Carnegie Mellon experience.

Central to our success is a commitment to cultivating deep and meaningful one-to-one relationships with students. We build and sustain collaborative relationships throughout the university to best serve the needs of our student body. Programs, services, and efforts are dedicated to the development of an engaged community among students, faculty, staff and alumni where meaningful and authentic exchanges are valued. Division of Student Affairs staff help students navigate and reflect upon challenges and transitions, and we empower them to become architects of their own learning and development.

The Office of the Dean of Students provides central leadership of metacurricular experience at Carnegie Mellon, including divisional strategic planning, coordination of student support and crisis intervention, and facilitation of divisional assessment.

Student Affairs is comprised of the following offices and departments, which offer services aimed at enhancing the student experience at CMU.

Athletics, Physical Education and Recreation

Josh Centor, *Director & Associate Vice President*
Location: Skibo Gym 204, Frew St. & Tech St, Pittsburgh, PA 15216
Phone: 412-268-8054
http://athletics.cmu.edu

The Department of Athletics, Physical Education and Recreation has a transformative impact through divers programs that inspire leadership, teamwork, wellness and resilience, and offers students, staff and faculty opportunity to develop intellect, ethics and character needed to lead meaningful lives while impacting society in profound ways. View more information about Athletics, Physical Education and Recreation (p. 57).

Career and Professional Development Center

Kevin Monahan, *Director & Associate Dean of Student Affairs*
Location: West Wing, 2nd Floor, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-2064
career@andrew.cmu.edu
www.cmu.edu/career

The Career and Professional Development Center (CPDC) is Carnegie Mellon University's centralized career services center providing a comprehensive range of services, programs and materials focusing on career exploration and decision making, professional development, experiential learning and employment assistance to meet today's evolving workplace and student goals of finding satisfying work.

Students wishing to explore how majors and minors relate to career choice, as well as gain information about particular fields, will work with a career consultant to examine their skills, interests, and values and how they relate to various career fields. Career consultants also coach students in writing resumes and cover letters, networking, locating internship and job opportunities, preparing for interviews, and pursuing graduate school opportunities. Career consultants are assigned to each college and provide individualized support, general career programming, and college-specific workshops. In addition to the workshops presented by the staff, consultants coordinate an annual professional development series presented by prominent alumni and recruiters in various industries and fields.

Handshake

Several thousand summer internships and professional full-time job opportunities are made available to Carnegie Mellon students through Handshake, an online job listing resource. Students can access Handshake through the center's homepage and can also use the service to search for student employment and on-campus jobs. Handshake also provides information on the hundreds of employers that visit our campus each year. These organizations interview students for internships and professional employment, as well as hold informational sessions in the evenings that are open to the entire campus.

Center for Student Diversity and Inclusion

Location: Cohon University Center, Lower Level, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-2150
C (ocsi@andrew.cmu.edu)SDI@andrew.cmu.edu (CSDI@andrew.cmu.edu)
www.cmu.edu/student-diversity

The Center for Student Diversity and Inclusion actively cultivates a strong, diverse and inclusive community capable of living out these values and advancing research, creativity, learning and development that changes the world.

The Center offers resources to enhance an inclusive and transformative student experience in dimensions such as access, success, campus climate and intergroup dialogue. Additionally, the Center supports and connects historically underrepresented students and those who are first in their family to attend college in a setting where students' differences and talents are appreciated and reinforced.

Cohon University Center

Marcia Gerwig, *Director*
Location: Cohon University Center 103, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-2107
infodesk@andrew.cmu.edu
www.cmu.edu/cohon-university-center

Designed to support health, wellness, and community engagement, the Cohon University Center offers conference space and meeting rooms, a studio theater, a state-of-the-art fitness center, gymnasium, swimming pool, multiple dining locations, and plenty of gathering and study space.

Counseling and Psychological Services

Shane Chaplin, *Executive Director*
Location: Morewood Gardens E-Tower, Pittsburgh, PA 15213
Phone: 412-268-2922
www.cmu.edu/counseling (https://www.cmu.edu/counseling)

Counseling and Psychological Services (CaPS) addresses the mental health needs of the university community by providing treatment to students and collaborating with staff, faculty and family members. CaPS helps students improve their psychological health by facilitating insight and fostering deeper understanding of their personal struggles needed to make better choices for themselves. Services at CaPS are developmental in nature, aimed at supporting students in the moment and in their personal growth and maturation over time.

CaPS is attentive to issues of diversity and equality. We respect and value each person as a unique individual. We offer a safe and supportive space for students who identify as LGBTQ+ to navigate the challenges of exploring and integrating their gender and sexual identities.

Confidential services for students include consultation, short-term individual psychotherapy, crisis support and psychiatric referral when appropriate. Our staff provides consultation and education for students, faculty, staff and family members to address concerns regarding the well-being of a student, and questions about our services or psychological treatment.

CaPS staff also provide training and education for students and staff in support roles (i.e., advisors, RAs, OCs).

Dining Services

Pascal Petter, *Director*
Location: Residence on Fifth, 4700 Fifth Ave, Second Floor Pittsburgh, PA 15213
Phone: 412-268-2139
dining@andrew.cmu.edu
www.cmu.edu/dining

Carnegie Mellon Dining Services offers a diverse portfolio of dining destinations, enriches and nourishes lives, and enhances the CMU transformative experience for students. We are always looking for new ways to improve CMU's dining experience.

Housing Services & Residential Education

Tom Cooley, *Executive Director of Housing Services & Space Planning*
Housing Location: Residence on Fifth, 4700 Fifth Ave, Second Floor, Pittsburgh, PA 15213
Residential Education Location: Morewood Gardens, Student Life Suite, 1060 Morewood Ave, Pittsburgh, PA 15213
Phone: 412-268-2139 (Housing), 412-268-2142 (Residential Education)
housing@andrew.cmu.edu, resed@andrew.cmu.edu
www.cmu.edu/housing

The residential experience at Carnegie Mellon embraces all aspects of a student's life. Together, Housing Services and the Office of Residential Education create a lived experience that supports, engages, and inspires students throughout their university experience. It's the place they call home, the place where they will learn more about themselves, their community, and the world around them. Within a 24/7 community of support, staff and residents build meaningful relationships that inspire exploration, growth, and learning.

Office of Community Standards and Integrity

Lenny Chan, *Director*
Location: Morewood Gardens, 1060 Morewood Ave, Pittsburgh, PA 15213
Phone: 412-268-2140
ocsi@andrew.cmu.edu
www.cmu.edu/student-affairs/ocsi

The Office of Community Standards and Integrity (OCSI) is staffed by an experienced team of professionals dedicated to the growth and development of students both in and outside of the classroom. When faced with a challenging or complicated situation, the OCSI can serve as a resource for students, staff, faculty, and family members looking for guidance. Our staff strives to be approachable, knowledgeable, and current with best practices in the field of student conduct and academic integrity. The heart of our work is rooted in the value and support of our campus community members. We welcome inquiries regarding educational programming, student support, and guidance with the university's student conduct and academic integrity processes.

Religious and Spiritual Life Initiatives

Mandy Best, *Coordinator of Spirituality & Interfaith Initiatives*
Location: 5000 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-2142
mandyb@andrew.cmu.edu
www.cmu.edu/student-affairs/spirituality

Carnegie Mellon is committed to the holistic growth of our students, including creating opportunities for spiritual and religious practice and exploration for individuals all along the spectrum of spiritual and religious development. Carnegie Mellon encourages an explorative mindset for all students - creating programs and resources for students to pause, engage in self-inquiry, and to reflect upon and articulate one's moral fabric.

Additionally, we offer programs and initiatives that cross traditional religious boundaries in order to increase our students' knowledge of and appreciate for the full diversity of the world's religious and spiritual traditions.

Office of Student Leadership, Involvement, and Civic Engagement

Elizabeth Vaughan, *Director & Associate Dean of Student Affairs*
Location: Cohon University Center, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-8704
slice@andrew.cmu.edu
www.cmu.edu/student-affairs/slice

The Office of Student Leadership, Involvement, and Civic Engagement (SLICE) complements students' academic experiences by providing services and resources that engage students in creating campus culture through social, cultural, intellectual, spiritual, athletic, recreational, artistic, political, and service opportunities. Our staff is committed to delivering quality advising, resource materials, leadership development opportunities, and administrative support services to impact students' growth and development and enhance the success of each student organization.

Our office partners with students to create a vibrant culture of student life on the Carnegie Mellon campus. Our community is home to nearly 250 recognized student organizations that are supported by the Student Activities staff team. In addition to serving as individual advisors to many organizations and providing resources, support, and ad hoc advising to all student organizations, our office also coordinates a slate of opportunities to help Carnegie Mellon students get involved in campus life.

First-Year Orientation

Julie Schultz, *Associate Dean for Parent & Family Engagement and First-Year Orientation*
Location: 1060 Morewood Gardens, Pittsburgh, PA 15213
Phone: 412-268-2142
o (julieschultz@cmu.edu)rientation@andrew.cmu.edu (orientation@andrew.cmu.edu)
www.cmu.edu/first-year-orientation (https://www.cmu.edu/first-year-orientation)

Orientation & First-Year Programs is responsible for providing vision and leadership for a comprehensive approach to new student orientation and transition programs. The office provides programs, opportunities and services to help students and family members successfully transition to the Carnegie Mellon community.

The office is responsible for program, development, marketing and implementation of orientation and transition programs. Areas of concentration include new student orientation, parent's programming such as Family Weekend, freshman programming series, and special event planning.

Family & Parents

Julie Schultz, *Associate Dean for Parent & Family Engagement and First-Year Orientation*
Location: 1060 Morewood Gardens, Pittsburgh, PA 15213
Phone: 412-268-2142
parents (parents@andrew.cmu.edu)@andrew.cmu.edu (career@andrew.cmu.edu)
www.cmu.edu/parents

We encourage our students to develop independence and the life skills necessary to successfully navigate their personal affairs as young adults. We also know that family plays an important role and are key partners in our students' success. We're here to share information about general campus resources, important events and developmental milestones in your student's experience so that you have information to facilitate meaningful interactions with your student about their Carnegie Mellon journey.

Pre-College Summer Programs

Susie Sheldon Rush, *Director of Pre-College Programs*
Location: Cohon University Center, 5000 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-5914
Email: pc-life@andrew.cmu.edu
Website: www.cmu.edu/student-affairs/pre-college

Our Pre-College Summer Programs will show you what life at Carnegie Mellon is about - from the classroom to what's happening on weekend. You'll meet people from all over the world, be inspired by our world-renowned faculty, take part in the excitement of campus and have the opportunity to explore the city of Pittsburgh.

University Health Services

Beth Kotarski, *Executive Director*
Location: 1060 Morewood Ave., Pittsburgh, PA 15213
Phone: 412-268-2157
health (health@andrew.cmu.edu)@andrew.cmu.edu
(career@andrew.cmu.edu)
w (http://www.cmu.edu/career)ww.cmu.edu/health-services

Student Health Services is staffed by physicians, advanced practice clinicians, registered nurses, and professional staff who provide medical care, health promotion and insurance services. A list of current services and fees may be found on the University Health Services website (https://www.cmu.edu/health-services/services-and-fees).

Patients are seen by appointment; however, walk-in urgent care is provided. Appointments may be made by calling the office.

HEALTH INSURANCE

In addition to providing medical care, University Health Services administers the Student Health Insurance Program, which offers a high level of coverage in a wide network of health care providers and hospitals. It also covers most of the fees for care at Student Health Services. All full-time students are required to carry health insurance and will be assessed a charge for the individual basic mandatory plan offered through the university student health insurance program. The charge will appear on the invoice of the first semester of attendance in the academic cycle. The student is required to take one of the following three actions: (1) enroll in the basic plan as charged; (2) upgrade the benefit plan by enrolling in the enhanced student health insurance options during the open enrollment period; (3) apply for a waiver from the mandatory plan if covered by family/other insurance.

Wellness

Angie Lusk, *Program Director for Student Affairs Wellness Initiative*
Location: Cohon University Center, 111E, 5032 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-2142
alusk@andrew.cmu.edu
www.cmu.edu/wellness

We believe our individual and collective well-being is rooted in healthy connections, to each other and to campus resources. How we care for ourselves and others is important to our success. There are a wide variety of resources, opportunities, and people that want to help you thrive inside and outside of the classroom. Every voice matters as we continually enhance the quality of life for students, faculty, and staff and community partners. Join us in our shared commitment to engage and to empower.

Undergraduate Options

This section of the catalog introduces some of the options that undergraduate students can choose from to supplement their degree program, advance their career objectives, or focus on an interest that may be unrelated to their major. From IDeATe, which offers minors and courses in areas that merge technology and creativity like Game Design, to Student Defined Majors, which is designed for students whose academic goals cannot be adequately served by curricula of existing majors or minors, learn more about the additional options offered to CMU's undergraduate students.

Additional Majors/Dual Degrees

Students interested in pursuing more than one area of study are encouraged to consider an additional major or dual degree. Students who complete an additional major will earn a single degree in two areas. Generally, it is possible to fulfill the requirements of both majors in four years by taking the course requirements of the second major in the elective spaces allowed by the first major.

Some majors are offered only as additional majors:

- Students in the College of Engineering may elect to double major in Biomedical Engineering (p. 84) or Engineering and Public Policy (p. 125), which are offered only as an additional major.
- Students from any college may pursue an additional major in Human-Computer Interaction (p. 643), Science, Technology and Public Policy (p. 126), or Robotics (p. 649).

Dual Degree programs allow students to earn two degrees. Students who are interested in an additional major or dual degree are encouraged to review the specific possibilities with the relevant academic advisor.

Accelerated Master's Programs

Qualified undergraduates may apply to one of several programs to earn their bachelor's and master's degrees in five years. For further details about these programs, please refer to the appropriate college or departmental sections.

College of Engineering

The five-year Integrated Master's/Bachelor's programs offered by the Departments of Electrical and Computer Engineering and Civil and Environmental Engineering offers students superior technical preparation for careers in industry. The Departments of Chemical Engineering and Mechanical Engineering also offer fifth-year Accelerated Master's programs. The Department of Materials Science and Engineering offers a cooperative Industrial Internship Option in which students alternate coursework with practical experience in industry. Admission is highly competitive and leads to a Master of Science degree.

Dietrich College of Humanities and Social Sciences

The Department of Philosophy offers a bachelor's/master's degree option: the Bachelor's/Master's in Logic and Computation degree. The Institute for Politics and Strategy offers an accelerated Master of Science degree in International Relations and Politics. The Master of Arts in Teaching English to Speakers of Other Languages (TOESL) is a fifth-year master's option for Modern Language students who are concentrating in English as a Second Language. Also, the Department of English offers an accelerated program for undergraduates to obtain a Master of Arts in Professional Writing.

Heinz College of Information Systems and Public Policy

Heinz College's Accelerated Master's program allows qualified undergraduate students to earn a prestigious Master of Science degree in Public Policy and Management. For students in the College of Fine Arts or the Bachelor of Humanities and Arts degree program who are interested in careers in arts management, the program leads to a Master of Arts Management degree.

Mellon College of Science

The Honors Programs in the Departments of Chemistry and Mathematics are demanding, accelerated programs that give highly qualified students the opportunity to earn their bachelor's and master's degrees in just four years. Admission is by invitation only.

Tepper School of Business

Students who are interested in business management may wish to consider the Tepper School of Business 3-2 program. Qualified undergraduate students may earn their Master of Business Administration in addition to their bachelor's degree.

Health Professions Program

Jason D'Antonio, PhD, *Director*
Location: Doherty Hall 1324
Phone: 412-268-8494

The Health Professions Program (http://www.cmu.edu/hpp) (HPP) at Carnegie Mellon University is an advising and resource center for all university students and alumni who are interested in one or more aspects of the health professions. This program complements a student's curricular advising and is meant to help students explore their interests, prepare for graduate programs in the health professions, and facilitate their application process. Students can enroll in the program at any time during their academic career, but the importance of early planning is communicated to interested first-year students. Once enrolled, students meet regularly with the director to discuss course requirements, medical exposure opportunities, and other aspects of preparing to be a competitive candidate.

Students in the HPP span all colleges of the university and have many diverse career interests including medicine, dentistry, optometry, biomedical research, medical physics, rehabilitation engineering, medical informatics, and health policy.

For students interested in medicine or dental medicine, regardless of a student's major, the basic course requirements outlined below must be completed prior to matriculation:

1. One year of Biology with one lab, plus Biochemistry.

This is typically fulfilled by the following Carnegie Mellon courses:

03-121	Modern Biology	9-10
or 03-151	Honors Modern Biology	
42-202	Physiology	9
or 03-220	Genetics	
or 03-320	Cell Biology	
03-124	Modern Biology Laboratory	9-12
or 03-343	Experimental Techniques in Molecular Biology	
or 03-206	Biomedical Engineering Laboratory	
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	

2. One year of Inorganic Chemistry with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-207	Techniques in Quantitative Analysis (non-Chem majors)	9
or 09-221	Laboratory I: Introduction to Chemical Analysis	

3. One year of Organic Chemistry with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

09-217	Organic Chemistry I	9-10
or 09-219	Modern Organic Chemistry	
09-218	Organic Chemistry II	9-10
or 09-220	Modern Organic Chemistry II	
09-208	Techniques for Organic Synthesis and Analysis (non-Chem majors)	9
or 09-222	Laboratory II: Organic Synthesis and Analysis	

4. One year of Physics with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
33-122	Physics II for Biological Sciences and Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	
33-100	Basic Experimental Physics	6-9
or 33-104	Experimental Physics	

5. One year of Math.

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
or 36-201	Statistical Reasoning and Practice	

6. One year of English.

This is typically fulfilled by the following Carnegie Mellon courses:

76-101	Interpretation and Argument	9
76-xxx	English course of the student's choice, typically 200-level or higher	

In addition to these general course requirements, recommended coursework includes statistics, behavioral sciences, ethics, and languages. Interdisciplinary studies are also strongly encouraged, and many students design an undergraduate curriculum that incorporates majors and/or minors in both the natural and social sciences.

Undergraduate research is a hallmark of the educational experience at Carnegie Mellon in many disciplines. Whether in the psychology lab studying the impact of breast cancer diagnosis on family social dynamics, in the NMR lab imaging metabolic function in the heart or brain, or in the surgery suite testing robotic devices, our students have made significant achievements in research, well beyond the more traditional guided experiments.

Our university policy is to train students to be first class scientists, engineers, artists, writers, managers, or whatever their passion may be. We do not train students to be “pre-med,” but if they choose to use their talents in a health profession, we offer many services to help them obtain their life goals. Regular advising, application workshops, health issue seminars and symposium, community outreach activities, and preceptor-ship/ internship experiences are all part of our programming. The student pre-health organizations on campus: the Doctors of Carnegie (DOCs); the Minority Association of Premedical Students (MAPS); Alpha Epsilon Delta; Global Medical Brigades; and Global Public Health Brigades, together with the HPP, provide students with many opportunities to learn, explore, and prepare for their chosen area of professional interest.

The HPP has been successful in helping students to define, prepare for, and obtain their professional goals. Our students are regularly accepted at top-level medical, dental and graduate programs, and our alumni continue to serve as outstanding ambassadors of Carnegie Mellon and the training and experience they received here.

IDeATe

The Integrative Design, Arts and Technology (IDeATe) (http://ideate.cmu.edu) network offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in the IDeATe labs and classrooms based in Hunt Library. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of eight interrelated areas, all of which can be shaped into minors that students pursue alongside their primary majors. The themes of these areas integrate knowledge in technology and arts:

- **Game Design:** Enhance your knowledge of key component areas of games such as dramatic narrative and character development, programming and engine development, game assessment and redesign. Create games for varied platforms from mobile devices to home entertainment systems and theme parks.
- **Animation & Special Effects** (http://coursecatalog.web.cmu.edu/schoolofcomputerscience/addlmajorsminors/#ideateminorstext)**:** Explore the technical and artistic aspects of 3D and 2D animation in an integrated manner and within different application contexts (from film animation and special effects to interactive displays).
- **Media Design**: Learn to design digitally mediated experiences across different platforms, from mobile apps to large-scale installations, and for varied applications (from media for daily living to mediated performances).
- **Design for Learning:** Design effective new media systems for learning using new technologies, learning science principles and media arts knowledge. Produce engaging and effective experiences from games to tangible learning tool kits and remote systems.
- **Sonic Arts:** Create experimental music or explore new, technology-enabled applications and markets for sound design, music creation, and performance.
- **Innovation and Entrepreneurship:** Work collaboratively in hands-on explorations of the complete 21st century innovation ecosystem. You will experience integrated models of innovation that increase the likelihood of home-run products and services that will captivate society and/or the marketplace.
- **Intelligent Environments:** Develop spaces and devices that support efficiency and high quality of experience, in contexts like daily activity, built environment, making process (from laying plaster to robot development), and arts performance.
- **Physical Computing:** Build interfaces and circuitry to embed in physical contexts, such as mobile environments and new creative practice instruments

Individuals who make significant contributions, academically and professionally, in these areas are solidly prepared in a related discipline. Their preparation is combined with the ability to work in multidisciplinary teams that span technology and the arts. IDeATe serves as a multidisciplinary collaborative learning addition to the education (and learning outcomes) that students receive through their disciplinary major rather than a standalone learning experience.

Innovation and advancement in the eight IDeATe areas, as in many complex areas of inquiry, is the result of collective inquiry and requires deep expertise in all contributing areas of knowledge (i.e., expert technologists and artists). Carnegie Mellon is the only university in the United States with highly ranked departments in key technological and artistic domains. With these resources, Carnegie Mellon is uniquely positioned to create faculty and student teams that contain all necessary, high-level expertise in tech-arts areas of inquiry.

Students who participate in IDeATe will be able to combine the unique experience of a "deep dive" in their chosen discipline while connecting to the diverse areas of knowledge and skill across the university. To help facilitate this experience, the educational objectives of the IDeATe are:

- Students from any undergraduate major can integrate a tech-arts area of study into their curricular plan through the IDeATe minors, which enhance and synthesize the tech-arts ecosystem at CMU.
- Students in IDeATe have the opportunity to:
  - Immerse themselves in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology
  - Engage in active "learning by doing" in shared labs and maker spaces
  - Address current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and integrative approaches.

Across the eight IDeATe areas, there are over 50 multi-disciplinary technology-arts courses that a student can choose from to customize their paths. Students are assisted in their choice of courses and minor by a dedicated IDeATe advisor who works in tandem with the advisor in their home department.

The IDeATe Portal Courses introduce students to the concepts and practices of knowledge areas beyond their discipline that contribute to the subject of each minor/concentration. After completing the portal courses, students should be able to (1) interpret cross-disciplinary communication from their collaborators (and use that interpretation productively in the collaborative work), (2) translate their own disciplinary expertise to describe ideas and outcomes in a way their cross-disciplinary collaborators can understand, and (3) develop interdisciplinary tech-arts prototypes (that include perspectives from multiple disciplines and enable further interdisciplinary communication and collaboration).

The remaining courses of IDeATe deepen exploration in a given area. Each course is focused on a key aspect of the area that it is categorized under. By taking these courses, the student can become familiar with many of the technical and creative issues in the area of the minor and the collaborative processes they entail. These courses are collaborative because they promote hands-on learning through making, critique, and iterative design and they promote learning from both the instructor and the interdisciplinary peer cohort. At the conclusion of each course a student should be in a position to collaboratively plan and implement an established outcome in the area within a limited amount of time and apply skills from both technology and arts disciplines to prototype ideas and leverage the diversity of perspectives to produce innovation in the field.

A completion of a minor should provide multidisciplinary training in the area of the concentration and furthermore *enhance collaborative learning experience and skills of students*: diversify the cohorts of the student, enhance collaboration skills, promote cognitive versatility, facilitate skill transfer across technology and the arts, and produce graduates that can innovate in 21st century creative industries.

For more information, please visit the IDeATe website (https://ideate.cmu.edu).

Minors

In addition to a student's primary degree, they can choose a minor that is a secondary focus to the student's area of study, which can enhance a student's breadth of study and overall experience while not requiring the same amount of coursework as a second major or degree. The following list shows available minors. Unless otherwise indicated, minors are generally open to all university undergraduate students.

Intercollege:

- Game Design (IDeATe) (p. 784)
- Health Care Policy and Management (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#minorinhealthcarepolicyandmanagementtext) (jointly between the Dietrich College of Humanities and Social Sciences, the H. John Heinz III College, and Mellon College of Science)
- Music Technology (p. 272) (jointly between the School of Music and School of Computer Science)
- Neural Computation (p. 648) (jointly between the School of Computer Science, Mellon College of Science, and Dietrich College of Humanities and Social Sciences)

College of Engineering:

The following engineering minors are open to all Carnegie Mellon students:

- Biomedical Engineering (p. 163)
- Engineering Studies (p. 163)
- Technology and Policy (p. 163)

Designated Minors (open only to engineering students):

- Additive Manufacturing (p. 165)
- Audio Engineering (p. 166)
- Automation and Controls (p. 166)
- Colloids, Polymers and Surfaces (p. 167)
- Electronic Materials (p. 167)
- Global Engineering (p. 168)
- Materials Science and Engineering (p. 168)
- Mechanical Behavior of Materials (p. 168)

College of Fine Arts:

- Architectural Design Fabrication (p. 183) (available only to B. Arch candidates)
- Architectural Representation and Visualization (p. 183) (available also to B. Arch candidates)
- Architectural Technology (p. 183)
- Architecture (p. 183)
- Architecture History (p. 183) (available also to B. Arch candidates)
- Art (p. 184)
- Building Science (p. 183) (available only to B. Arch candidates)
- Collaborative Piano (p.) (available only to Piano majors in the School of Music)
- Conducting (p. 272) (available only to students in the School of Music)
- Design (p. 185)
- Drama (p. 186)
- History of the Arts (p. 184)
- Media Design (p. 184) (IDeATe)
- Music (p. 186)
- Music Education (p. 272) (available only to students in the School of Music)
- Music Technology (p. 272)
- Music Theory (p. 272)
- Musicology (p. 186)
- Photography (p. 188)
- Sonic Arts (p. 186) (IDeATe)
- Sound Design (p. 272) (IDeATe)

Dietrich College of Humanities and Social Sciences:

- African and African American Studies (p. 522)
- Anthropology (p. 363)
- Arabic Studies (p. 417)
- Chinese Studies (p. 417)
- Cognitive Neuroscience (p. 472)
- Creative Writing (p. 323)
- Cybersecurity and International Conflict (p. 397)
- Decision Science (p. 487)
- Economics (p. 309)
- English (p. 323)
- Ethics (p. 451)
- Film and Media Studies (p. 522)
- French and Francophone Studies (p. 417)
- Gender Studies (p. 523)
- German Studies (p. 417)
- Global Systems and Management (p. 523)
- Hispanic Studies (p. 417)
- Humanities Analytics (p. 323)
- International Relations and Politics (p. 398)
- Japanese Studies (p. 417)
- Linguistics (p. 525)
- Logic and Computation (p. 451)
- Philosophy (p. 451)
- Policy and Management (p. 488)
- Politics and Public Policy (p. 399)
- Professional Writing (p. 323)
- Psychology (p. 472)
- Religious Studies (p. 527)
- Russian Studies (p. 417)
- Science, Technology and Society (p. 527)
- Social & Political History) (p. 363)
- Sociology (p. 528)
- Statistics (p. 503)
- Technical Writing (p. 323)

Mellon College of Science:

- Biological Sciences (p. 548)
- Chemistry (p. 572)
- Computational Finance (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#majorminorincomputationalfinancetext)
- Discrete Mathematics and Logic (p. 592)
- Environmental and Sustainability Studies (p. 620)
- Mathematical Sciences (p. 592)
- Neuroscience (p. 548)
- Physics (p. 608)
- Scientific Computing (p. 621)

School of Computer Science:

- Animation & Special Effects (p. 645) (IDeATe)
- Computational Biology (p. 638)
- Computer Science (p. 642)

- Design for Learning (IDeATe) (p. 645)
- Human-Computer Interaction (p. 644)
- Intelligent Environments (p. 645) (IDeATe)
- Language Technologies (p. 647)
- Machine Learning (p. 647)
- Physical Computing (p. 645) (IDeATe)
- Robotics (p. 651)
- Software Engineering (p. 651)

Tepper School of Business:

- Business Administration (p. 744)
- Innnovation and Entrepreneurship (p. 745) (IDeATe)
- Operations and Supply Chain Management (p. 745)

Pre-Law Advising Program

Director: Joseph Devine, *Associate Dean for Undergraduate Studies, Dietrich College*
Location: Dietrich College Dean's Office, Baker Hall 154
www.cmu.edu/pre-law

"Law School" is an objective that students frequently mention when asked about post-baccalaureate plans. It seems in its brevity to be a simple enough answer, but in reality it masks a host of complex and momentous personal decisions and strategic tasks.

First and foremost, seeking entry into law school implies an informed decision about the rigors of law school and the realities of professional life as an attorney, as well as a strong and mature commitment to achieving these objectives at significant cost and investment (financial, personal, and intellectual). Second, it implies an understanding of the prolonged sequence of steps involved in the process of selecting law schools to which to apply, actually applying, ultimately selecting a school to attend, financing a law school education, and succeeding in law school. Finally, it implies an understanding of this as one of many options that should be carefully considered before a choice is made that will so significantly influence the course of one's personal and professional life.

To address these needs, the university offers a pre-law advising program for students and alumni who are contemplating or actively seeking to enter law school. The program consists of a range of support services, coordinated centrally, designed to assist these groups in engaging the complex questions associated with decisions about law school, and in successfully negotiating the sequence of tasks associated with selecting, applying and gaining admission to the best law schools possible.

The emphases of this program are:

- early identification of pre-law candidates;
- stimulation at early stages and throughout this process to consider the essential questions of personal suitability for law school and professional life as an attorney;
- engagement with meaningful substantive issues rooted in the law that illustrate the intellectual complexities of our legal system and the corresponding intellectual acumen needed to enter and thrive in this profession;
- timely direction in designing and executing a well-planned law school research, selection and application strategy;
- gathering and using accurate data on university alumni entering law school and the legal profession.

The program proper consists of several components, organized and made available as an ongoing service to all students and graduates of the university. These components include periodic workshops and seminars, a pre-law website, a pre-law newsletter, and linkage with law school admissions offices, the Law School Admissions Council, and associations (both regional and national) of pre-law advisors. The program also works closely with the student Pre-law Society.

Student Defined Majors

Carnegie Mellon offers the opportunity for undergraduate students to pursue a Student Defined Major. Some colleges have specific processes for Student Defined Majors within their college (see relevant college section of the catalog). For information and advice, interested students are encouraged to speak to the associate dean of their current home college or the college most relevant to the proposed course of study.

The requirements for successful completion of a Student Defined Major include a student proposal approved by an advisor, relevant college(s), the vice provost for education, and successful completion of the approved course of study. In brief:

- A student interested in pursuing a student-defined major must develop a proposal which outlines an intellectually coherent area of study (with degree title) and a plan of study (courses to be taken, pedagogical rationale, and proposed schedule). The proposal should include an explanation of why it is not appropriate or possible to pursue such a program through the curriculum of any one of the colleges. It should outline a program of study for both general education (for example, the core requirements of one of the most relevant colleges or equivalent general education plan) and major requirements. The proposal should designate one of the participating colleges as de facto "home college" for tracking and verification purposes.
- **Proposals must be approved at least one academic year prior to expected graduation.** Students should therefore submit their proposals by the end of their fifth semester, to allow ample time for approval.
- The student's proposal must be approved by a faculty advisor within a college who takes pedagogical responsibility for the program, by the de facto "home college" and by any other colleges involved in granting the degree. The signed proposal will be submitted to the Provost's Office for a final review and approval.
- Once approved by the faculty advisor, colleges, and the Provost's Office, the student's major will be administered by the advisor and their progress tracked by the dean's office of the "home college." The "home college" will be responsible for monitoring the student's progress and reminding any collateral colleges of the approval of the Student Defined Major so that these colleges may insure the student's ability to enroll in the necessary courses. Upon successful completion of the course of study, the "home college" will be responsible for contacting all the relevant colleges and verifying the completion of the degree. Upon consultation with the "home college", students may receive their diploma in the most relevant department's ceremony.

Note: To distinguish Student Defined Majors from regularly offered majors at Carnegie Mellon, the phrase "(Student Defined Major)" will be added to the end of the major name. This notation will appear on all official documents (transcripts, verification letters, diplomas, etc.).

Student-Taught Courses (StuCo)

The Student College (StuCo) was established in 2001 to provide Carnegie Mellon students with the opportunity to share knowledge through educational, self-designed courses. Students can teach classes on any topic of their choice. However, the course cannot be available through regular university offerings. Courses typically meet once a week (for a full semester) and follow the current Carnegie Mellon academic calendar. Instructors and students receive credit (3 elective units - pass/no pass) for their work.

- All CMU students are eligible to teach StuCo courses and to join the Executive Committee that governs StuCo.
- All currently-enrolled CMU students, staff and community members are eligible to take StuCo courses.
- StuCo classes are taught during the fall and spring semesters.

StuCo courses vary semester to semester. Current classes offered by StuCo for fall 2019 include:

98-003	Student Taught Courses (StuCo): Introduction to Sketch Comedy	3
98-012	Student Taught Courses (StuCo): Fun with Robots	3
98-127	Student Taught Courses (StuCo): Game Creation for Ppl Who Want to Create Games	3
98-128	Student Taught Courses (StuCo): Fundamentals of Improv Comedy	3
98-182	Student Taught Courses (StuCo): Billiard Games: From Noob to Pro	3
98-205	Student Taught Courses (StuCo): Introduction to Minecraft	3
98-218	Student Taught Courses (StuCo): Fun With Python	3
98-230	Student Taught Courses (StuCo): Avatar: The Last Airbender & The Legend of Korra	3
98-242	Student Taught Courses (StuCo): Intro to Esoteric Programming Languages	3
98-244	Student Taught Courses (StuCo): Sign Language Through Pop Music	3
98-247	Student Taught Courses (StuCo): Harry Potter & JK Rowling's Wizarding World	3

98-251	Student Taught Courses (StuCo): Principles of Racecar Engineering	3
98-262	Student Taught Courses (StuCo): Intro to Boardgames	3
98-269	Student Taught Courses (StuCo): Intro to Sabermetrics & Exploring Baseball Data	3
98-275	Student Taught Courses (StuCo): Marvel Film and Media Studies	3
98-279	Student Taught Courses (StuCo): Lights, Camera, Architecture	3
98-288	Student Taught Courses (StuCo): Star Wars: The Course Awakens	3
98-291	Student Taught Courses (StuCo): Android Development	3
98-295	Student Taught Courses (StuCo): Lock Picking and Physical Security	3
98-296	Student Taught Courses (StuCo): The Doctor WhoCo	3
98-300	Student Taught Courses (StuCo): Elementary Cantonese	3
98-303	Student Taught Courses (StuCo): Introduction to Freestyle Rap	3
98-315	Student Taught Courses (StuCo): Masculinity in the Wild	3
98-317	Student Taught Courses (StuCo): Hype for Types	3
98-319	Student Taught Courses (StuCo): Game of Thrones	3
98-329	Student Taught Courses (StuCo): Civilization V: Understanding Civilizations	3
98-330	Student Taught Courses (StuCo): Fundamentals of Personal Development	3
98-331	Student Taught Courses (StuCo): Animation and Video Editing	3
98-335	Student Taught Courses (StuCo): Introduction to Glowstringing/Poi	3
98-339	Student Taught Courses (StuCo): Introduction to Slacklining	3
98-347	Student Taught Courses (StuCo): Introduction to Names	3
98-348	Student Taught Courses (StuCo): Introduction to Old Icelandic	3
98-349	Student Taught Courses (StuCo): Design and Analysis of Logic Puzzle Games	3
98-350	Student Taught Courses (StuCo): Introduction to Bridge	3
98-351	Student Taught Courses (StuCo): Developing Speed-Power Athletes	3
98-352	Student Taught Courses (StuCo): Introduction to Star Trek	3

For detailed information on the Student College, please visit the StuCo website (http://www.cmu.edu/stuco).

Study Abroad Programs

Carnegie Mellon students from every major may be able to study in any part of the world for a semester, year or summer. Short-term programs during spring and winter break are also possible. A well planned study abroad program, in coordination with one's academic advisor, will allow a student to receive credit for study abroad and graduate on time. Most students study abroad during their junior year; however, a growing number of students are studying abroad during their sophomore and senior years.

The study abroad advising staff offers general information sessions as well as individual advising appointments to assist students in all stages of the study abroad process. The Office of International Education (OIE) has a large in-house library as well as useful web links to help students find the most appropriate study abroad program. In addition, OIE offers orientations to help with personal, academic and acculturation issues, before and after a study abroad experience.

Carnegie Mellon offers students a variety of payment options for study abroad to allow students to study abroad regardless of financial need. There are three categories of programs: Exchange Programs, Sponsored Programs, and External Programs. A description of each program follows.

More detailed information can be found at www.cmu.edu/studyabroad.

Exchange Programs

Students who participate in exchange programs pay Carnegie Mellon tuition and receive their regular financial aid package. Students are responsible for room, board, travel and miscellaneous expenses.

University Exchanges

Carnegie Mellon University has university-wide exchange programs with institutions located in Australia, Chile, Hong Kong, Israel, Japan, Mexico, Qatar, Singapore, and Switzerland.

Departmental Exchanges

Architecture, Art, Chemical Engineering, Design, Drama, Electrical and Computer Engineering, English, Heinz College, Information Systems, Materials Science and Engineering, Modern Languages, Computer Science and Business offer departmental exchange programs. Students should contact their department or the study abroad website for additional information.

Sponsored Programs

The university has designated a few study abroad programs administered by other organizations or universities as sponsored programs. To participate in these programs students pay a university fee equivalent to current tuition, room and board, and retain their eligibility for all financial aid. Carnegie Mellon in turn pays the program costs to the study abroad sponsor. Where applicable, funds are distributed to the student for room, board, travel, and personal expenses.

Currently Carnegie Mellon has 38 sponsored programs available around the world. A full list can be found at www.cmu.edu/studyabroad or in consultation with a study abroad advisor.

External Programs

Students may also participate in a program sponsored by another university or study abroad organization if the student's home department approves the program and its course offerings. Students will pay the other organization or institution directly. Students who receive institutional aid from Carnegie Mellon will not be eligible for this aid while they are abroad. However, students with state and federal aid will still qualify. Students can learn more about external program options during study abroad advising appointments and by exploring the study abroad website and library.

Undergraduate Academic Regulations

All enrolled students are required to comply with the university's Academic Regulations, as well as official University Policies (www.cmu.edu/policies). Students are expected to familiarize themselves with these regulations and are also advised to pay special attention to all academic dates and deadlines (www.cmu.edu/hub/calendar). The university reserves the right to changes regulations and policies whenever such action is deemed appropriate or necessary.

Academic regulations are compiled by the University Registrar's Office. Students who have questions regarding these regulations should consult with their academic advisor.

Courses & Registration

Availability of Required Courses

In order to insure that students do not have to compete for access to their required courses, registration priority is given to students who are registering for courses in their primary major. Although the university encourages the exploration of other disciplines, access to courses outside a student's primary major (including those courses that fulfill requirements for an additional major, minor, etc.) is on a space-available basis and is not guaranteed.

Change in Schedule (Add/Drop)

Scheduling changes must be made within the period in the semester as established in the Official Academic Calendar (https://www.cmu.edu/hub/calendar). A student **cannot** drop a course by simply notifying the instructor or by ceasing to attend class. A student dropping all of their courses (with the intent of leaving the university) must file an Application for Withdrawal or an Application for Leave of Absence (see the “Student Leave Policy” (p.) for more information).

Undergraduate students at Carnegie Mellon may drop a course by following the instructions for dropping a course in Student Information Online (SIO) on or before the appropriate deadline as published in the Official Academic Calendar. When a course is dropped by the drop deadline, the course is removed and does not appear on the academic record. Students may also use a late drop voucher for a limited number of course drops after the deadline during the pursuit of their degree. This action must be taken through consultation with their academic advisor or associate dean. Undergraduate students will receive three course drop vouchers throughout their undergraduate academic career and master's students will receive one voucher per 12 months of study. Only one drop voucher may be used per semester. In order to drop below 36 units, students must see their advisor for special permission. International students who wish to drop below full-time must consult the Office of International Education.

Undergraduate students who wish to withdraw from a course after the drop deadline must complete a Course Withdrawal form and **must** obtain their academic advisor's signature. The advisor will indicate whether they "recommend" or do "not recommend" withdrawal from the course on the form, sign the petition and submit it to the University Registrar's Office. When a course is withdrawn by the course withdrawal deadline, a "W" grade appears on the academic record.

The Late Add form is used for adding a course or switching sections after the add period and during the semester in which the course is offered. Students can check SIO to see if the appropriate schedule changes have been made. Undergraduate students who add a course or switch a section after the add period are required to obtain the permission of their advisor and home dean's office. Graduate students must have the permission of their department.

Free Electives

A free elective is any Carnegie Mellon course that a student completes that is not being used to fulfill a college, school, major or minor requirement. A maximum of nine units of physical education and/or student-taught (StuCo) courses may be included in the tally of units required for graduation.

Overloads

The university is committed to insuring that each degree candidate has access to a normal course load before it permits other students to register for a greater than normal number of units. A normal course load has been established by each academic department. Students should check with their academic advisor, department head, or dean's office for the definition of a normal course load. Individual colleges may have overload policies that are more restrictive, therefore students should consult with their advisor when considering an overload. Students may register for an overload up to 12 units with the approval of their academic advisor if they have demonstrated their ability to successfully complete a normal course load. Successful completion of a normal course load is defined as having earned at least a 3.00 (3.50 for students in ECE) cumulative QPA through the preceding semester or at least a 3.00 (3.50 for students in ECE) semester QPA in the current semester (in which case all final grades must be recorded before the student can register for the overloaded class). Overloads greater than 12 units or other exceptions must have the approval of the student's associate dean. Freshmen and transfer students are limited to a normal course load in their first semester of attendance.

Summer Classes

Per the Associate Deans’ Council, undergraduate students are now limited to registering for 24 units in summer sessions without advisor approval. If the student's advisor wishes to approve additional units after consulting with the student, the advisor can increase the student's course load units.

Conduct of Classes

Students are expected to attend all scheduled classes unless the instructor explicitly informs the class that other ways of doing the work are acceptable. The action to be taken in regard to tardiness, absence from class or making up late work is the responsibility of the individual instructor; the instructor should consult with the department head and the student's dean if major action, such as dropping the student from the course, is being considered.

All classes will be held at their scheduled hour on days immediately before and after all holidays and recesses. Both faculty and students are expected to be present.

Members of athletic teams and other student organizations are permitted to be absent from classes to participate in authorized contests and presentations, either at home or out of town, provided the following conditions are met:

- All work missed must be made up to the satisfaction of the instructor concerned;
- No trip shall involve an absence of more than two days, excluding days when classes are not scheduled;
- The total number of days of absence shall not exceed six per sport or per organization annually;
- Each student will obtain an absence authorization signed by the director or sponsor of the organization involved and by the Dean of Student Affairs. The student will present this authorization to the instructor. This is not an excuse for work missed.

Technology affords many students access to mobile devices. It is expected that students will respect the wishes of faculty with regard to the use of electronic devices within the academic environment.

Students who, because of religious beliefs, cannot attend class may arrange as individuals to be absent, provided the work missed is made up in a manner satisfactory to the instructor of the class missed.

No student shall leave a scheduled exercise because of the absence of the instructor until a reasonable time has passed. By tradition and as a matter of courtesy a student should wait 10 minutes before leaving.

Course Attendance, STUDENT ACCOUNT BALANCE and Enrollment

A student is responsible for the payment of charges incurred at the university by the stated payment deadline. The purpose of this policy statement is to detail the specific process and action steps to be used to resolve any outstanding student account balance.

Students will be held financially and academically accountable for courses they attend or for which they are enrolled. Enrollment in a course which is not actively taken, or contrarily, the taking of a course for which enrollment has not been completed, will result in the assignment of a grade and responsibility for applicable tuition charges.

Students who fail to resolve their enrollment and balances will be prohibited from using university academic and administrative services. The services include, but are not limited to, computing facilities, library services, housing, dining, career center services, degree verification and the release of academic transcripts for the upcoming semester.

Undergraduate Course Meetings

Usually, no undergraduate classes, exams, academic, or artistic activities (including extra help sessions, rehearsals, ROTC drill, make-up exams, etc.) are scheduled on weekdays between 4:30 and 6:30 p.m. On occasion, some courses may be scheduled during these hours by the University Registrar's Office when they also are offered at other times; students may elect to take such courses during the 4:30 to 6:30 p.m. period.

Grades, Transfer Credit, Advanced Placement

Grading Policy

www.cmu.edu/policies/student-and-student-life/grading.html

This policy offers details concerning university grading principles for students taking courses, whether those students are undergraduates, non-degree students or graduate students. This policy covers the specifics of assigning and changing grades (including final and mid-semester grades, incompletes and conditional failures), grading options (audit and pass/fail), drop/withdrawals, and course repeats, as well as defines the undergraduate and graduate grading standards.

Questions about grading for a specific course should be addressed to the instructor of the course in question. Graduate students with questions about pass/fail and drop/withdrawal should contact their individual program. Appeals for an exception to any grading policy may be made by the dean's office of the student's home college.

Definitions

Certain terms are used in this document with specific meanings, as defined in this section.

Student means any full-time or part-time degree-seeking undergraduate or graduate student, or full-time or part-time non-degree student.

Non-degree student means a student who is not in a university degree program.

Faculty means members of the university's Faculty Organization as defined in the Faculty Handbook, plus instructors and special faculty appointments (even in the first year), and part-time faculty.

Instructor means a faculty member, teaching assistant, and /or lecturer who is the instructor of record, as recorded in the Student Information System (S3).

Policy Provisions

Assigning Grades

Final grades are awarded to each student, in each course scheduled, at the end of the semester, mini-semester or summer session. All students taking a course at Carnegie Mellon must be assigned grades.

The University Registrar's Office will query instructors who do not assign a grade to a student. Copies of the query regarding the lack of grade will be sent to the course's department head and associate dean. If the instructor does not assign a letter grade or an incomplete grade within one month of that query, the teaching department head will be responsible for insuring that a grade is assigned.

Changing a Grade

A student who believes that an assigned grade is incorrect, may request that a final grade be changed. Final grades will be changed only in exceptional circumstances and only with the approval of the instructor and, for undergraduates, with the approval of the dean's office of the college/school offering the course; for graduate students, department approval is required. The intention of this policy is to insure that, under normal circumstances, all students in a class are treated equally and no student is unduly advantaged.

Mid-Semester Grades

Mid-semester grades provide valuable feedback to students as they assess their performance in courses. Furthermore, mid-semester grades and the QPA's they generate are used by deans and advisors in identifying and dealing in a timely way with students in academic trouble. Therefore it is imperative that mid-semester grades accurately reflect student performance and are turned in on time.

Mid-semester grades are not permanent and are kept only until final grades are recorded. Because mid-semester grades are not permanent, changes of mid-semester grades as a rule will not be accepted.

Incomplete Grades

Carnegie Mellon students are expected to complete a course during the academic semester in which the course was taken. However, if the instructor agrees, a grade of I (incomplete) may be given when a student, for reasons beyond their control, has been unable to complete the work of a course, but the work completed to date is of passing quality and the grade of incomplete provides no undue advantage to that student over other students.

In awarding an I grade, an instructor must specify the requirements for completing the work and designate a default letter grade where no further work is submitted. Students must complete the required course work no later than the end of the following academic semester, or sooner if required by prior agreement. The instructor must record the permanent grade by the last day of the examination period of that following semester, or the University Registrar's Office will administratively assign the default grade.

Pass/No Pass Grades

Undergraduate students may elect to take a free-elective course pass/no-pass unless precluded by the course, the course's department or the student's home department/college. Policies for graduate students vary and students should be advised to check with their individual colleges/departments/programs for details.

A student must submit a Pass/No-Pass form to the University Registrar's Office indicating the course they are electing as pass/no-pass before the end of the university's withdraw period. This decision is irreversible thereafter. No information regarding the student's decision will be passed on to the instructor. Instructors will submit letter grades, which will automatically be converted to pass/no-pass.

Work graded A through D will receive credit for units passed and be recorded as P on the student's academic record; below D work will receive no credit and will be recorded as N on the student's academic record. No quality points will be assigned to P or N units; P or N units will not be factored into the student's QPA.

In exceptional circumstances, departments may ask to designate a course pass/no-pass or request that the course be evaluated only with letter grades. The College Council must approve designating a course as pass/no-pass only or as graded only. If such a decision will have an adverse effect on the requirements of any other college, Academic Council must review the decision. The decision to designate a course as graded or pass/no-pass must be made before the add period for the course and is irreversible thereafter.

Audit Grades

Auditing is presence in the classroom without receiving academic credit, a pass/fail or a letter grade. The extent of a student's participation must be arranged and approved by the course instructor. A student wishing to audit a course is required to register for the course, complete the Course Audit Approval form, obtain permission of the course instructor and their advisor, and return the form to The HUB prior to the last day to add a course.

Any student enrolled full-time (36 units) may audit a course without additional charges. Part-time or non-degree students who choose to audit a course will be assessed tuition at the regular per-unit tuition rate.

Drop/Withdrawal Grades

Students at Carnegie Mellon may drop a course by accessing online registration in SIO on or before the drop deadline as published in the official university calendar. Policies for graduate students vary and students should be advised to check with their individual colleges/ departments/programs for details. When a course is dropped by these deadlines, the course is removed and does not appear on the academic record.

Undergraduate students who wish to withdraw from a course after the drop deadline must complete a Course Withdrawal form and **must** obtain their academic advisor's signature. The advisor will indicate whether they "recommend" or do "not recommend" withdrawal from the course on the form, sign the petition, and assign the "W" (withdrawal) grade in S3. The "W" grade will appear on the academic record. Withdrawal grades do not apply to graduate students, except in CFA, DC and SCS. Students may use a late drop voucher for a limited number of course drops after the deadline during the pursuit of their degree. This action must be taken through consultation with their academic advisor or associate dean.

Undergraduates who are registered as full-time students as of the 10th day of classes are expected to remain full-time for the duration of the semester. Full-time is defined as registered for a minimum of 36 units. Permission to drop below the 36-unit minimum can only be granted in extraordinary circumstances by the student's home associate dean. Undergraduates who are registered as part-time are also subject to the above deadlines to drop or withdraw from a course.

Course Repeats

When a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. This is the case regardless if the first grade for the course is a passing or failing grade, including pass/fail.

Undergraduate students who wish to repeat a course already passed must obtain approval from the student's dean or department head. When a student takes a course they have already passed, only one set of units will count toward graduation requirements.

University Grading Standards

The undergraduate student grading standard is as follows:

Grade	Quality Points	Definition
A	4.0	**Excellent**
B	3.0	**Good**
C	2.0	**Satisfactory**
D	1.0	**Passing**
R	0.0	**Failure**
P	Non-Factorable	**Passing**
N	Non-Factorable	**Not Passing**
O	Non-Factorable	**Audit**
W	Non-Factorable	**Withdrawal**
I	Non-Factorable	**Incomplete**
AD	Non-Factorable	**Credit granted for work completed at another institution or examination credit**

This grading standard is for all students classified as seeking an undergraduate degree and special students taking undergraduate courses.

Any +/- grades received by undergraduate students when taking graduate-level courses will automatically convert to the corresponding letter grade as listed in the scale above.

The graduate student grading standard is as follows:

Grade	Quality Points	Definition
A+	4.33	**(Not applicable to CIT or Dietrich College students)**
A	4.0	
A-	3.67	
B+	3.33	
B	3.00	
B-	2.67	
C+	2.33	
C	2.00	
C-	1.67	
D+	1.33	**(Not applicable to Tepper School, Heinz College, or Dietrich College students)**
D	1.00	**(Not applicable to Tepper School, Heinz College, or Dietrich College students)**
R	0.0	**Failure**
S	Non-Factorable	**Satisfactory**
P	Non-Factorable	**Passing**
N	Non-Factorable	**Not Passing**
O	Non-Factorable	**Audit**
W	Non-Factorable	**Withdrawl**
I	Non-Factorable	**Incomplete**
AD	Non-Factorable	**Credit granted for work completed at another institution or examination credit**

Grading standards are based upon a student's home academic program and is defined by their home college. The college's standards determine if certain grades are applicable and if undergraduate course are factored into their mid-semester and final semester quality point averages (QPA). Otherwise, the university policy is that only graduate courses (600 level and higher) are factored into the semester QPA.

Pass/fail policies for graduate students vary and students should be advised to check with their individual college/department/program for details.

Minimum passing grades in graduate courses are determined by the department and college policy. Any course that a graduate student completes will be graded using this scale.* This includes undergraduate courses taken by graduate students, and non-degree students taking graduate courses.

Contact

Questions concerning this policy or its intent should be directed to the University Registrar's Office at 412-268-7404.

Units and Quality Points

Carnegie Mellon has adopted the method of assigning a number of “units” for each course to represent the quantity of work required of students. For the average student, one unit represents one work-hour of time per week throughout the semester. The number of units in each course is fixed by the faculty member in consultation with the college offering the course. Three units are the equivalent of one traditional semester credit hour.

Hence, a 9-unit semester-long course should require 9 hours of student engagement, on average, including class time; if the instructor requires 3 hours of lecture and 1 hour of recitation, they can expect students to spend 5 hours outside of class engaging in class work. For mini courses that run for only seven weeks, the conversion from units to number of hours per week during the mini involves multiplying by 2. For example, a 6 unit mini course should on average involve 12 hours of student engagement; if the instructor requires 3 hours of lecture and 3 hours of lab, they can expect the students to spend 6 hours outside of class.

Final grades are given “Quality Point Values” as follows:

Grade	Meaning	Quality Point Value
A	Excellent	**4**
B	Good	**3**
C	(satisfactory)	**2**
D	Passing	**1**
R	Failure	**0**

Units earned for a course multiplied by the Quality Point Value of the grade given for that course equals the quality points for that course. For example, a 9-unit course assigned a “C” grade is awarded 18 quality points (9 units x 2 quality points = 18 quality points). Total Quality Points divided by Total Units Factorable equals the Quality Point Average.

For example, a student's record in one semester might be:

11 units x 4 quality points	=	**44 quality points**
10 units in Physics “R”		
10 units x 0 quality points	=	**0 quality points**
9 units in Chemistry “B”		
9 units x 3 quality points	=	**27 quality points**
9 units in History “C”		
9 units x 2 quality points	=	**18 quality points**
9 units in English “D”		
9 units x 1 quality point	=	**9 quality points**
Total Units = 48		
Total Quality Points = 98		
Quality Point Average (98 divided by 48) = 2.04		

“I” (incomplete), “P” (pass), and “W” (withdrawal) grades are not awarded quality points and are not considered as “factorable” units when calculating the QPA.

The same procedure is applied to all grades earned at the university to establish the Cumulative Quality Point Average.

Dean's List

Undergraduate students who meet specific academic requirements are added to their home college's Dean's List each semester. This is noted on the student's transcript for applicable semesters. Each college may have its own requirements for Dean's List qualification; these are described in the individual college sections of the catalog.

Note: Only undergraduate *degree-seeking* students may earn a place on the Dean's List. Non-degree students are not eligible.

Transfer Credit Evaluation and Assignment Policy

The Policy on Grades for Transfer Courses, originally dated January 13, 1993, and approved by the Committee on Educational Programs and Student and Faculty Affairs states:

“Carnegie Mellon University offers students the opportunity to take courses for credit through a cross-registration program and through the receipt of transfer credit from other accredited institutions. The Carnegie Mellon University transcript will include information on such courses as follows:

Carnegie Mellon courses and courses taken through the university's cross-registration program will have grades recorded on the transcript and be factored into the QPA. All other courses will be recorded on this transcript indicating where the course was taken, but without grade. Such courses will not be taken into account for academic actions, honors or QPA calculations. (Note: Suspended students may take courses elsewhere; however, they may receive transfer credit only if their college's and department's policies allow this).

Definitions

A Carnegie Mellon course is one conducted under Carnegie Mellon University regulations regarding course content and grading and taught by faculty under the supervision of a Carnegie Mellon academic unit. Courses taught by Carnegie Mellon faculty on the Carnegie Mellon campus qualify. Courses that are part of the regular offerings of other universities do not qualify, unless faculty at the other universities receive appointments at Carnegie Mellon and handle Carnegie Mellon students under Carnegie Mellon academic regulations.

Courses offered for cross-registration are those taken under the PCHE (Pittsburgh Council on Higher Education) agreement during the regular academic year.”

Only official and final college or university transcripts will be accepted for the awarding of transfer credit. Grade reports, letters and the like are not acceptable. It is the responsibility of the Office of Undergraduate Admission and the University Registrar's Office to verify official transcripts. Official transcripts for the awarding of transfer credit will reside in the student's permanent university academic folder in the University Registrar's Office.

It is the responsibility of each academic department to review and establish transfer course credit for their degree-seeking students.

Transfer Credit Evaluation Procedure

External Transfer Students

External applicants applying for transfer to Carnegie Mellon will arrange for submission of:

- official transcripts to the Office of Undergraduate Admission as part of the admission process.
- official, final transcripts to the Office of Undergraduate Admission once they are admitted and prior to their beginning coursework at Carnegie Mellon.

As part of the admission process, Admission will verify the official final transcripts, and then send them to the appropriate academic unit responsible for college/department acceptance decisions. Each unit will be responsible for student's review of transfer credit and the establishment of transfer course credit for each individual student.

Current Students

Current Carnegie Mellon students taking courses at other accredited institutions (colleges and universities), during either summer semesters or as part of exchange programs or other departmentally approved programs, or while on leave from Carnegie Mellon, must arrange for the submission of official final transcripts to the University Registrar's Office.

Upon receipt, Enrollment Services will verify these official transcripts and send a copy of the transcript to the appropriate academic unit responsible for that student's college/department transfer credit decisions. The official transcript will reside in the student's university academic folder in Enrollment Services. Each unit will be responsible for its students' transfer credit review and the establishment of transfer course credit for each individual student. Should a unit receive the official transcript, it must be sent immediately to the University Registrar's Office.

Standard Course Equivalents for Advanced Placement/International Baccalaureate Units Policy

The university has standard units assigned to Advanced Placement (AP) and International Baccalaureate (IB) credits for all majors. Standard course equivalencies for each exam will be determined by “expert departments” in each college for each acceptable AP/IB score.

Under this procedure, students' AP or IB credit for a particular course will only go toward their degree requirements if allowed by the home department or college policies. Should a student decide to transfer to another major and/or academic unit within the university, AP/IB credits applicability to new degree requirements will depend upon the requirements of the new home department (or college). Students may only be granted credit for the Higher Level IB exams. This policy assumes no significant AP and/or IB exam changes. In the event of significant exam changes, students will be notified of any resulting policy changes no later than July 30 prior to their enrollment to take effect the fall of that year.

Rank in Class

Undergraduates at Carnegie Mellon pursue degrees in one or more of our ten schools or colleges. They may choose to pursue coursework, majors and minors within and between schools/colleges. In an institution where students' educational experiences are so varied, class rank is not a meaningful way to measure achievement.

Carnegie Mellon and Enrollment Services does not report nor record students' rank in class, rank in college and rank in department. For those graduate school and/or employment requests that request a students' rank, they will be completed with the statement "Carnegie Mellon does not report rank in class."

Transcripts & Verifications

Transcripts

The student's official transcript is to be considered the official record for all degree(s), major(s), minor(s), and honors. The official Carnegie Mellon transcript includes both the undergraduate and graduate record. All transcripts come in individually sealed envelopes, unless otherwise specified. Transcript requests are not processed if the student has an outstanding obligation, financial or otherwise. We cannot accept phone or email requests and we are not able to fax a transcript under any circumstances.

Visit www.cmu.edu/hub/registrar/student-records for complete information, including how to order a transcript.

Verifications

Enrollment/degree verifications are available for currently enrolled Carnegie Mellon students and Carnegie Mellon Alumni.

An enrollment/degree verification officially confirms information about you. Please note that we cannot fax your QPA or verifications that contain anything besides the following:

- Name
- Local address
- Local phone number
- Email address
- Class
- College
- Department
- Dates of attendance
- Date(s) of graduation
- Degree(s) awarded

The most common reasons for requesting a verification are:

- Student loan agencies and insurance companies wanting to know if a student is enrolled.
- Scholarship committees wanting to know if a student maintained a certain QPA.
- Potential employers wanting to know if a student graduated with a certain degree.

Online Verification Ordering

Currently enrolled Carnegie Mellon students may order enrollment verifications via Student Information Online (SIO) (https://s3.as.cmu.edu/

sio). Additional information can be found at www.cmu.edu/hub/registrar/student-records.

Full-Time Status

Undergraduates who are registered as full-time students as of the end of the course add period (typically, the 10th regularly scheduled class day) are expected to remain full-time for the duration of the semester. Full-time is defined by a minimum of 36 units. Permission to drop below the 36 unit minimum must be granted by the student's Associate Dean. Undergraduates who are registered as part-time are also subject to the above deadlines to drop or withdraw from a course.

Students carrying a full-time course load as of the end of the course add period (typically, the 10th regularly scheduled class day) are not ordinarily permitted to drop below 36 units after that time. Exceptions must be authorized by the student's associate dean.

Status, Class Standing

Students should refer to the sections of the catalog pertaining to their college and/or department to determine the number of units required each academic year by their specific curriculum. Students must achieve passing grades in order to earn units; students do not earn units for incomplete or failed courses.

A freshman student becomes a sophomore after earning passing grades in three-fourths of the units required by their freshman curriculum.

A sophomore student becomes a junior after earning the number of units required by their curriculum for the freshman year plus three-fourths of the number of units for the sophomore year.

A junior student becomes a senior after earning the number of units required by their curriculum for the freshman and sophomore years plus three-fourths of the number of units for the junior year.

Classification of students is made only at the time of their first registration in any academic year and remains unchanged throughout the rest of that academic year.

Course Description Requests (for prior years)

Please note that University Archives does not have access to transcript and verification information. They maintain only the course description archives. If you call or email this office, your request will not be processed. Please contact:

Archives/Art Inventory Specialist
Carnegie Mellon University Libraries
4909 Frew St.
Pittsburgh, PA 15213
412-268-5021 (phone)
412-268-7148 (fax)

Graduation & Diplomas

Degree Requirements

Students are responsible for checking to ensure that the degree requirements (as listed in the appropriate catalog at the time of their matriculation) have been met. They may also refer to the Stellic (https://academicaudit.andrew.cmu.edu) online degree audit application. If the degree requirements have been modified by College Council action, the student is responsible for checking to ensure that the modified requirements have been met.

To be eligible to graduate, undergraduate students must complete all residence and course requirements for their program with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

No student may receive a diploma until all financial obligations to the university have been met.

Residency Requirement

A candidate for the bachelor's degree must complete at the university a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework. Note that these are minimum residency requirements applicable to all university undergraduates. Some of the university's colleges and departments have developed more restrictive requirements in this area. Students should consult that section of the catalog in which their college or department's academic regulations are presented for the residency requirements applicable to them. Deviation from these policies requires action by the Dean of the student's home college.

Implications of Residency Requirements for transfer students seeking second undergraduate degree: Students who received degrees from other universities could have up to 2 years of credits earned elsewhere applied to their Carnegie Mellon degree requirements and would need to meet Carnegie Mellon's Residency Requirement and complete at the university a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework. Deviation from these policies will require action by the dean of the student's home college.

Diplomas

A Carnegie Mellon diploma is a student's certificate of accomplishment. The diploma is printed with the name the student approved within Student Information Online (SIO) , along with the student's primary degree (i.e., Bachelor of Arts in Creative Writing). Minors are not listed on a diploma, although they do appear on an official transcript.

Diplomas are distributed to graduates during or immediately following the May Commencement Ceremony. Certain circumstances will result in students receiving their diplomas at a later date, and such students will be informed of this well before the ceremony. If a student is unable to attend the ceremony, diplomas will be available for pick-up or mail-out in the weeks following commencement. Diplomas are not available prior to the stated date of graduation. August and December graduates will receive their diploma via the mail.

The diploma is 14x17 inches and is marked with a multi-colored and gold seal.

Graduation with University Honors

In recognition of exemplary academic achievement as undergraduates, some candidates for undergraduate degrees will be named to the University Honors List. Each of the undergraduate colleges will select students for honors on the basis of a cumulative grade point average (typically when cumulative QPA is greater than 3.5) and/or recommendation of the faculty.

Standard Degree Terminology

Carnegie Mellon University offers a wide variety of programs; the opportunities vary greatly between and among the colleges. For the purposes of clarification, this section defines:

- standard degree terminology;
- changes to the existing degree declaration process;
- the existing procedure for creating new degrees, majors and minors.

Degree

Examples: B.S. (Bachelor of Science); M.F.A. (Master of Fine Arts); Ph.D. (Doctor of Philosophy)

Major

Field studied in greatest depth by fulfilling a department-determined set of course requirements. The primary major is the field in which the degree is granted.
Example: Creative Writing; Physics; Marketing
Students may pursue an additional major(s) in a single degree program.

Minor

Field(s) studied for educational enrichment by fulfilling a department-determined set of course requirements. Graduate students may not pursue minors. Minors are not listed on the diploma but appear, instead, on the student's transcript. The type of degree sought is determined by the major (that of the home department), not the minor. Examples: Film Studies; Game Design

Option

(Now referred to variously as track, option, etc.)
A specific area of study associated with the major or additional major(s), which transforms the title of the major or additional major.
Examples: Civil Engineering (Biomedical Engineering Option) Physics (Computer Science Option)

Concentration

(Now referred to variously as track, option, etc.)
A specific area of study generally associated with a major or an additional major, which appears only on the transcript.

Home College

The college into which the student was originally admitted or into which the student formally transferred.

Home Department

The department into which the student was originally admitted or the department offering the major which the student has declared.

Concurrent College/Department

College/department other than the home college/department, granting the second of multiple degrees, or offering the additional major(s) of double or triple major, or minor.

Single Degree/Major

One diploma, stating the degree and the major field of study. Currently, the Statute of Limitations on earning an undergraduate degree is eight years.
Examples: B.A. in Psychology; M.S. in Industrial Administration
Requirements: Fulfillment of all requirements of the home college.
Declaration: At least by registration time (early November), first semester junior year.
Certification: Home college, home department

Major-Declaration Process

For undergraduates, depending on the student's college, the major is usually declared at the end of the freshman or sophomore year. Departments enter the appropriate majors upon declaration.

For graduates, the major is usually indicative of the department and is supplied by the department.

Joint Degree

Degree program offered between two or more colleges/departments or offered in conjunction with an outside university.

Examples: M.S. in Colloids, Polymers, and Surfaces (Chemistry and Chemical Engineering); B.H.A from College of Fine Arts and Humanities and Social Sciences.

Multiple Degrees

More than one degree granted by the university (whether simultaneous or sequential). One diploma for each degree. When awarded simultaneously, two degrees are referred to as dual degrees, three degrees as triple degrees. Multiple graduate degrees may be given in conjunction with an outside university.

Examples of how such degrees appear on the respective diplomas:

- Bachelor of Fine Arts in the field of Art; Bachelor of Science in the field of History
- Bachelor of Science in the field of Physics; Bachelor of Science in the field of Computer Science

Requirements: Multiple bachelor's degrees

Declaration: Undergraduates: at least by registration time (early November), semester junior year

To receive multiple bachelor's degrees the student must:

- satisfy all requirements for each degree.
- complete an aggregate number of units that exceeds, by at least 90, the minimum unit requirement for the degree with the smallest such requirement (i.e., if the one of the degrees requires a minimum of 360 units and the other requires 380 units, a total of at least 450 units (90 plus 360, the smallest of the two) is required to obtain both degrees).
- comply, for each degree, with the statute of limitations regarding the time at which units are earned.
- while working towards more than one degree simultaneously, designate one of the departments (and if necessary colleges) as the home college/department.

Additional Major

One degree, stating the major in the home department first and the additional major second. The type of degree given (B.A., B.S.) is determined by the major of the home department.

For example, a student whose home department is Physics:

This degree is valid: B.S. in Physics with an additional major in History

This degree is not valid: B.S. in History with an additional major in Physics

The intent of a double major is an in-depth understanding of two major fields. Students may pursue a second major in a field where the primary degree is different from the degree associated with the additional major: i.e., B.S. in Economics with an additional major in History.

Requirements: If the double majors involve two different colleges OR the same college, the student must fulfill:

- all requirements (including core) for the first major degree as defined by the home college;
- all major requirements (including core prerequisites) for the additional major;
- any specific requirements for double majors imposed by the department(s)/college(s) involved.

Declaration: At least by registration time (early November), first semester junior year.

Certification: Home college, home department; concurrent college (if any), concurrent department (if any).

Additional Majors

One degree, stating the major of the home departments first, the second and the third major afterwards. The type of degree sought (B.A., B.S.) is determined by the major in the home department.

For example, a History student, this degree is valid: B.A. in History with additional majors in Professional Writing and in Hispanic Studies. This degree is not valid: B.A. in Professional Writing with additional majors in History and in Spanish.

Requirements: If the triple major involves two or three different colleges OR the same college, the student must fulfill all requirements listed for each additional major.

Declaration: At least by registration time (early November), first semester junior year.

Certification: department

Concurrent college (if any), concurrent department (if any)

Second concurrent college (if any), second concurrent department (if any)

Minor

One degree, stating the major first and the minor second (or third, if there is also (an) additional major(s) involved). The type of degree sought (B.A., B.S.) is determined by the major (that of the home department). Minors are not listed on the diploma, but appear on the transcript.

Examples: B.F.A. in Music Performance (Voice) with a minor in Theatre Arts; B.S. in Applied History with an additional major in Information Systems and a minor in Mathematics.

Requirements: The student would generally take 45 units pertaining to the minor, in addition to fulfilling all requirements for the major degree (as defined by the home college). The “minor” courses are negotiated between the student and the department certifying the minor.

Declaration: At least by registration time (early November), first semester junior year.

Certification: department

Options (Tracks, Specializations, Area Cores, etc.)

These concentrations will not be considered part of the student's degree title unless included are part of the major or (an) additional major(s) field title.

Additional Majors/Minors Declaration Process

For undergraduates, all variations on a student's sought degree and major field must be declared by the end of the first semester of the student's junior year. Having already declared a major, students should be well prepared by this time to choose additional majors and/ or minors.

It is assumed that by these proposed deadlines, the student will have taken a majority of degree requirements and electives. The student can then, in conjunction with an advisor, review their course history and decide which options may or may not apply towards the desired degree and field(s).

A student who wishes to pursue additional majors and/or minors should consult with their advisor and receive a detailed curriculum for attaining the additional desired degree, major or minor. The student should then notify the college/department offering the additional program. Upon receipt of this notification, the college/department will update the Student Information System which will reflect this information to the Commencement System for graduation. This procedure ensures that when a student is expected to graduate, all degree/major information is immediately accessible, and certification of the degree is simplified.

Multiple Degrees Involving Graduate Degrees

Policies involving multiple graduate degrees or a graduate/undergraduate degree program or sequence are dictated by each college involved.

Examples: M.S. in Public Management and Policy and the degree of Juris Doctor (Heinz College/University of Pittsburgh School of Law).

Declaration: Undergraduates: at least by registration time (early November), first semester junior year.

Declaration: Graduates: upon admittance OR by the end of the semester preceding the expected graduation date.

Certification: Home college, home department and concurrent college (if any), concurrent department (if any).

Academic Actions

Each college may have its own regulations and procedures regarding academic actions, but in general, the following apply to all undergraduate students.

Student Suspension/Required Withdrawal Policy

Policy Statement

University Suspension is a forced, temporary leave from the university. There are three types of suspension for students that apply to both graduate and undergraduate students:

- **Academic Suspension** is the result of poor academic performance or violation of academic regulations and is imposed by the student's college or academic department (see university and college academic policies).
- **Disciplinary Suspension** is the result of serious personal misconduct and is imposed by the Office of Student Affairs (see The Word/Student Handbook (https://www.cmu.edu/student-affairs/theword)).
- **Administrative Suspension** is the result of failure to meet university financial obligations or failure to comply with federal, state or local health regulations and is imposed by Student Financial Services (see Student Financial Obligation Terms (https://www.cmu.edu/sfs/billing/sfo.html)).

Suspended students may not:

- register for courses
- attend classes
- live in residence halls or Greek housing
- use campus facilities, including athletic facilities, libraries and computer clusters
- participate in student activities
- be members of student organizations
- have student jobs*

**Students on academic suspension may have a summer campus job if they accepted the job before they were suspended.*

Employment

Although suspended students may not hold student jobs, students on academic suspension may, under certain circumstances, have a non-student job with the university; students on disciplinary or administrative suspension may not.

To have a non-student job, students on academic suspension must receive approval from their associate dean (undergraduate students) or department head (graduate students) to ensure that the job will not violate their suspension terms. Students in violation of this will lose their degree student status, meaning they would have to reapply for admission to Carnegie Mellon through either Undergraduate Admission or the appropriate graduate department.

Transfer Credit

Suspended students may take courses elsewhere; however, they may receive transfer credit only if their college's and department's policies allow this.

Appeals

To appeal any action of this policy, the student may write to the following individuals:

- Academic Suspension - Associate Dean (undergraduate students) or Department Head (graduate students)
- Disciplinary Suspension - Dean of Student Affairs
- Administrative Suspension - Associate Vice President & Director of Enrollment Services, and the Dean of Student Affairs, in consultation with the student's Associate Dean

Returning from Suspension

In order to return from a suspension, a student must have the following approval:

- Academic Suspension - Associate Dean (undergraduate students) or Department Head (graduate students)
- Disciplinary Suspension - Dean of Student Affairs
- Administrative Suspension - Associate Vice President & Director of Enrollment Services, and the Dean of Student Affairs, in consultation with the student's Associate Dean

Procedure for the Appeal of Grades & Academic Actions

In the event a student believes an assigned grade or an imposed academic action is incorrect or not appropriate, the student may follow the processes outlined below to seek prompt and equitable resolution of the matter.

If a student believes a grade has been incorrectly assigned, the student should:

1. Present the case to the faculty member responsible for the course, providing all supporting data concerning the nature of the discrepancy.
2. If, after a decision is rendered, the student believes that their concerns have not been adequately resolved, the student may pursue a formal appeal with the department responsible for the course. To appeal to the department, a student must present a written statement detailing the grounds for the appeal with appropriate documentation to the head of the department responsible for the course. This appeal must be submitted within seven (7) days of receipt of the faculty member’s decision. The department head will provide a written decision, including the basis for it, within thirty (30) days, or as soon thereafter as practical.
3. If the student is not satisfied with the department head’s resolution, the student may pursue the appeal at the college level. To appeal at the college level, the student must present copies of all documents originally sent to the faculty member and department head, along with a formal letter of appeal, to the dean of the college responsible for the course. This appeal must be submitted within seven (7) days of receipt of the department head’s decision. The dean, or the dean’s designate, will review the appeal and will render a written decision, including the basis for it, within thirty (30) days, or as soon thereafter as practical.

If a student believes an academic action is inconsistent with the policies of the college or merits additional review, a student should:

1. Submit a formal written appeal, as specified in the initial academic action, to the associate dean of the college responsible for the decision, with a copy to the dean, requesting review of the action including all relevant materials to substantiate their case and support their concerns.
2. The dean of the college, or the dean’s designate, will review the appeal and issue a decision and the basis for it within thirty (30) days.

If, after carrying out the steps of either process described above, the student believes that the matter has not been adequately resolved, or if no decision has been rendered by the appropriate date, the student may appeal at the university level. To appeal at the university level, the student must present copies of all previously submitted documents and a formal letter of appeal to the provost. The provost or another designated university officer will respond in writing with a final resolution, including the basis for it, within thirty (30) days, or as soon thereafter as practical.

Other Academic Regulations

English Fluency for Non-Native English Speakers

To be successful at Carnegie Mellon University, students who are nonnative speakers of English need to begin their undergraduate work with a strong foundation in academic English and a high level of proficiency with speaking, reading and writing in English. The importance of English language abilities cannot be overstated since there are no basic ESL language courses at Carnegie Mellon. All students will have sufficient English language proficiency to be able to participate fully in the academic work and to interact in daily life outside of the classroom.

Students' English fluency will enable them to handle the demands of academic work, including the ability to comprehend, process, and master complex material presented in English, both in written and spoken form. Students will possess the fluency to communicate their ideas and questions to faculty, classmates, and others, in a classroom environment that is often highly participatory. For example, many classes require group discussion, team projects, oral presentations, and/or independent research. In addition to fluent English skills, studying in a new culture requires openness and flexibility to adapt to a new, and often very different, academic system.

To assess the language of nonnative speaking applicants, a minimum TOEFL score of 600 (paper based, PBT), or 100 (internet based, iBT) has been established as the standard for admission. This minimum score indicates that an applicant has the fundamental building blocks of language needed for academic tasks and for continued language development. Since neither the PBT or CBT versions of TOEFL access speaking, students who took these tests should additionally seek feedback on their speaking skills and work to improve conversational skills before beginning academic work.

Exchange Students

Each term, Carnegie Mellon welcomes exchange students from partner institutions around the world. Exchange students enrich the learning experience at Carnegie Mellon and are expected to be full participants in the curricular and meta-curricular life. Therefore, their admission should adhere to the English language guidelines described above. Exchange students submit standardized English language testing scores (such as the TOEFL) as part of the Exchange application process, and present the same high level of English language abilities as degree-seeking students. With exchange students, high-level English abilities are particularly critical since academic, personal and extracurricular experiences must be maximized in a short period of time sometimes only four months in duration.

Withdrawal of a Degree

The university reserves the right to withdraw a degree even though it has been granted should there be discovery that the work upon which it was based or the academic records in support of it had been falsified. In such a case the degree will be withdrawn promptly upon discovery of the falsification.

Information for Graduates

Graduating students may wear one stole ONLY with their academic regalia. Students are certainly permitted to receive/purchase more than one stole if they are a member of multiple organizations that issue stoles and may chose to wear a particular stole to the main commencement ceremony and another to their diploma ceremony.

Graduating seniors that are a member of a club/organization that issues a pin to designate affiliation are permitted to wear more than one pin with the academic regalia in addition to one stole.

Retention of Student Work

The university reserves the right in all colleges to retain indefinitely any student work the faculty may select. All work not retained by the university must be claimed at the time specified on the bulletin boards (or other forms of communication) of the department concerned; otherwise, the work will be destroyed.

Degree Statute of Limitations

https://www.cmu.edu/policies/student-and-student-life/ug-statute-of-limitations-student.html

All units required for an undergraduate degree, whether earned in residence, transferred from another institution or granted via advanced placement, must have been earned within eight years of the date on which the degree is granted. This statutory period can be extended by the Dean of the student's college under the following conditions:

- the courses taken prior to the statutory period still represent a reasonable part of the student's total academic program;
- the prior courses provide adequate preparation for courses which must still be taken to fulfill the degree requirements;
- there is a legitimate reason(s) for the student not completing the academic program within the statutory period.

A request for a waiver of the statute of limitations must be submitted to the dean of the student's college. The request for a waiver should address all of the above conditions for an extension. For cases in which a waiver is granted, the waiver covers specific courses and is intended for a specific period during which the program must be completed.

Transitional Student Status

Transitional student status has been instituted by the university to assist students who have changed their minds about their original field of study or who have been judged unlikely to make satisfactory progress in their chosen field. Becoming a Transitional Student gives a student an opportunity to maintain a relationship with the home college while re-orienting academic plans and goals. It also gives a student time to explore their options and/or enhance admissibility to another college in the university, or to another institution. Ordinarily, a student will be permitted to register as a Transitional Student for no more than one semester. Although, in exceptional circumstances, a student may be allowed to extend the status beyond one semester. A student must obtain the permission of their home college associate dean to initiate this option.

Transitional Student status may be available to students upon the advice of their advisor, or upon their own request. Interested students must make an appointment with the associate dean of their home college to discuss this option.

Note: Students at Carnegie Mellon in good academic standing may transfer from one program to another as long as they meet curricular or artistic requirements and as long as there is space in the program into which they wish to transfer.

New Degree, Major, or Minor

Departments proposing new degrees, majors, additional majors, and/or minors must complete a New Academic Program Process (NAPP Step 2) form. This should include any and all notations to the university diploma and/or transcript (new degrees, majors, minors, options). Departments proposing to offer a new degree, major, additional major and/or minor must follow university policies for approval as follows:

- Document the program by completing the New Academic Program Process (NAPP Step 2) form. Departments proposing new degrees and majors must complete this form and attach course descriptions, curriculum proposal, list of present faculty who will support the program, and verify the availability of other units' courses. This documentation must indicate the starting semester for the program, and in the case of new majors, also indicate if it is available only as a major/additional major/minor, or in combination.
- Receive department approval.
- Receive dean and College Council approval.
- Submit all program documentation complete with College Council approval to the Vice Provost for Education. New majors or degrees will not be processed without the approval of the Provost's Office.
- The Provost's Office will approve or deny, and inform the sponsoring department and Enrollment Services.
- The department may then publicize and offer the program for student enrollment.

University Policies

A University Policy is a rule that has been officially sanctioned by the president of Carnegie Mellon University and that generally has university-wide applicability. A policy may include governing principles, may either mandate or constrain action, may ensure compliance with laws, or may mitigate the university's risk. Broadly, a policy is either academic or administrative in scope and application and must be approved by the president (and Board of Trustees as required), in order to become official University Policy.

Additional University Policies and information may be found at www.cmu.edu/policies.

Academic Integrity

www.cmu.edu/policies/student-and-student-life/academic-integrity.html

Students at Carnegie Mellon are engaged in intellectual activity consistent with the highest standards of the academy. The relationship between students and instructors and their shared commitment to overarching standards of respect, honor and transparency determine the integrity of our community of scholars. The actions of our students, faculty and staff are a representation of our university community and of the professional and personal communities that we lead. Therefore, a deep and abiding commitment to academic integrity is fundamental to a Carnegie Mellon education. Honesty and good faith, clarity in the communication of core values, professional conduct of work, mutual trust and respect, and fairness and exemplary behavior represent the expectations for ethical behavior for all members of the Carnegie Mellon community.

Policy Statement

In any manner of presentation, it is the responsibility of each student to produce their own original academic work. Collaboration or assistance on academic work to be graded is not permitted unless explicitly authorized by the course instructor(s). Students may utilize the assistance provided by Academic Development, the Global Communication Center, and the Academic Resource Center (CMU-Q) unless specifically prohibited by the course instructor(s). Any other sources of collaboration or assistance must be specifically authorized by the course instructor(s).

In all academic work to be graded, the citation of all sources is required. When collaboration or assistance is permitted by the course instructor(s) or when a student utilizes the services provided by Academic Development, the Global Communication Center, and the Academic Resource Center (CMU-Q), the acknowledgement of any collaboration or assistance is likewise required. This citation and acknowledgement must be incorporated into the work submitted and not separately or at a later point in time. Failure to do so is dishonest and is subject to disciplinary action.

Instructors have a duty to communicate their expectations including those specific to collaboration, assistance, citation and acknowledgement within each course. Students likewise have a duty to ensure that they understand and abide by the standards that apply in any course or academic activity. In the absence of such understanding, it is the student’s responsibility to seek additional information and clarification.

Policy Violations

Cheating occurs when a student avails themself of an unfair or disallowed advantage which includes but is not limited to:

1. Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
2. Use of an alternate, stand-in or proxy during an examination.
3. Copying from the examination or work of another person or source.
4. Submission or use of falsified data.
5. Using false statements to obtain additional time or other accommodation.
6. Falsification of academic credentials.

Plagiarism is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

1. Text, either written or spoken, quoted directly or paraphrased.
2. Graphic elements.
3. Passages of music, existing either as sound or as notation.
4. Mathematical proofs.
5. Scientific data.
6. Concepts or material derived from the work, published or unpublished, of another person.

Unauthorized assistance refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work to be graded. Such sources of support may include but are not limited to advice or help provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

1. Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
2. Submission of work completed or edited in whole or in part by another person.
3. Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
4. Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
5. Use of unauthorized devices.
6. Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses.

Procedures for dealing with allegations of these policy violations are detailed in the university’s Academic Disciplinary Action Procedures for Undergraduate Students and the Academic Disciplinary Action Procedures for Graduate Students, which are published in The WORD student handbook. Periodic review of these procedures will be overseen by the Dean of Student Affairs or designee in consultation with Faculty Senate and the relevant student governing bodies. Any amendments to these procedures are subject to the approval of Faculty Senate. Additional guidelines and procedures for graduate students may exist at the college/department/program level, in which case they are communicated in the college/department/program graduate student handbook.

Computing Policy

www.cmu.edu/policies/information-technology/computing.html

Statement

The purpose of this policy is to set forth guidelines so that members of our community may use the campus network and computing facilities in ways that are responsible and respectful of privacy. This policy sets forth the university’s expectations of acceptable behavior on the part of computer systems users at Carnegie Mellon by providing guidelines for appropriate use of computing and related communication systems and examples of inappropriate use. These standards of acceptable behavior also extend beyond the campus community into the Internet. Just as it is unacceptable to violate others’ rights to privacy, property and resources within Carnegie Mellon, it is also unacceptable to violate those rights on systems that are not at Carnegie Mellon but are accessible through Carnegie Mellon’s connection to the Internet.

This policy applies to all users of Carnegie Mellon computing systems, including students, faculty and staff, and any others granted the use of university computing resources. It applies to the use of all computing facilities owned, leased, operated or contracted by Carnegie Mellon University. As used in this policy, terms such as “computing,” “computing/communications systems,” “computing resources,” etc., refer to all computers, communication systems, and peripherals, software, telephones and systems with similar functions, which are owned by Carnegie Mellon, or which utilize Carnegie Mellon infrastructure such as telephone lines or computer networks.

Although this policy does not attempt to deal specifically with legal issues, university members are responsible to act in compliance with the law, including any federal, state and local laws governing computer and telecommunications use, as well as all other applicable university policies.

Privileges and Responsibilities

Every member of the Carnegie Mellon community who uses computing and related communications systems at Carnegie Mellon, or systems that belong to Carnegie Mellon or which rely on Carnegie Mellon’s infrastructure has the responsibilities described in this policy. This includes members of the

Carnegie Mellon community who have restricted privileges, such as alumni who may have electronic mail forwarding access, but no access to "login" resources. Individuals with personally-owned computers, but who rely upon the university network to connect those computers (either through an on-campus or remote network connection, such as Ethernet, wireless, dialup, DSL) are expected to abide by the policies set forth in this document. Personally-owned computers operating in stand-alone mode or networked through a non-university connection are not covered under this policy, but those users are encouraged to consult the usage policies set forth by their Internet Service Provider.

A fundamental premise of this policy is that anyone sharing computing resources with other individuals should behave as a reasonable, mature and ethical person. The user must recognize that computer systems and networks do not exist in some special rule-free environment; on the contrary, use of computers is a form of communication, and every component of a computing environment and every piece of information it contains belong to the university, the university community as a whole, or some individual or group within that community.

Access to Carnegie Mellon's computing resources is contingent upon being a member of the university community and adhering to university and Computing Services policies, guidelines and procedures, including this policy. Misuse may result in the loss of access and/or university disciplinary action. For some users and certain systems, access may be authorized by specific departments, research centers or other organizations affiliated with Carnegie Mellon. In such cases, any department- or group-specific policies and guidelines must be adhered to when using resources provided by the department or group. This is in addition to university policies and Computing Services guidelines and procedures.

Any user who suspects a violation of the University's computer use policies, or who has knowledge of potential vulnerabilities or security loopholes in a system or network at Carnegie Mellon, should immediately notify the Computer and Network Security Coordinator or abuse@andrew.cmu.edu.

Maintain the Security and Confidentiality of your Account

Users assume personal responsibility for the use made of their computer accounts. This responsibility begins with selecting a secure password, and involves maintaining the confidentiality of that password and changing the password regularly in order to assure the continued security of your account. For guidance in selecting a secure password, see Managing Your Andrew Password. If you believe that someone has made unauthorized use of your account, you should change your password immediately and report the incident to the Computer and Network Security Coordinator or abuse@andrew.cmu.edu.

Respect for Others' Property and Privacy Rights

Users are responsible to respect copyright agreements and intellectual property ownership. Any material that is the work of another, whether explicitly copyrighted or not, should not be distributed by a user without appropriate acknowledgement and/or permission of the creator; unless permission has been granted by the owner of copyright protected materials, distribution of copyright protected material via the university network or computer systems is prohibited. So while the university has been granted permission by software vendors to distribute certain software packages via the network, it is not generally permissible for individual users to distribute that same software to others via the university network or computer systems. See the sections in this policy on Misuse and Inappropriate Behavior. While there may be cases in which property rights to particular programs, data, etc., are ambiguous or in dispute, the user must assume that any information not created by themselves belongs to someone else and must respect that person's privacy and property rights to that information. (In certain situations, even information created by the user may not belong to that user but rather to the university or others.) This policy is not intended to limit "fair use" as permitted under the Copyright Act and users having questions about whether a particular use constitutes a "fair use" may consult the General Counsel for advice.

Improper/Illegal Communications

Any communications that would be improper or illegal on any other medium are equally so on the computer: libelous material, obscene messages, harassment, forgery, threats, etc. However, this is not intended to restrict the free expression of ideas. Communication conducted in accordance with the university policy on Free Speech and Assembly and Controversial Speakers and with the statement on Academic Freedom and Responsibility enunciated in the Appointment and Tenure Policy of Carnegie Mellon University will not be considered a violation of this policy. For further guidelines, see also the university policy on Separation of Individual's and Institution's Interests.

Responsible Sharing of Resources

Where a resource such as memory, CPU time or access to network resources belongs to the whole community collectively, it must be shared.

It is unacceptable to make such excessive use of system or network resources that other users cannot obtain access. Examples include excessive use of CPU time during a period of heavy use on a timesharing system, excessive use of disk space on a system that does not limit such utilization, the use of an excessive amount of network bandwidth in an environment of networked computers, and any activity that makes a system unusable or significantly degrades performance for others. A novice user might be unaware that a particular action constitutes "excessive use" but, without doubt, once a system administrator makes them aware of the fact that such an action is unreasonable, that user will be held responsible for any further such infractions. If you are unsure whether your needs constitute excessive use, contact the system administrator. Similarly, if you need an unusual amount of disk space, CPU time or other resources, check with the system administrator to find out whether this use can be accommodated, rather than risk interfering with the work of others on the system.

Risks of Data Loss and Data Persistence

Although the university will make efforts to secure the network and university controlled servers from abuse and damage, it cannot guarantee against data loss by a student, faculty, member or staff, either on a university-operated or an individually-owned computer.

Users should know that even those files that they have "deleted" using the appropriate procedures in the application or operating system, may indeed be recoverable if they exist in a system backup file or other persistent form. If the university is asked to recover such data by subpoena, it must cooperate, and data that the user believes to have been destroyed may be recovered in the process.

Personal Use

While the university makes computer resources available primarily to achieve its goals of education and research, and for administrative activities, it realizes the need to encourage the personal use of computing for the convenience of the campus community. Thus, it is reasonable to allow the use of computing resources for computer mail, document preparation, personal or course Web page publication, or other activity that can facilitate convenience or enhance productivity, to the extent that the activity is within the limits described by Responsible Sharing of Resources. Any personal use of computing resources related to operating a personal business or commercial enterprise is prohibited unless permission to do so has been specifically granted by the provost or the provost's designee.

We do recognize the difficulty of distinguishing whether certain cases of "personal use" are allowable, such as activities that result in personal financial gain (e.g. checking stock prices online), relate to a commercial business (e.g. university-sponsored technology transfer efforts), or support (but do not constitute operating) a personal business (i.e., a student developing a business plan or a faculty member writing a report for a consulting engagement outside the university). In such cases, we rely on individuals to be responsible and judicious in the use of university's shared computing resources. In particular ensuring:

- appropriate use of resources (e.g. any such work is completed outside of university time and does not utilize shared resources such as CPU cycles or network bandwidth to a degree that adversely impacts academic or research activities);
- appropriate use of licenses (e.g. do not use software procured with academic use licenses for commercial applications or development, unless the license explicitly permits such use);
- appropriate marketing (e.g. no creation of ".com" domains within Carnegie Mellon's "edu" domain, no advertising services and products using Carnegie Mellon email accounts, and no advertising using web pages on Carnegie Mellon servers (any server with a .CMU.EDU host name).

In cases of questionable personal use of resources, you may contact advisor+@andrew.cmu.edu to determine whether a particular activity is permissible.

We reserve the right to restrict personal use of university systems and networks by an individual or by the community at large, if the use of resources for such activities becomes excessive. If you need unlimited access to computer networks for private or business purposes, you can subscribe to a commercial service.

For information regarding the use of resources to produce intellectual property and profit from the development of such property see Carnegie Mellon University's Intellectual Property Policy and the Policy on Conflict of Interest/Commitment.

Privacy

The user must presume that the contents of any other users' directory are private unless expressly designated otherwise, just as one would presume that the contents of someone's apartment or office are private.

The only exceptions to this rule are: that in some environments, files such as "plan files" may be considered public even if the user has not expressly designated them as such; and that some services such as web pages and anonymous or "guest access" ftp services may be considered to be public, but only for those areas not protected by password and which are "obviously" public. An unprotected account or shared device (such as a shared disk on a networked computer) are not considered to be public unless the name or service expressly indicates that it is. In such cases, any files or other data which would appear to be private in nature, by virtue of the file name or data stored, even if "publicly accessible" should be considered to be private. The user accessing such files has a responsibility to ask the owner of the files or service if the files are intended to be publicly accessible before the user does more than a "cursory glance" sufficient to cause the question.

A user can explicitly grant access to his or her directories, files or to services run from his or her systems. However, users who issue general or vague invitations to browse through their files incur a special obligation to protect any material that they do not wish others to see. Indeed, all users are urged to maintain protection levels on their files consistent with the access they are actually willing to give to other users.

Access to Faculty Data

Electronic data on a faculty member's account, whether stored on a computer in the faculty member's office or elsewhere under the proprietary control of that faculty member, may not be examined, i.e., the contents of the data read by a person, without the faculty member's consent, except in cases of emergency or in response to a valid subpoena, search warrant, or order of a court. Posting of data by a faculty member on servers available to the public or to students shall be understood to imply consent, and electronic access given to specific parties by the faculty member will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the faculty member, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency." Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the faculty member whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith, and, whenever possible and legally permissible, sufficient time must be allowed, before intrusion, to allow the faculty member to file a motion to quash. Information obtained from an examination warranted by an emergency cannot be used as evidence in University sanctions of any faculty member, and cannot be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime concealment of which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any intrusion by an employee of the University into a faculty member's electronic data must be reported to the faculty member as soon as possible, and within five days of the event in writing both to the faculty member, if possible, and unless prohibited by order of court, and to an Ombudsman, who shall be a member of the regular faculty selected annually by the Nominating Committee of the Faculty Senate and who has been endorsed by majority vote of the Faculty Senate. The Ombudsman shall be a current or retired regular faculty member who holds no administrative appointment and is not a member of the Faculty Review Committee. The Ombudsman shall have authority to investigate whether an intrusion was warranted by the policy and, (i) shall inform the President and the affected faculty member of the Ombudsman's findings; (ii) where a violation of the policy is found, shall inform the Faculty Review Committee of the policy violation; and (iii) where appropriate, in the absence of the affected faculty member, to bring a grievance before the Faculty Review Committee. Violation of any aspect of this policy is a sanctionable offense.

For purposes of this section, the term "faculty" shall mean any person who is a member of the Faculty Organization as defined in Article III of the Constitution of the Faculty Organization.

Access to Staff Data

Electronic data on a staff member's account, whether stored on a computer in the staff member's office or elsewhere under the proprietary control of that staff member, may not be examined, i.e., the contents of the data read by a person, without the staff member's consent, except in cases of emergency, in response to a valid subpoena, search warrant, order of a court, or by specific request by the staff members' supervisor for the purpose of accessing work-related electronic data. Posting of data by a staff member on servers available to the public or to members of the university shall be understood to imply consent, and electronic access given to specific parties by the staff member will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the staff member, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency." Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the staff member whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith. Information obtained from an examination warranted by an emergency will not be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime concealment of which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any such findings may be reported to the staff member's supervisor, department head, or to Human Resources for appropriate investigation and action. Any intrusion by an employee of the University into a staff member's electronic data must be reported to the staff member as soon as possible, and within five days of the event via electronic mail unless prohibited by order of court, or due to a continuance of an ongoing investigation by the University. Violation of any aspect of this policy is a sanctionable offense.

When possible, staff members will be informed about the issuance of court orders, or other intrusions into their electronic data. In cases where a staff member believes that electronic data in their account has been inappropriately accessed by another staff member, the incident should be reported to Human Resources.

Access to Student Data

Electronic data stored in a student account, whether stored on a computer in the student's residence or elsewhere under the proprietary control of that student, may not be examined, i.e., the contents of the data read by a person, without the student's consent, except in cases of emergency or in response to a valid subpoena, search warrant, order of a court, or by order of the Office of the Dean of Student Affairs. Posting of data by a student on servers available to the public shall be understood to imply consent, and electronic access given to specific parties by the student will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the student, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency". Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the student whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith. Information obtained from an examination warranted by an emergency will not be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime of concealment which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any findings of potential wrongdoing unrelated to the original intent of the search, must be reported to the Office of the Dean of Student Affairs for appropriate investigation and action. Any intrusion by an employee of the University into a student's electronic data must be reported to the student as soon as possible, and within five days of the event via electronic mail to the student, if possible, unless prohibited by an order of the court or because of an ongoing investigation conducted by the University. Violation of any aspect of this policy is a sanctionable offense.

When possible, students will be informed about the issuance of court orders, or other intrusions into their electronic data, including the purpose of the search. In cases where a student believes that electronic data in their account has been inappropriately accessed by a staff member, the incident should be reported to Office of the Dean of Student Affairs.

Note: Removable media such as floppy disks, zip drives, tapes, or CDs in a faculty or staff office, or in a residence hall are not subject to search by

Computing Services, though Computing Services will assist authorized law enforcement agencies or authorities to read data after they are obtained, at the agencies' or authorities' request.

Protecting Confidential Information

Users who maintain confidential information, such as records relating to employees or students, are responsible for following privacy-related policies and laws.

Protecting Personal Information

As is described throughout this policy, data transmitted across the university network or stored on university systems may be accessed by others as a result of misuse by an individual, as an incidental result of the routine operation of the network and systems, or in response to a court subpoena or university investigation into suspected or alleged misuse. While complete privacy of personal data may not be possible, users who wish to ensure a higher degree of privacy for their data are encouraged to use encryption, PGP security, or other techniques to reduce the risk that others may access their data. For more information on these techniques, see various newsgroups (e.g. comp.security.pgp) or web references (e.g. comp.security.pgp FAQ).

Misuse and Inappropriate Behavior

The following activities are expressly prohibited at Carnegie Mellon:

- Using a computer system without proper authorization granted through the University, college, or department management structure. Some activities such as "port scanning" are not expressly prohibited. However, if the target of such scanning requests that an individual or system stop performing such actions, the person or system performing the scans must stop scanning the target machine unless the scans are being carried out by a system administrator who has the authority and responsibility over the machine(s) being scanned or for the network being used.
- Concealing your identity, or assuming the identity of another (e.g., by sending forged electronic mail). Note that some forms of electronic communication, such as browsing Web pages, passively "identify" users. Keeping your identity private either by not setting an identity in your browser or by using a Web-anonymizer in order to protect yourself from being put onto mailing lists is not a violation of this policy.
- Sharing your password or account with the specific exception of staff or faculty members allowing their support personnel to access their accounts in order to provide services appropriate to their job functions. Note that some policies for the accessing of specific systems or data (see Data and Computer Security, Confidentiality of Administrative Data) explicitly forbid the sharing of passwords used to access them, and that such restrictions for those specific systems override this policy.
- Using another person's computer account, userID, files, or data without appropriate permission, as described in the previous bullet (e.g. using an account found "logged in" on a cluster machine).
- Deleting or tampering with another user's files or with information stored by another user on any information-bearing medium (disk, tape, memory, etc.). Even if the user's files are unprotected, with the exception of files obviously intended for public reading, such as Web pages, it is improper for another user to read them unless the owner has given permission (e.g. in an announcement in class or on a computer bulletin board).
- Attempting to "crack" or guess other users' passwords. System administrators or those specifically designated by the administrator or owner of a system may attempt to crack passwords in order to test and enhance the security of the system. In cases where an individual or department "owns" machines which use password files controlled by another organization (e.g. Andrew machines or their like), the owner may not attempt to crack passwords without explicit permission by the owners of the password database.
- Obtaining passwords by other means, such as password capturing programs.
- Attempting to circumvent system security (e.g. breaking into a system or using programs to obtain "root" access), without the explicit permission of the owner of that system.
- Denying appropriate access to resources to other users (e.g. "ping flooding" another system, sending "mail bombs," or modifying a login file in order to cause a user to not be able to log in).
- Releasing programs such as viruses, Trojan horses, worms, etc., that disrupt other users, damage software or hardware, disrupt network performance, or replicate themselves for malicious purpose.
- Sending commercial solicitations via electronic mail (i.e. spamming) to individuals, or to newsgroups or mailing lists where such advertising is not part of the purpose of the group or list. (It is permissible to send a commercial solicitation to a "for sale" newsgroup, provided that the advertisement conforms to other policies and guidelines at Carnegie Mellon.)
- Any "mass mailing" which is solicitous in nature, unless the mailing is in the conduct of university business.
- Reselling of services based on the university network, such as web hosting, mailing services or the selling of shell accounts.
- Running a proxy server which results in inappropriate or unauthorized access to university materials to non-university members.
- Advertising commercial businesses or ventures on Web pages hosted by Carnegie Mellon, unless prior authorization has been granted.
- Using mail messages to harass or intimidate another person (such as by repeatedly sending unwanted mail or broadcasting unsolicited mail).
- Violations of any local, state or federal laws, such as the distribution of copyright-protected materials (e.g. the distribution of commercial software, music or films in electronic format without appropriate permissions by the owner, even if the user distributing the materials notifies others of their copyright status).
- Tampering with, willful destruction of or theft of any computer equipment, whether it belongs to the university or to an individual. Tampering includes any deliberate effort to degrade or halt a system, to tie up a system or to compromise the system/network performance. Willful destruction includes any deliberate disabling or damaging of computer systems, peripheral equipment such as scanners or printers, or other facilities or equipment including the network, and any deliberate destruction or impairment of software or other users' files or data.
- The unauthorized removal of university or another's computing equipment, which constitutes theft.

This list should not be considered to be complete or exhaustive. It should, however, serve as a set of examples of obviously inappropriate behaviors. If you are in doubt about the appropriateness of something that you want to do, contact the Computing Services Help Center at 8-HELP, or send mail to advisor+@andrew.cmu.edu and ask first.

Enforcement

Inappropriate behavior in the use of computers is punishable under the general university policies and regulations regarding faculty, students and staff. The offenses mentioned in this policy range from relatively minor to extremely serious, though even a minor offense may be treated severely if it is repeated or malicious. Certain offenses may also be subject to prosecution under federal, state or local laws.

Appropriate disciplinary action depends not only on the nature of the offense, but also on the intent and previous history of the offender. The range of possible penalties includes reprimands, loss of computing privileges, course failures for students, disciplinary probation, suspension or dismissal from the university and/or criminal prosecution.

Offenses that are minor or appear to be accidental in nature are often handled in a very informal manner such as through electronic mail. More serious offenses will involve formal procedures pursued through the Division of Student Affairs for students, Human Resources and/or the hiring university department or administrative unit for staff, or the Faculty Review Committee for faculty.

Restrictions of Privileges During Investigations

During the course of an investigation of alleged inappropriate or unauthorized use, it may be necessary to temporarily suspend a user's network or computing privileges, but only after determining there is at least a prima facie case against the individual, as well as a risk to the university or it's computing resources if privileges are not revoked. In these cases, it is important to recognize that the restriction of network or computing privileges is intended to protect the system rather than to punish the individual. For example, if a computer account has been used to launch an attack on another system, that account will be rendered inactive until the investigation is complete. This is a necessary action taken to prevent further misuse and does not presume that the account holder initiated the misuse. Unsubstantiated reports of abuse will not result in the suspension of accounts or network access unless sufficient evidence is provided to show that inappropriate activity occurred. For example, if someone reports that their computer was "attacked" by a Carnegie Mellon system, the burden will be upon the complainant to provide sufficient data logs or other evidence to show that the incident did, indeed at least appear to be an attack.

Adverse Impact on Shared Systems

The university reserves the right to discontinue communication with external systems that are known to harbor spammers or account crackers, despite the fact that this may restrict certain acceptable communications. When deemed necessary, this action will be taken to protect the security and safety of our systems. Similarly, there may be cases where a particular service or activity on a given University system will, by the very nature of its legitimate operation, tend to generate attacks from other Internet sites. If these attacks are frequent and severe enough to cause service interruptions for larger parts of the campus community, it may be necessary to temporarily or permanently remove these systems from the campus network. In cases where such an action is deemed necessary, network administrators will work with the maintainers of the system to identify alternative methods of network access. In cases where the university restricts access to external sites or removes network access for internal sites, the purpose of the action is to maintain the security and reliability of the computer systems and networks rather than to punish an individual or a site, or to restrict the free expression of ideas.

Policies on Examinations

www.cmu.edu/policies/student-and-student-life/examination-policies.html

Preamble

The Faculty Senate adopted the following policies on the administration of examinations for the undergraduate courses (defined as courses that are numbered 6xx or below). These policies represent an understanding between faculty and student concerning an important but often stressful period, especially at the conclusion of each academic semester and at mid-semester. There should be no expectation that the following points will cover every conceivable situation. The student should anticipate the demands of the exam schedule, plan accordingly and early, and be prepared. The faculty should recognize that the student is encumbered with many tightly orchestrated and intensive obligations during this period over which they have no control: expectations should be reasonably consistent with the number of course units and, of course, should be made known to the student well in advance of the final examination period, preferably as part of the course syllabus.

In order to help students plan their time and study optimally for examinations, this document lays out in some detail the policies regarding final and in-term examinations. Instructors are requested to provide notification of the major in-term examinations in the course syllabus. The final examination date is posted early in the semester. It is the responsibility of the student to give his or her instructor sufficient notice and to work with the instructor to reschedule examinations if this is needed.

Definitions

- Final examination period.The university's official final examination period begins on the Monday immediately following the last day of classes and continues through the last day of scheduled final examinations, with the exception of reading day(s).
- Scheduled final examinations. Scheduled final examinations are those scheduled by Enrollment Services.
- Self-scheduled examinations.An instructor may choose not to fix a schedule for the final examination, but instead allow each student to choose the examination time; such exams are called self-scheduled examinations.
- Final examinations. Final examinations can either be comprehensive, covering all course materials, or non-comprehensive, covering only a part of the course.
- In-term examinations. Major examinations during the semester are referred to here as in-term examinations.

I. In-Term Examinations

1. All in-term examinations should be given during the regularly scheduled class time. However, if the exam requires additional time to complete, then examinations may be administered outside of regularly scheduled class time.
2. No examinations given outside of class time (excluding make ups and self-scheduled examinations) shall be administered on a Friday after 4:30 pm, or at any time Saturday or Sunday.
3. The instructor administering an exam (or another required class event) that falls outside class time must make any and all reasonable accommodations to provide an alternative time to students who have conflicts with the proposed time period, including those conflicts due to activities, meetings, other classes, etc. (provided that the instructor is notified of such conflict in a timely manner).
4. No student shall be required to take more than two full-period in-class or out-of-class examinations on the same day. It is the responsibility of the student to notify the instructor in a timely manner of their circumstance so that appropriate accommodations can be made.

II. Final Examinations

1. All scheduled final examinations are held at the end of the semester during the university's official final examination period. Comprehensive final examinations are not required for each course, but are given at the option of the department or instructor. The reading day and weekend preceding the examination days shall never be used for examination purposes of any kind, unless a student opts to take a self-scheduled examination during this time. Non-comprehensive final examinations or final projects (but not both) are allowed during this final examination period only in courses that do not give a final comprehensive examination.
2. Instructors are expected to return all work assigned no later than the last regular day of classes in courses for which there is a final examination. In cases when this is not possible, an answer key, solution sets or equivalent feedback should be provided unless the final examination will not cover material in work that has not been returned.
3. No other coursework, including laboratory or studio work, will be due during the final examination period unless it is assigned in advance and in lieu of the course's final examination. Regardless of whether there is a final examination in the course, no classes other than review sessions shall be held during the final examination period. Review sessions should be scheduled for optimal attendance, and a serious effort should be made to accommodate students who cannot attend. In appreciation of the time required to prepare for final examinations, no other examinations, portfolio reviews, critiques or juries shall be scheduled for the last class day of a course with a final examination.
4. Instructors shall never exert or submit to pressures to move an examination so that people can leave earlier nor pressure students to take an examination on a reading day or weekend preceding examinations.
5. No student is required to take more than two scheduled examinations that start within a 25-hour period. A student who has more than two examinations scheduled within a 25-hour period or has two examinations scheduled at the same time should first contact the instructors of the courses for assistance in resolving conflicts. If the problem cannot be resolved by that means, the student should contact the associate dean of his or her home college.
6. Take-home final examinations shall be given for any 24-hour period of the student's choosing during the final examination period.
7. Students are expected to present themselves at the place assigned at the start of the examination; late arrival will reduce the total time a student has to complete the examination, unless instructor's course policy indicates otherwise. Instructors reserve the right to require attendance within a specific time period. Students who miss an examination with a reasonable excuse and wish to petition for a make-up final examination should check with the instructor. Instructors are encouraged to include late arrival policy and make-up exam policy in the course syllabus.
8. Any student shall be permitted to review his or her corrected, graded final examination in the presence of an instructor or a teaching assistant. Any controversy arising from this review shall be dealt with in accordance with the university procedure for the appeal of grades and academic actions. A final examination that is not returned to a student will be kept available for a year for review. In the event that the instructor or teaching assistant is not available for the review, the responsibility shall rest with the department head of the instructor offering the course or his or her designee. Since instructors are expected to return all work assigned before the final examinations, they are not responsible for retaining unclaimed coursework.
9. Concerns related to final examination, complaints about violations of the final examination policy or alterations of the final examination schedule should be directed to the department head of the instructor offering the course or to the associate dean of the student's home college.

Contact

Questions concerning this policy or its content should be directed to the Vice Provost for Education, (412) 268-5865.

Final Examination Conflict Guidelines

Recognizing that students will, on occasion, encounter foreseeable or unforeseeable conflicts with scheduled final examinations, the following guidelines have been approved by the University Education Council (UEC), the Associate Deans' Council (ADC), and the Associate Deans for Graduate Programs (ADGP) to inform the actions of students and the decisions of instructors.

Foreseeable Conflicts:

Before negotiating any exam conflicts, students should recognize the following expectations. Students should carefully consider the dates of each semester's final exam period as reflected in the university's official academic calendar. Until the university publishes the detailed final examination schedule (usually by early October in the Fall semester and by late February in the Spring semester), students should plan according to the assumption that their final exams could be scheduled for any day/time during the final exam period. Therefore, students should avoid making any personal arrangements (such as travel) that could ultimately conflict with the final exam period.

In developing the final examination schedule, the University Registrar's Office deploys significant effort in consultation with associate deans to minimize direct and 25-hour conflicts for individual students. Once the final exam schedule is published for the semester, each student should immediately review the schedule to determine whether there are conflicts. If the student's schedule presents any final exams that directly conflict with each other, or if the student's schedule presents more than two final exams to begin in a twenty-five hour period, then the student is responsible for immediately initiating the following process so that the relevant instructors can reach a timely and effective resolution that is consistent with university policy (noting that no action is necessary if a student voluntarily elects to take the exams according to the published schedule):

1. The student should begin by discussing the conflict with all relevant instructors to determine if they can suggest a resolution. This discussion should be completed at least two weeks prior to the exams.

2. If one of the course instructors offers an alternate time for the exam, the student must agree to that resolution unless another exam conflicts with the alternate proposed time.

3. If a resolution cannot be found, the following hierarchy is recommended for compromise (Student’s Home Department> Student’s College> Smallest Course Size> Higher Course level):
    - If one of the courses is offered in the student’s home department, the home department should be the first to accommodate.
    - If the course is offered within the student’s home college, then the student’s college should accommodate a course that is not within the student’s college.
    - An instructor teaching a smaller course size should accommodate before an instructor from a larger course size accommodates.
    - Finally, if a resolution still has not been reached, an instructor teaching a higher course level should accommodate before an instructor from a lower course level accommodates.

At any point during this process, the student's academic advisor or academic associate dean from the home academic college may be consulted to verify the existence of the conflict and assist in the negotiation and resolution.

Other foreseeable conflicts may be personal in nature, such as a religious holy day or observance, or a singular, significant obligation. As stated earlier, students are expected to review the final exam schedule as soon as it is published to identify such conflicts. A student faced with such a conflict should first exhaust all reasonable means to otherwise resolve it. If such efforts are unsuccessful, then the student should immediately contact the instructor and explain the circumstances, recognizing that the current Policy on Examinations (http://www.cmu.edu/policies/documents/Exams.htm) does not require the instructor to offer an alternate exam time in response to foreseeable, personal conflicts. The mutual respect and goodwill between instructor and student should guide their negotiation of such conflicts as they attempt to balance the student's needs with those of the academic enterprise. At any point in the process, the student's academic advisor, academic associate dean and/or student affairs liaison may be consulted to assist in identifying reasonable accommodations or solutions.

Students hoping to resolve cases involving foreseeable conflicts should expect that their instructors may require them to take a rescheduled final examination on the Make Up Final Exam Day (http://www.cmu.edu/hub/courses/exams/makeup-faq.html).

Unforeseeable Conflicts

In exceptional circumstances, a student may encounter a medical, personal or family emergency that unexpectedly interferes with their ability to participate in a scheduled final examination. When encountering such a situation, the student should contact the instructor as soon as is reasonably possible, and ideally before the final examination has been administered. The student's academic advisor, academic associate dean and/or student affairs liaison may serve as both advocate for the student and point of verification for the instructor. After reviewing the matter, should an accommodation be granted by the instructor, the instructor may elect to institute one of several options, including: rescheduling the exam for later in the final examination period; assigning an "I" incomplete grade until a make-up exam can be administered in the following semester; or utilizing another method for resolving missed exams that has been outlined in the course syllabus.

Student Health Insurance Policy

www.cmu.edu/policies/student-and-student-life/student-health-insurance.html

Reason for Policy

The high cost of health care in the United States presents a potentially serious health and financial risk to students and their accompanying dependents. The absence of adequate insurance coverage can result in temporary or permanent interruption of a student's education. The university is committed to offering student health insurance that provides access to quality health care and achieves a balance between premium cost and adequate coverage without overburdening students' financial resources. This balance is best achieved through a mandatory/hard waiver insurance program that mitigates the effect of adverse selection.

Policy Statement General Requirements

All full-time students are required to carry health insurance and will be assessed a charge for the individual basic mandatory plan offered through the university student health insurance program. The charge will appear on the invoice of the first semester of attendance in the academic cycle. The student is required to take one of the following three actions:

1. Enroll in the basic plan as charged.
2. Upgrade the benefit plan by enrolling in the enhanced student health insurance options during the open enrollment period.
3. Apply for a waiver from the mandatory plan.

Requirements for Waiver

Application for a waiver from the university student health insurance plan must be made to Student Health Services by the last day of the open enrollment period. Students applying for waiver must provide documentation of continuing coverage verifying that they are enrolled as the dependent, partner/spouse or principal in an employer or government-sponsored insurance plan. Additionally, the plan must meet minimum standards for coverage as set forth below:

- It must offer at least 75% coverage for inpatient and outpatient medical services in the Pittsburgh area.
- It must include mental health benefits.
- The deductible must not exceed $500 per accident or illness.
- It must offer medical benefits of at least $50,000 per accident or illness.
- It must cover pre-existing conditions.

Contact

Questions should be directed to Student Health Services at 412-268-2157.

Carnegie Mellon Freedom of Expression Policy

www.cmu.edu/policies/administrative-and-governance/freedom-of-expression.html

Freedom of Expression Policy

Carnegie Mellon University values the freedoms of speech, thought, expression and assembly - in themselves and as part of our core educational and intellectual mission. If individuals are to cherish freedom, they must experience it. The very concept of freedom assumes that people usually choose wisely from a range of available ideas and that the range and implications of ideas cannot be fully understood unless we hold vital our rights to know, to express, and to choose. The university must be a place where all ideas may be expressed freely and where no alternative is withheld from consideration. The only limits on these freedoms are those dictated by law and those necessary to protect the rights of other members of the university community and to ensure the normal functioning of the University.

Rights

On Carnegie Mellon's Campus, anyone may distribute printed material, offer petitions for signature, make speeches, and hold protests or demonstrations outside university buildings. All such activities must be peaceful, avoiding acts or credible threats of violence and preserving the normal operation of the university. No event shall infringe upon the rights or privileges of anyone not in sympathy with it, and no one will be permitted to harm others, damage or deface property, block access to university buildings or disrupt classes. The enforcement of these conditions will not depend in any way on the message or sponsorship of the act or event. When guests are invited by a recognized campus organization, they may express their ideas not because they have a right to do so, but because members of the campus community have a right to hear, see, and experience diverse intellectual and creative inquiry. Defending that right is a fundamental obligation of the university. Controversy cannot be permitted to abridge the freedoms of speech, thought, expression or assembly. They are not matters of convenience, but of necessity.

Responsibilities

Freedom of expression must be at once fiercely guarded and genuinely embraced. Those who exercise it serve the Carnegie Mellon community by accepting the responsibilities attendant to free expression. University organizations that sponsor invited guests to campus are expected to uphold Carnegie Mellon's educational mission by planning carefully to create safe and thoughtful experiences for those involved. Hosts are responsible for the behavior of their guests and should exercise due care to ensure that all participants abide by relevant university policies.

Considerations for Planning Campus Events

Consistent with the rights and responsibilities outlined in the university's policy on Freedom of Expression, university hosts must follow all applicable policies related to space reservation, use, safety and security, keeping in mind the responsibility to have campus police present for any event with 100 or more persons in attendance.

Hosts should consider the items below as guidance in planning campus events, recognizing that not all of the items will apply to all events:

1. A public declaration of the event, its purpose, the identification of sponsors and co-sponsors, and contact information for those seeking further information.
2. A plan for advertising the event, including advance notice to relevant members of the community who may wish to co-sponsor, protest, or host other events in response to the planned activity.
3. Where appropriate, a clear and detailed contract with outside speakers, artists, or suppliers of services to ensure continuity of purpose and the ability of the host to control the event reasonably, consistent with the host's intent.
4. A plan for access to the event, including notifying the community of reserved seats, ticketing, queuing protocol, or other relevant details or restrictions well in advance of the activity.
5. A provision for security before, during, and after events, managed in coordination wit the University Police. Specifically, non-university security personnel must have their allowable duties clearly delineated, in partnership with the University Police, with their role generally limited to personal security and not to space management.
6. A plan for participant engagement at the event, such as through a question and answer session, if relevant, with a clear delineation of the planned ground rules for the event set out well in advance.
7. A strategy for hosting of additional events, discussions, or town meetings before or after a principal event to help provide a context in which the principal event may be best experienced.

The Office of Student Activities and the Office of the Dean of Student Affairs may assist in, or directly coordinate, some aspects of campus events, such as fostering discussions preceding or following an event, or accommodating an opposing view at an alternative event. It is assumed that the spirit of community, both among people with groups with opposing views, as well as between event sponsors and the Student Activities and Student Affairs staffs, will foster communication and cooperation in the planning of campus events. Wherever possible, Student Affairs will work in concert with University Police to notify occupants of buildings in advance of any potential disruption caused by such events.

Security Personnel Statement

At times, members of the campus community or their invited guests may have a legitimate basis for being accompanied by independent security personnel. It is incumbent upon the host of such an individual to ensure that University Police approve in advance the presence and scope of involvement of any such security personnel.

Human Subjects in Research at Carnegie Mellon

The university is committed to the protection of the rights and welfare of human subjects in research investigations conducted under the jurisdiction of the university. The university believes that review independent of the investigator is necessary to safeguard the rights and welfare of human subjects of research investigations. All research involving human subjects is conducted in accordance with federal regulations, including Title 45 of the Code of Federal Regulations, Part 46 (45 CFR 46). Under federal regulations, human subjects are defined as: living individual(s) about whom an investigator conducting research obtains:

- data through intervention or interaction with the individual, or
- identifiable private information.

An Institutional Review Board (IRB) is established under the provost to ensure adequate safeguards. The provost is responsible for the composition of the IRB with respect to: (1) the qualifications of IRB members in terms of educational background and research or other relevant experience, and (2) broad representation of relevant university interests.

This IRB is responsible for reviewing investigational procedures involving human subjects prior to the initiation of the research procedure in reference to (1) the rights and welfare of the individuals involved, (2) the appropriateness of the methods used to obtain informed consent, and (3) the risks and potential benefits of the investigations. The IRB is responsible for determining when additional expertise is required for adequate review and for obtaining that additional expertise. The IRB is further responsible for maintaining records of its review activities and decisions and for ensuring that records of informed consent are developed and kept by investigators where appropriate.

It is the responsibility of investigators who plan to use human subjects in research to obtain written consent from the IRB prior to conducting an investigation involving human subjects. It is the investigator's further responsibility to take whatever steps are determined necessary for the protection of the subjects, and to meet the reporting requirements established by the IRB.

Student Immunization Policy

www.cmu.edu/policies/student-and-student-life/immunizations.html

Reason for Policy

Vaccine-preventable diseases continue to occur on American campuses and pose a significant threat to the public health of the campus community. Outbreaks not only impose a significant cost to infected individuals in terms of mortality and morbidity but also can be costly to the university by disrupting university activities.

Policy Statement

The goal of the Student Health Services and the university is to provide adequate protection of the campus community against vaccine-preventable diseases by requiring students to be vaccinated against and/or screened for certain highly contagious diseases. This goal can best be achieved through a mandatory prematriculation immunization requirement. The following requirements are consistent with Pennsylvania State Law and with the recommendations of the American College Health Association, the Advisory Committee on Immunization Practices.

Requirements for All Full-Time Students

All entering full-time students born after 1956 must demonstrate proof of immunity against measles, mumps and rubella by either providing dates of inoculation of two doses of the measles vaccine and at least one dose of mumps and rubella or providing blood titers that demonstrate immunity to these infections or providing documentation from a physician of having had the infection.

Additional Requirements for Students Residing in University Housing

- All students residing in university housing must demonstrate immunity against Hepatitis B by either providing documentation of having initiated or completed the three dose vaccination series.
- The student is expected to complete the series within six months of initiation of the series.
- All students residing in university housing must provide documentation of having been vaccinated against meningococcal meningitis within three years prior to enrollment in the university.
- All full-time international students must provide documentation of having had a PPD skin test to screen for tuberculosis within one year prior to enrollment in the university regardless of prior BCG inoculation. If the results of the skin test are positive, a chest x-ray is required.

Request for Waiver

- A student may request a waiver from any vaccination for medical reasons or if vaccination conflicts with personal or religious beliefs. Application for waiver is to be made in writing to Student Health Services prior to the first day of classes in his/her first semester of attendance at the university. In the case of an outbreak of a contagious disease on campus for which the student has not been immunized, the university reserves the right to ask the student to leave campus until the outbreak is over.
- A student may request a waiver from tuberculin skin testing if the student is from a country that has been identified by the Centers for Disease Control as having low prevalence of tuberculosis.

Penalty for Noncompliance

- If the student fails to comply with the immunization policy, the Student Health Services will notify Enrollment Services who will place a hold on the student's registration until the requirements are met and assess a fee of no more than $50 to the student's account.
- Additionally, if the student is a resident in university housing and fails to comply with the immunization requirements, they will be removed from housing.

Contact

Questions should be directed to Student Health Services at 412-268-2157.

Related Policies and Procedures

The university complies with OSHA regulations regarding occupational exposure to blood-borne pathogens. Questions regarding these regulations should be directed to Environmental Health & Safety at 412-268-8182.

Additional recommendations

A PPD skin test for tuberculosis is recommended for domestic students who have traveled to an area where tuberculosis is endemic. All students should have a booster dose of tetanus/diphtheria every ten years after completion of the primary series.

Intellectual Property Policy

www.cmu.edu/policies/administrative-and-governance/intellectual-property.html

1. Purpose

The policy reflects the following goals:

- To create a university environment that encourages the generation of new knowledge by faculty, staff, and students.
- To facilitate wide transfer of useful inventions and writings to society.
- To motivate the development and dissemination of intellectual property by providing appropriate financial rewards to creators and the university, and administrative assistance to creators.
- To ensure that the financial return from the development of intellectual property does not distort decisions and operations of the university in a manner contrary to the mission of the university.

The policy is based upon the following principles relating the university to society:

- The mission of the university remains the generation and dissemination of knowledge.
- Intellectual property will be generated within the university, and there exists an obligation to disseminate it. An interface is needed if better technology transfer is to be achieved, and the university will provide mechanisms for that function.

The policy is based upon the following principles relating faculty, staff and students to the university:

- Intellectual property is created by individuals, or by groups of individuals, who are entitled to choose the course of disclosure; academic freedom of individuals is a higher priority than possible financial rewards.
- There exists a historical tradition allowing authors to retain ownership of intellectual property rights from textbooks and works of art.
- The university is the support of the whole campus community, and is thereby entitled to share in financial rewards.
- There should be incentives for all parties to pursue financial rewards together, consistent with the expressed goals of the policy. The distribution of these rewards should reflect, insofar as possible, the creative contributions of the creator, and the resources contributed by and risks assumed by both the creator and the university in developing intellectual property.
- Since it is frequently difficult to assess risks meaningfully, resources and potential rewards, negotiated agreements are to be encouraged whenever possible.

2. Definitions

Certain terms are used in this document with specific meanings, as defined in this section. These definitions do not necessarily conform to customary usage.

Intellectual Property includes any patentable invention, any copyrightable subject matter, or trade secret. It also includes works of art, and inventions or creations that might normally be developed on a proprietary basis.

University means Carnegie Mellon.

Student means any full-time or part-time graduate or undergraduate student, regardless of whether the student receives financial aid from the university or from outside sources. It is the responsibility of students who are also employees of other outside entities to resolve any conflicts between this policy and provisions of agreements with their employers prior to beginning any undertaking at the university that will involve the development of intellectual property.

Faculty means members of the university's Faculty Organization as defined in the Faculty Handbook, plus instructors and special faculty appointments (even in the first year), and part-time faculty.

Staff means any employee of the university other than students and faculty as defined above. If a student is also a part-time university employee, he is considered as staff with regard to intellectual property developed as a result of his employment, and as a student with regard to other intellectual property. A full-time non-faculty employee who is also taking one or more courses is considered to be staff. Visitors to the university who make substantial use of university resources are considered as staff with respect to any intellectual property arising from such use. (The distinction between faculty and staff does not affect intellectual property rights except for representation on the Intellectual Property Adjudication Committee [see Section 5].)

Creator means any person or persons who create an item of intellectual property.

Net proceeds to the university means all proceeds received by the university on intellectual property that it assigns, sells or licenses, minus any application, litigation, interference, or marketing costs directly attributable to the intellectual property being licensed. Deducted costs shall be reasonable and fair, and shall be properly disclosed; the sources and amounts of compensation shall also be properly disclosed.

Net proceeds to the creator means all proceeds received by the creator from intellectual property owned by him that he sells, assigns or licenses, less the costs of application, legal protection, or litigation, interference, travel and other marketing costs directly attributable to the intellectual property being exploited. Such net proceeds do not include compensation legitimately received by the creator for consulting services or interest or other return on invested labor or capital. Deducted costs shall be reasonable and fair, and shall be properly disclosed; the sources and amounts of compensation shall also be properly disclosed.

Substantial use of university facilities means extensive unreimbursed use of major university laboratory, studio or computational facilities, or human resources. The use of these facilities must be important to the creation of the intellectual property; merely incidental use of a facility does not constitute substantial use, nor does extensive use of a facility commonly available to all faculty or professional staff (such as libraries and offices), nor does extensive use of a specialized facility for routine tasks. Use will be considered “extensive” and facilities will be considered “major” if similar use of similar facilities would cost the creator more than $5000 (five thousand dollars) in constant 1984 dollars if purchased or leased in the public market. Creators wishing to directly reimburse the university for the use of its facilities must make arrangements to do so before the level of facilities usage for a particular intellectual property becomes substantial. (This provision is not intended to override any other department or university policy concerning reimbursement for facilities usage.)

In general:

In any given year the equivalent figure for a particular amount of money in constant 1984 dollars will be obtained by multiplying that amount of money by the ratio of the most recent quarterly Disposable Personal Income Deflator divided by the average monthly Disposable Personal Income Deflator for the year 1984.

As used in this policy, the masculine gender includes the feminine gender, singular or plural, wherever appropriate.

3. Policy Provisions

This section states the policies concerning ownership of intellectual property created at the university. In order of precedence, ownership of intellectual property shall be as follows:

3-1. Externally Sponsored Work

Ownership Provisions: Intellectual property created as a result of work conducted under an agreement between an external sponsor and the university that specifies the ownership of such intellectual property shall be owned as specified in said agreement. If the university declares itself to be a sponsor, but does not declare itself to be the owner of the intellectual property, ownership shall be determined in accordance with 3-6-4 below.

Procedural Provisions: It is the responsibility of the Office of Sponsored Research of the university to inform each person whose intellectual property rights are limited by an externally sponsored contract of the intellectual property provisions of that contract in advance of the beginning of work thereon. Such notice is to be in writing and the university may require written acknowledgment of such provisions by any person working on externally sponsored projects. A summary of external sponsorship agreements limiting the intellectual property rights of potential creators will be maintained by the Office of Sponsored Research and will be available to the general university community.

If the university fails to notify a creator, effectively and in advance, of limitations imposed on his intellectual property rights by external sponsorship agreements, the creator is entitled to receive from the university 50% (fifty percent) of the net proceeds to the university resulting from his intellectual property.

3-2. Internally Sponsored Work

Ownership Provisions: When the university provides funds or facilities for a particular project to the extent of substantial use, it may also choose to designate itself as sponsor of that work. The university may declare itself the owner of intellectual property resulting from said work. In such cases the university must specify in advance the disposition of any intellectual property rights arising from the project. If the university declares itself to be a sponsor, but does not declare itself the owner of the intellectual property, ownership shall be determined in accordance with 3-6-4 below.

Procedural Provisions: It is the responsibility of the Office of Sponsored Research of the university to inform each person whose intellectual property rights are limited by internally sponsored work of the intellectual property ownership rights specified by the university as to that work in advance of the beginning of work thereon. Such notice is to be in writing and the university may require written acknowledgment of such provisions by any person working on internally sponsored projects. A summary of work for which university sponsorship limits the intellectual property rights of potential creators will be maintained by the Office of Sponsored Research and will be available to the general university community.

If the university fails to notify a creator, effectively and in advance, of limitations imposed on his intellectual property rights by internal university sponsorship, the creator is entitled to receive from the university 50% (fifty percent) of the net proceeds to the university resulting from his intellectual property.

3-3. Individual Agreements

Ownership Provisions: Intellectual property which is the subject of a specific agreement between the university and the creator(s) thereof shall be owned as provided in said agreement. Such agreements by the university and the faculty are encouraged.

Procedural Provisions: Except where limited by external sponsorship agreements, creators and the university may negotiate individual agreements to govern ownership of intellectual property regardless of the applicability of any other provision hereof.

3-4. Intellectual Property Created Within Scope of Employment

Ownership Provisions: Intellectual property created by university employees who were employed specifically to produce a particular intellectual property shall be owned by the university if said intellectual property was created within the normal scope of their employment. Faculty are presumed not to be hired to produce a particular intellectual property. On the other hand, computer programs written on the job by staff computer programmers would fall under this provision.

3-5. Public Dedication

Ownership Provisions: Except when limited by sub-parts 3-1, 3-2, 3-3 or 3-4 above, the creator of any intellectual property may choose to place his or her creation in the public domain. In such cases both the creator and the university waive all ownership rights to said property.

Procedural Provisions: Creators wishing to place their intellectual property in the public domain are responsible for ascertaining that the right to public dedication of that intellectual property is not limited by any external agreement, university sponsorship arrangement or terms of employment as described in Provisions 3-1, 3-2 or 3-3. The university provost will provide such a determination in writing upon request by the creator. It is also the creator's responsibility to ensure that disclosure does not include valuable intellectual property owned by others. (This provision does not release the university from its general obligation to notify creators of limitations to intellectual property rights specified in Provisions 3-1 and 3-2.)

To facilitate the actual transfer of knowledge of the intellectual property to the public at large, the creator shall provide the university with a complete description and documentation of the property placed in the public domain, specifically including a copy of the property in the case of printed material, and complete machine-readable source code in the case of software. All such material provided to the university will be placed in the University Library and made available to the public at large. The university will take appropriate action on a regular basis to publicize summary descriptions of intellectual property recently placed in the public domain. The university will also provide any member of the general public copies of such material on a cost-recovery basis.

The provisions of this section do not apply to the normal scholarly or creative publication processes unless the creator intends to waive all proprietary rights to the publication.

3-6. In General

Unless governed by sub-parts 3-1, 3-2, 3-3, 3-4 or 3-5 above, owner-ship of intellectual property created at the university shall be deter-mined as follows:

3-6-1. Traditional Rights Retained

Ownership Provisions: In keeping with academic traditions at the university, the creator retains all rights to the following types of intellectual property, without limitation: books (including textbooks), educational course-ware, articles, non-fiction, novels, poems, musical works, dramatic works including any accompanying music, panto-mimes and choreographic works, pictorial, graphic and sculptural works, motion pictures and other similar audio-visual works, and sound recordings, regardless of the level of use of university facilities. This provision does not include computer software (other than educational course-ware) or data bases.

Procedural Provisions: The types of intellectual property listed in the preceding paragraph share the attribute that they display information or visual or auditory appearances which are fully revealed to the purchaser or consumer. Thus, for example, source code listings would also be considered within this category. On the other hand, most computer software and data bases do not share this attribute; they are characterized by their capacity to perform tasks. Because of their utilitarian nature, ownership rights with respect thereto are governed by 3-6-3 or 3-6-4. Educational course-ware is included in this provision in all cases because of its role in furthering the primary educational mission of the university.

This provision applies regardless of any university sponsorship of the work, and it may be modified only by a specific prior agreement between the creator and the university. The use of university-owned computers and other facilities in the preparation of books and similar works does not alter this provision, though other university policies may limit such use or require reimbursement to the university. Similarly, the use of externally sponsored resources does not alter this provision, unless the creator is effectively notified in advance of such limitations to his rights in accordance with 3-1.

3-6-2. No Substantial Use of University

Facilities Ownership Provisions: The creator owns all intellectual property created without substantial use of university facilities, including intellectual property rights in computer software and data bases.

3-6-3. Substantial Use of University Facilities - No External or Internal Sponsorship

Ownership of intellectual property created with substantial use of university facilities, but not directly arising from externally sponsored work, or from work for which the university has declared itself as sponsor, shall be determined as set forth hereinafter depending on whether the creator or the university develops said property.

3-6-3-1. Development by Creator

Ownership Provisions: The creator originally owns intellectual property created with substantial use of university facilities but no external or internal sponsorship, and retains said ownership by commercial development of said property subject to the following:

(i) the university shall receive 15% (fifteen percent) of the net proceeds to the creator above $25,000 (twenty-five thousand dollars) in constant 1984 dollars from all sources (in the case of patents and copyrights, this provision shall be limited to the life of the patent or copyright), and

(ii) the university shall receive a perpetual, non-exclusive, non-transferable, royalty free license to use said intellectual property. In the case of software, this license includes access by specified university personnel to the source listings, and the university shall require each person to whom a disclosure is made to execute in advance a binding confidentiality agreement in favor of and enforce-able by the creator. If the intellectual property is created solely by a student or students, the creator is exempt from the obligation to pay to the university a fraction of his net proceeds, but not from the provision of this paragraph for a non-exclusive license to the university.

Procedural Provisions: If the creator develops an intellectual property that is covered by this provision, he must make full and fair disclosure to the university of all such sources of compensation relating to that intellectual property.

3-6-3-2. Development by the University

Ownership Provisions: When intellectual property is created with substantial use of university facilities, but not directly arising from sponsored research, the creator will originally retain the rights to the property, provided that he desires to commercially develop the property himself or to make it available to the public. If, however, the creator elects not to commercially develop same or fails to show diligence in pursuing such development, then the ownership rights to that property may be acquired by the university. Intellectual property acquired by the university in this fashion will be treated as in 3-6-4-1 below.

Procedural Provisions: At the time the intellectual property is disclosed to the university's provost as required under Section 4-1, or at any time thereafter, the university may request that the creator decide whether he will develop the intellectual property or will grant the rights to the university, and execute documents to pass on the title. Such a decision must be made within one year of the request or the creator will automatically lose his rights in favor of the university.

3-6-4. Substantial Use of University Facilities - External or Internal Sponsorship

Ownership of intellectual property created with substantial use of university facilities and directly arising from work sponsored under an agreement between an external sponsor and the university, or from work for which the university has declared itself a sponsor, but for which neither the external sponsor nor the university have specified the ownership of resulting intellectual property shall be determined as set forth hereinafter depending on whether the creator or the university develops said property.

3-6-4-1. Development by University

Ownership Provisions: The university originally owns intellectual property created with substantial use of university facilities provided by an external agreement or internal university sponsorship and retains said ownership by commercial development of said property, subject to the following: in all cases, the creator shall receive 50% (fifty percent) of the net proceeds to the university.

Procedural Provisions: When an intellectual property is created with substantial use of university resources provided by an external research contract or a specific university sponsorship agreement, and when that contract or agreement either does not specify the disposition of the intellectual property rights arising from that sponsorship, or it permits the university and/or creator to retain or acquire such intellectual property rights, the university will originally retain the rights to such intellectual property.

3-6-4-2. Development by Creator

Ownership Provisions: When intellectual property is created with substantial use of university facilities provided by external or internal sponsorship, the university will originally retain the rights to the property, provided that it desires to commercially develop the property or to make it available to the public. If, however, the university elects not to commercially develop same or fails to show diligence in such development, the ownership rights to that property may be acquired by the creator. Intellectual property acquired by the creator in this fashion will be treated as in 3-6-3-1 above. This assignment of rights to the creator may be prohibited by the terms of an external sponsorship agreement with the university or by an internal university sponsorship declaration, but in such cases the creator must be notified in advance, as in Provisions 3-1 and 3-2.

Procedural Provisions: At the time the intellectual property is disclosed to the university's provost as required by Section 4-1, or at any time thereafter, the creator may request that the university decide whether it will commercially develop the intellectual property or execute an assignment of the intellectual property rights to the creator. Such a decision must be made within 120 (one hundred twenty) days of the request or the university automatically waives its rights in favor of the creator, and it must execute an assignment of these rights to the creator.

3-6-5. Consulting Agreements

Ownership Provisions: Work done by individuals as consultants to outside firms is presumed not to involve unreimbursed substantial use of university facilities, and the rights to intellectual property created under consulting agreements are retained by the outside firms or the individual as specified by the terms of the consulting agreement and the terms of Provision 3-6-2 above.

Procedural Provisions: Under university policy consulting work must not make substantial unreimbursed use of university facilities except by explicit prior agreement. Any member of the university community who is engaged in consulting work or in business is responsible for ensuring that provisions in his agreements are not in conflict with this policy of the university or with the university's commitments. The university's Innovation Transfer Office will, upon request, provide assistance in this respect. The university's rights and the individual's obligations to the university are in no way abrogated or limited by the terms of such agreements. Each creator of intellectual property should make his obligations to the university clear to those with whom he makes such agreements and should ensure that they are provided with a current statement of the university's intellectual property policy. Appropriate sample contract wording to cover various possible external consulting arrangements shall be available from the university provost.

4. General Procedures

4-1.

The creator of any intellectual property that is or might be owned by the university under this policy is required to make reasonably prompt written disclosure of the work to the university's provost, and to execute any document deemed necessary to perfect legal rights in the university and enable the university to file patent applications and applications for copyright registration when appropriate. This disclosure to the provost should be made at the time when legal protection for the creation is contemplated, and it must be made before the intellectual property is sold, used for profit, or disclosed to the public. Whenever legal protection for intellectual property is anticipated all persons engaged in such creative activity are encouraged to keep regular notebooks and records.

4-2.

Whenever the university undertakes commercial development it shall do so, if possible, in a fashion that provides for the widest possible dissemination, avoiding suppression of inventions from which the public might otherwise benefit, providing for non-exclusive licensing at reasonable royalties, and giving consideration to more favorable or royalty-free licensing to non-profit charitable institutions, minority businesses or enterprises in developing countries.

4-3.

The university's share of any proceeds under this policy will be used to reimburse the university for its expenses for commercial development of intellectual property. Any additional return to the university will be used to further the academic purposes of all the disciplines of the entire university.

5. Resolution of Disputes

This policy constitutes an understanding which is binding on the university and on the faculty, staff, and students upon whom it is effective according to the terms of Section 6 below, as a condition for participating in research programs at the university or for the use of university funds or facilities.

Any question of interpretation or claim arising out of or relating to this policy, or dispute as to ownership rights of intellectual property under this policy, will be settled by the following procedure:

- The issue must first be submitted to the university's Intellectual Property Adjudication Committee in the form of a letter setting forth the grievance or issue to be resolved. The committee will review the matter and then advise the parties of its decision within 60 days of submission of the letter.
- If any of the parties to the dispute is not satisfied with the committee's decision, the party may seek binding arbitration in Pittsburgh,

Pennsylvania and in accordance with the Rules of the American Arbitration Association then in effect. Judgment upon the award rendered by the arbitrator(s) may be entered in any court having jurisdiction thereof. The arbitrator(s) will give some weight to the decision of the Intellectual Property Adjudication Committee in reaching a decision. The losing party of the arbitration hearing will pay for all costs of the arbitration unless the arbitrator(s) specifies otherwise.

The Intellectual Property Adjudication Committee will consist of a chair who is a member of the tenured faculty, four other members of the faculty, and four other members representing, respectively, the university administration, the technical staff, and the graduate and undergraduate student bodies. Initially, half of the members of the committee (including the chair) will be appointed for two-year terms of office, and the remaining half will be appointed for a one-year term. After one year new members of the committee will be appointed for two-year terms of office. The chair will be appointed by the chair of the Faculty Senate, with the advice and consent of the Faculty Senate Executive Committee, and the remaining eight members of the committee will be appointed by the president of the university or his designee. At all times at least one of the faculty members will have had significant practical experience with intellectual property development and exploitation. The faculty members appointed by the president of the university will be selected from a list of nominees prepared by the Faculty Senate or its designated committee and nominees with experience in intellectual property development will be identified as such by the Faculty Senate. The staff representative will be selected from a list of nominees prepared by Staff Council, and the administration representative will be named directly by the president of the university or his designee. The graduate student representative will be selected from a list of nominees prepared by the Graduate Student Organization. The undergraduate representative will be chosen from a list of nominees prepared by the Student Senate. The committee will use the guidelines set forth in this policy to decide upon a fair resolution of any dispute.

If possible, the committee will also provide on request informal advisory opinions to creators and the university indicating how it is likely to interpret the provisions of this policy as it applies to special cases.

6. Effective Date of Policy

This policy will become effective August 27, 1985. Once effective this policy will be binding on new faculty, administration, and staff when hired, and on graduate and undergraduate students when admitted. Current faculty and staff will also become bound by this policy when they sign new employment contracts as the result of the renewal of limited-term appointments or promotion. Other university personnel, including tenured faculty, and current staff and students may choose to become bound by this policy for future and pending intellectual property by voluntary written consent. Unless the creator and the university agree to a different arrangement, intellectual property that is already partially developed at the time this policy becomes effective will be treated according to the provisions of the patent policy by which the University creator is currently bound. Similarly, members of the university working under contracts signed before the effective date of this policy who do not choose to accept this policy will remain bound by the patent policies that already apply to them. With respect to intellectual property developed during the course of employment at the university, this policy shall continue to be binding on any person whose relationship with the university becomes terminated. The university should take all administrative steps necessary to ensure that employees and students sign, upon initial employment, registration or at other appropriate times, forms that indicate their acceptance of this policy.

7. Amendments of the Policy

Amendments of this policy may be proposed by the Faculty Senate, Staff Council or university administration. Proposed amendments must be approved by a two-thirds majority of votes in the Faculty Senate and subsequently approved by a simple majority of votes cast in a referendum administered by the Faculty Senate that is open to all members of the faculty as defined by this policy and to the exempt staff, provided that this majority constitutes at least 25% (twenty-five percent) of those eligible to vote. This referendum must be preceded by an opportunity for public discussion open to all interested faculty, administration, staff and students. Amendments that are supported by the faculty and staff must then be approved by the president of the university and adopted by the university trustees. Once adopted, amendments will become binding on new faculty, administration, and staff when hired, on existing faculty and staff when they sign new employment contracts, and on graduate and undergraduate students when admitted. Other university personnel, including tenured faculty, and current staff and students may choose to become bound by this policy for future and pending intellectual property by voluntary written consent. Intellectual property that is already developed or under development at the time that an amendment to the policy is ratified will not be bound by the terms of the amendment without the voluntary written consent of both the creator and the university.

Footnote:

[1] This document presumes the existence of a university office to facilitate technology transfer. Such an office would serve as a clearinghouse for contacts with outside partners, would perform patent and copyright tasks, and would develop an effective marketing capability.

Policy on Student Privacy Rights

www.cmu.edu/policies/student-and-student-life/privacy-rights-students.html

Policy Statement

Under the Family Educational Rights and Privacy Act (FERPA), you have the right to:

- Inspect and review your education records;
- Request an amendment to your education records if you believe they are inaccurate or misleading;
- Request a hearing if your request for an amendment is not resolved to your satisfaction;
- Consent to disclosure of personally identifiable information from your education records, except to the extent that FERPA authorizes disclosure without your consent;
- File a complaint with the U.S. Department of Education Family Policy Compliance Office if you believe your rights under FERPA have been violated.

1. Inspection

What are education records?

Education records are records maintained by the university that are directly related to students. These include biographic and demographic data, application materials, course schedules, grades and work-study records. The term does not include:

- Information contained in the private files of instructors and administrators, used only as a personal memory aid and not accessible or revealed to any other person except a temporary substitute for the maker of the record;
- Campus Police records;
- Employment records other than work-study records;
- Medical and psychological records used solely for treatment purposes;
- Records that only contain information about individuals after they have left the university;
- Any other records that do not meet the above definition of education records.

How do I inspect my education records?

- Complete an Education Inspection and Review Request Form (http://www.cmu.edu/hub/registration/docs/review-record.pdf) [PDF] and return it to The HUB in order to notify the University Registrar's Office.
- The custodian of the education record you wish to inspect will contact you to arrange a mutually convenient time for inspection, not more than 45 days after your request. The custodian or designee will be present during your inspection.
- You will not be permitted to review financial information, including your parents' financial information; or confidential letters of recommendation, if you have waived your right to inspect such letters.
- You can get copies of your education records from the office where they are kept for 25 cents per page, prepaid.

2. Amendment

How do I amend my educational records?

- Send a written, signed request for amendment to the University Registrar, Carnegie Mellon University, A19 Warner Hall, Pittsburgh, PA 15213. Your request should specify the record you want to have amended and the reason for amendment.
- The university will reply to you no later than 45 days after your request. If the university does not agree to amend the record, you have a right to a hearing on the issue.

3. Hearing

How do I request a hearing?

- Send a written, signed request for a hearing to the University Registrar, Carnegie Mellon University, A19 Warner Hall, Pittsburgh, PA 15213. The university will schedule a hearing no later than 45 days after your request.
- A university officer appointed by the Associate Vice President for Enrollment Services, who is not affiliated with your enrolled college will conduct the hearing.
- You may bring others, including an attorney, to the hearing to assist or represent you. If your attorney will be present, you must notify the university ten days in advance of the hearing so that the university can arrange to have an attorney present too, if desired.
- The university will inform you of its decision, in writing, including a summary of the evidence presented and the reasons for its decision, no later than 45 days after the hearing.
- If the university decides not to amend the record, you have a right to add a statement to the record that explains your side of the story.

4. Disclosure

Carnegie Mellon generally will not disclose personally identifiable information from your education records without your consent except for directory information and other exceptions specified by law.

What is directory information?

Directory information is personally identifiable information of a general nature that may be disclosed without your consent, unless you specifically request the university not to do so. It is used for purposes like compiling campus directories.

If you do not want your directory information to be disclosed, you must notify the University Registrar's Office in writing within the first 15 days of the semester.

Notifying the University Registrar's Office covers only the disclosure of centralized records. Members of individual organizations such as fraternities, sororities, athletics, etc. must also notify those organizations to restrict the disclosure of directory information.

Carnegie Mellon has defined directory information as the following:

- your full name,
- local/campus address and local/campus telephone number,
- email User ID (Andrew ID) and address,

(User IDs cannot be completely suppressed from our electronic systems. While it may be possible to suppress the association of an individual's name with their user id, doing so may adversely impact the delivery of electronic mail or other electronic services.)

- major, department, college,
- class status (freshman, sophomore, junior, senior, undergraduate or graduate)
- dates of attendance (semester begin and end dates),
- enrollment status (full, half, or part time)
- date(s) of graduation,
- degree(s) awarded,
- sorority or fraternity affiliation.

For students participating in intercollegiate athletics, directory information also includes:

- height, weight
- sport of participation.

What are the other exceptions?

Under FERPA, Carnegie Mellon may release personally identifiable information from your education records without your prior consent to:

- school officials with legitimate educational interests ("School officials" are Carnegie Mellon employees in administrative, supervisory, academic or support staff positions; Carnegie Mellon trustees; individuals and companies with whom the university has contracted, such as attorneys, auditors, or collection agencies; and individuals assisting school officials in performing their tasks. School officials have a "legitimate educational interest" if they need to review an education record in order to fulfill their professional responsibilities.);
- certain federal officials in connection with federal program requirements;
- organizations involved in awarding financial aid;
- state and local officials who are legally entitled to the information;
- testing agencies such as the Educational Testing Service, for the purpose of developing, validating, researching and administering tests;
- accrediting agencies, in connection with their accrediting functions;
- parents of dependent students (as defined in section 152 of the Internal Revenue Service Code);
- comply with a judicial order or subpoena (after making a reasonable effort to notify the student in advance of compliance so that the student can take protective action, except in cases where the university is legally required not to disclose the existence of the subpoena);
- appropriate parties in a health or safety emergency, if necessary to protect the health or safety of the student or other individuals;
- officials of another school in which the student seeks or intends to enroll;
- victims of violent crimes or non-forcible sexual offenses (the results of final student disciplinary proceedings);
- parents or legal guardians of students under 21 years of age (information regarding violations of university drug and alcohol policies);
- courts (records relevant to legal actions initiated by students, parents or the university).
- comply with federal laws concerning sex offenders and other individuals required to register under section 170101 of the Violent Crime Control and Law Enforcement Act of 1994.

5. Complaints

If you believe the university has not complied with FERPA, you can file a complaint with the:

Family Policy Compliance Office, Department of Education, 400 Maryland Avenue, S.W. Washington, DC 20202-4605

Footnote: Your Carnegie Mellon GUID (global user identification) number is also designated as directory information under FERPA, but does not contain personally identifiable information and therefore cannot be used by itself to determine your identity or to access your records.

Policy on Restricted Research

www.cmu.edu/policies/research/restricted-research.html

Universities have two primary purposes: to create knowledge and to disseminate knowledge. Carnegie Mellon University recognizes the importance of open intellectual communication within a research group, within the university, and within the larger community outside. Ideally, all units of the university would disseminate the results of research as quickly and as widely as possible. Some members or units of the university, however, desire to do research that may be difficult or impossible without restrictions or without access to classified or proprietary materials.

There exists, therefore, a tension between the university's goal of disseminating knowledge freely and the desire on the part of some of its members to conduct restricted research on important problems. The university intends to guarantee the academic freedom of all faculty members to do research in their own manner on topics of their own choosing, provided that such research is consistent with the overall purposes of the university.

This policy seeks to resolve the tension between the desire to participate in restricted research and the desire to maintain the open atmosphere of the university by confining restricted research to semi-autonomous units, which are not associated with any academic departments. It thereby establishes the principle that restricted research is inappropriate at Carnegie Mellon University except in the semi-autonomous units.

This policy does not attempt to anticipate all possible concerns about restricted research. In some cases, decisions will need to be made about particular research projects to which the application of particular policy guidelines are not clear. In choosing to accept or decline such projects, the university will weigh the potential of a project for generating and disseminating new knowledge for the benefit of society, against the project's potential for adversely affecting the climate for research conducted in a free and open environment. While this policy sets no explicit limits on the extent of classified research permitted in the semi-autonomous units, it is not the intent of the policy to encourage any unit of the university to engage in classified research as a primary ongoing activity. Indeed, it is expected that classified projects will never represent more than a small fraction of the total research effort in any unit.

Definitions

Research: all projects and investigations involving the creation of new knowledge of a theoretical or practical nature. The term “research” as used here encompasses both “research” and “development” as they are commonly defined.

Classified research: research, the free dissemination of the results of which is deemed to jeopardize national security. The federal government controls access to the environment in which such research is performed, restricts discussions about the work in progress to individuals with clearance and a “need to know,” and limits publication of research, results or access to data needed to verify results, for a specified period of time.

Proprietary research: research that results in intellectual property that is owned by entities other than Carnegie Mellon University. Such entities may wish to market products derived from inventions or ideas that are developed at the university. They might, therefore, desire to fund projects which restrict access to data and to discussions about work in progress to individuals with a “need to know,” and to seek, for a specified period of time, a delay in publication of research results or data needed to verify results. Such entities may also provide access to proprietary material, which researchers must agree not to include in publications.

Publication: oral or written dissemination.

Restricted research: includes all classified research, and any proprietary or other research that requires more than a six month delay in publication of the research results.

Semi-autonomous units: units of the university specifically so designated by the president, after consultation with the URC and the Faculty Senate, currently the Mellon Institute and the Software Engineering Institute.

Non-autonomous units: all university entities other than semi-autonomous units.

Restricted Research in Non-Autonomous Units

It is the policy of Carnegie Mellon that restricted research is inappropriate and, therefore, not permitted within its non-autonomous units.

It is also the policy of Carnegie Mellon not to permit involvement of students in projects which carry restrictions that may impede their progress toward a degree. Therefore, students should not be involved in contracts that require the delay of a student's publication of research results when such results are intended for use in obtaining academic credit, except that a sponsor may require a delay of thirty days for review of publications for removal of proprietary information that was provided by the sponsor for the conduct of the research.

Proprietary research is allowed within non-autonomous units provided it is subject to limitations (excluding students' publications as noted above) no more stringent than the following:

- A sponsor may request a delay of up to six months in publication so that steps may be taken to secure intellectual property rights to inventions or ideas developed under the contract.
- A sponsor may require a delay of thirty days for review of publications for removal of proprietary information which was provided for the conduct of the research.

Considerations for faculty/researchers:

The university recognizes that problems arise in both restricted research and research that is not itself restricted but that involves access to classified or propriety information or materials (hereinafter, restricted materials). Researchers may also have access to restricted materials when serving as consultants. Access to restricted materials gives rise to concerns about limitations on researchers' freedom to communicate. In such instances, researchers must exercise consider-able judgment to conduct their research in an open environment while protecting the restricted materials to which they have access. Researchers must also be aware that the university will judge their performance as researchers through their publications or through other scholarly products that arise from their research. Research that is restricted in dissemination, or not available for public review, cannot be considered in promotion or reappointment decisions or in evaluations of academic performance of any kind.

Considerations for faculty/researchers:

There are important concerns about the involvement of students in restricted research. It is necessary for students to publish their work in order to obtain degrees, course credit and professional recognition. Students rely to a large degree on their faculty advisor's judgment for guidance and advice. Research that is restricted in dissemination, or not available for public review, cannot be used for academic credit. Thus, before working on such research, a student must be notified in writing that work on this research may not be used for academic credit.

Restricted Research in Semi-Autonomous Units

The semi-autonomous units associated with Carnegie Mellon may conduct restricted research.

Faculty members may conduct restricted research in or in cooperation with semi-autonomous units only on a consulting basis or by means of a formal, internal leave of absence from their non-autonomous units.

Work that is restricted in any way may not be used for academic evaluations until it is released for publication, and then only with respect to future academic actions.

Students may occasionally be employed by the semi-autonomous units, provided that such employment does not interfere substantially with progress toward a degree. However, they must be made aware that work that is restricted cannot be used for academic credit. Work that was restricted and is later released for dissemination and review can be applied toward future academic credit. Students should be discouraged from working on restricted research in which dissemination may be delayed indefinitely.

Guidelines for all Units

Work by students on restricted research projects shall not be made a condition for admission or financial aid.

The principal investigator is responsible for informing all members of a project (faculty, staff and students) of any restrictions imposed on the dissemination of information related to the research. This must be done prior to the start of the project or prior to an individual joining an existing project.

Restrictions on access to university facilities due to the conduct of restricted research must be kept to a minimum. Access to and movement through the facilities in which restricted research is conducted must be consistent with standard university procedures.

The Provost's Office is responsible for obtaining signed documents from principal investigators on restricted research projects attesting that they are aware of all restrictions imposed on the research and that they have informed all participants of these restrictions.

The Office of Sponsored Research shall review all proposals and contracts prior to approval for conformity with these guidelines. Any that do not meet these guidelines will be referred to the University Research Council (URC) for review and recommendation of appropriate action to the provost.

To maintain a balance with the university's goals of broad dissemination of knowledge, the URC will conduct an annual review of all restricted research being conducted at the university. This review will be made based on a listing of all contracts that involve restricted research. This listing shall include the title and sponsor(s) of the research, name(s) of principal investigator(s), and the amount of funding of each contract.

The university community will be informed annually, through the URC's written report to the Faculty Senate and Student Senate, of the nature and overall impact of restricted research at Carnegie Mellon.

Existing sponsored research projects shall be allowed to continue under the terms of their present contract. However, renewal contracts must conform with this policy.

Student Activities Fee

www.cmu.edu/policies/student-and-student-life/activities-fee.html

By action of the Board of Trustees, a required Student Activities Fee in addition to tuition is charged to all under-graduate students and graduate students who enroll for 19 units or more. Student Government is responsible for administering the fee and for using it only for the support of projects under the following guidelines:

1. Activities and facilities which can be described as meeting the reasonably predictable social, cultural, recreational, or welfare needs of college students.

2. Publications which can reasonably be presumed to serve the needs of the student community for communication, expressions of opinion, and the conduct of their business.
3. Such enterprises of an entrepreneurial nature undertaken by the student body as can reasonably be expected to serve as an instrument for meeting the needs described above.

All functions and services provided by the fees described above must be in accordance with Carnegie Mellon's policy of non-discrimination. In addition, no use of such fees may be intended to violate or circumvent the policies of the university or the laws of the land.

Final responsibility for establishing the amount of any required fee rests with the Board of Trustees, which will consider changes only upon requests of the Student Government and the officers of the university.

Note: Historically, the Student Government has dedicated a specific portion of graduate students' activities fees to the Graduate Student Assembly to be used at their discretion.

Policy on Temporary Emergency Closing of the University

www.cmu.edu/policies/safety-and-security/emergency-closing.html

Policy Statement

Carnegie Mellon University has an important commitment to students, parents, sponsors, benefactors and the community. Accordingly, the university will make every attempt to operate normally during severe weather or other emergencies. This includes holding classes, conducting research programs, and operating facilities and services. The university will attempt to operate normally unless such operation represents a clear danger to students, staff or faculty.

There may be occasions when the university community is served best by suspending normal operations. In that event, only the president (or the president's designated representative) has the authority to close the university and to specify those persons or group of persons who are free to leave or refrain from coming to campus. Staff members who provide primary services, including certain members of Physical Plant, Dining Services and Security, may be asked to work.

Standard Operations

Unless the president announces that the university is closed, everyone is expected to be at work as usual. When the university is in session, faculty members are expected to meet their scheduled classes and other obligations. If a faculty member is unable to meet a scheduled class, he or she should notify the department office and arrange either for a qualified substitute or for a future make-up session.

If the university is open but a staff member is unable to come to work because of severe weather or other emergency, he or she should notify the supervisor as soon as possible. Staff members will be expected to make up lost time or use Paid Time Off (PTO), consistent with regular operating protocols.

Announcement of Closing

As soon as the president or designee determines that the university must be closed, University Relations will alert local radio and television stations. Also, announcements of closings will be posted on the Carnegie Mellon electronic bboard official.cmu-news.

Contact

Questions concerning this policy or its intent should be directed to the Office of the President at 412-268-2200.

Student Leaves & Returns

Student Leave Policy

www.cmu.edu/policies/student-and-student-life/student-leave.html

Students must sometimes interrupt their studies for a variety of reasons (financial, academic or personal). Students choosing to take a leave of absence must first contact their department advisor to discuss their plans while on leave to work out any conditions that may be necessary for a smooth return to Carnegie Mellon.

A student may leave Carnegie Mellon by either withdrawing from the university (this means leaving the university with no intention of returning) or by taking a leave of absence (this means leaving the university temporarily, with the firm and stated intention of returning).

A Leave of Absence Form must be completed by all students requesting a leave of absence. A Withdrawal Form must be completed by all students who are withdrawing. Notifying instructors or no longer attending classes does not complete the process. Forms are available on The HUB website (https://www.cmu.edu/hub/forms.html). Not completing the leave form results in tuition being charged to midpoint of the semester or the last date the student attended an academically-related activity such as an exam, tutorial or study group, or the last day a student turned in a class assignment.

Students are required to fill out all information on the form, including all comment sections relating to reasons for their leave of absence. After completion of the form, students must take it to their home department and dean's office for appropriate signatures. The process of taking a leave will not be complete until all necessary signatures are on the leave form. Under certain circumstances, students may also need the Dean of Student Affairs to sign off on the leave form. International students who are here on a F1 or J1 visa must consult the Office of International Education for information on possible visa implications prior to going on leave.

Students on leave are not permitted to live in university housing, attend classes or maintain employment as students at Carnegie Mellon while their leave is in effect.

Doctoral candidates in ABD (All But Dissertation) status who wish to take a leave of absence should refer to the Doctoral Student Status policy.

Leaves during the academic semester will take effect as of the date signed by the student's dean. After the Leave of Absence or Withdrawal Form is received by the University's Registrar's Office, it will be reviewed for the appropriate tuition refunds (see T (p. 15)uition Adjustment Policy (p.)) and grade implications. The recording of student courses and grades for taking a leave in a semester follows the deadlines for semester or mini courses, as follows:

- On or before the university deadline to drop classes with W (withdrawal) grades: all courses or grades are removed.
- After the university deadline to drop classes but before the last day of classes: W (withdrawal) grades will be assigned to all classes. (W grades apply to all undergraduate students, and graduate students in the Carnegie Institute of Technology, the Mellon College of Science or the Tepper School of Business.)
- After the last day of classes: Permanent grades assigned by the instructor will be recorded.

Student Return Policy

www.cmu.edu/policies/student-and-student-life/return-student.html

Students on leave wishing to return to Carnegie Mellon to resume their degree studies may do so under several conditions. In order to be considered for return from leave, a student must first obtain an Application for Return form from The HUB or their academic department. This application requires information from the student regarding the intended semester of return, current address information and information about their leave. This application must be submitted to their home department at least one month prior to the beginning of the semester.

Undergraduates may return within their same academic department within two years. After two years, students returning in the same academic department are subject to space constraints and academic performance review. Graduate students must negotiate their return with their home department and must follow their department policy.

The Application for Return requires approval of the student's academic department and dean. If a student's department chooses to deny the student's Application for Return, the student may appeal to their dean. Any constraints governing the student's eligibility to return will be specified directly on the application by the academic department and/or dean's office or the Office of Student Affairs.

Students who have taken courses elsewhere must submit an official transcript and course descriptions with their Application for Return. Transfer credit approval is determined by the academic department based on course level, performance and appropriateness to the student's curriculum requirements. Credit transfer is subject to college-specific policy. Failure to submit the necessary documents at the time of return will result in denial of transfer credit.

The process of returning is not completed until all necessary signatures on the Return form are obtained by the student and until all outstanding bills are paid. Enrollment Services will then notify the appropriate university offices of the student's return.

Tuition Adjustment Policy

www.cmu.edu/policies/documents/TuitionRefund.html

Application

This policy applies to withdrawals and leaves of absence by all students (graduate, undergraduate, non-degree) for all semesters (Fall, Spring, Summer 1, Summer 2, Summer All).

Official Date of Withdrawal/Leave of Absence

For students who notify the university of their intent to withdraw or take a leave of absence, the official date of withdrawal or leave of absence is the earliest of:

- the date the student began the withdrawal or leave of absence process;
- the date the student notified their home department;
- the date the student notified the associate dean of their college; or
- the date the student notified the Dean of Students.

For students who do not notify the university of their intent to withdraw or take a leave of absence, the official date of withdrawal or leave of absence is:

- the midpoint of the semester;
- the last date the student attended an academically-related activity such as an exam, tutorial or study group, or the last day a student turned in a class assignment.

Tuition Adjustment

Students who withdraw or take a leave of absence before completing 60% of the semester will be charged tuition based on the number of days completed within the semester. This includes calendar days, class and non-class days, from the first day of classes to the last day of final exams. Breaks that last five days or longer, including the preceding and subsequent weekends, are not counted. Thanksgiving and Spring Break are not counted. There is no tuition adjustment after 60% of the semester is completed. No tuition is charged to a student who is administratively withdrawn. See The HUB website (https://www.cmu.edu/sfs/tuition/adjustment) for the complete tuition assessment schedule for the current semester.

Housing, Dining Plan & Fee Adjustments

Housing charges are adjusted daily, beginning on check-in day and ending on the last day of final exams for the semester. Holiday breaks are included; however, the Winter Break period is not included.

Dining plan charges are adjusted per the bi-weekly period. DineXtra and PlaidCash are assessed based upon actual use.

There is no adjustment of the Port Authority Fee, Technology Fee or Student Activity fee.

Financial Aid Adjustment

Federal and institutional financial aid is adjusted on the same basis as tuition. A student earns 100% of their federal or institutional financial aid when 60% of the semester is completed.

State grants and non-federal outside scholarships are adjusted based upon the withdrawal policy of the agency awarding the funds.

Contact

Questions concerning this policy or its intent should be directed to The HUB at 412-268-8186.

Financial Aid Policy Statement

www.cmu.edu/policies/student-and-student-life/financial-aid-statement.html

University Academic Scholarship Renewals

Carnegie Mellon University awards academic scholarships as part of the freshman financial aid process. Each of these scholarships is renewable for four academic years of study (five for architecture) based upon the maintenance of a specific cumulative quality point average. The academic scholarship renewal criteria are included in the scholarship notification letter which is mailed to the student prior to the May 1 matriculation deadline.

Each scholarship recipient's cumulative quality point average is reviewed at the end of each academic year. If the student achieves the scholarship renewal criteria, then the scholarship is automatically renewed for the next academic year.

If the student does not meet the cumulative quality point average requirement for renewal, then they are given the opportunity to appeal. A merit scholarship appeal form and instructions are automatically sent to the student at the end of each academic year.

The student's completed appeal form is reviewed by members of the Enrollment Services staff. Input from the Associate Dean of the student's college is also considered. The student is notified, in writing, of the decision. The decision may be to renew the scholarship for the entire academic year, renew the scholarship for one academic term, or to reject the appeal. If the appeal is rejected, a written explanation is provided to the student.

Undergraduate Tuition Exchange Programs

Carnegie Mellon University assesses the standard tuition charge for the undergraduate tuition exchange programs.

Since Carnegie Mellon assesses the tuition charge, the student can be considered for all forms of institutional, state, and federal aid for which the student may have eligibility with the exception of any student employment program.

Undergraduate Study Abroad Programs

Carnegie Mellon University does not assess the tuition charge for any of the Study Abroad Programs.

Since Carnegie Mellon does not assess the tuition charge, the student is not considered for any institutional grants and scholarships. However, Carnegie Mellon will consider any student participating in an approved Study Abroad Program for all state and federal student aid programs for which the student may have eligibility with the exception of any student employment program.

The U.S. Department of Education and Carnegie Mellon University define an approved Study Abroad Program as one which is part of a contractual agreement between Carnegie Mellon and the host institution. Additionally, courses taken in the Study Abroad Program must be accepted for transfer to Carnegie Mellon by the Dean of the student's college.

Undergraduate Sponsored Study Abroad Programs

Carnegie Mellon assesses full tuition charges and all applicable fees to students participating in an undergraduate sponsored study abroad program.

Undergraduate International Students

Documentation Eligibility (U.S. Citizenship or Eligible Non-citizen)

You must be a U.S. Citizen or permanent resident alien to receive federal student aid. If you are a U.S. Citizen, but were not born in the United States, valid documentation includes a copy of your passport or naturalization certificate.

If you are a U.S. permanent resident alien or refugee, acceptable forms of verification include a photocopy of both sides of your I-551 or I-551C card.

Undergraduate international students are ineligible to receive any federal or state student financial aid. Additionally, Carnegie Mellon does not award any institutional financial aid funds to undergraduate international students.

Undergraduate Course Meeting Policy

www.cmu.edu/policies/student-and-student-life/ug-course-meeting.html

No undergraduate classes, exams, academic, or artistic activities (including: extra help session, rehearsals, ROTC drill, make-up exams, etc.) are scheduled on weekdays between 4:30 p.m. and 6:30 p.m. Extra class time beyond those regularly scheduled must take place either before 4:30 p.m. or after 6:30 p.m.

Undergraduate Course Meeting Procedure

This policy is not intended to reduce the rigor or vigor of the academic or artistic programs, but to ensure that students have a period in which they are free to carry on co-curricular activities and athletics. Scheduling classes, exams, or other academic and artistic activities makes it very difficult for the students to meet these commitments. Since we are all concerned about the quality of life at the university, this time must be held for the students.

In planning the academic course schedule, the University Registrar's Office will review all courses to ensure that no academic or artistic courses be scheduled in this period. In addition, any requests to schedule additional or makeup course meetings, review and/or study sessions, teaching assistant office hours, or other course-related meetings, must take place either before 4:30 p.m. or after 6:30 p.m. This includes meetings in all university spaces, not just within University Registrar's Office-controlled classrooms.

As with any policy, there must be a means of making exceptions. Any academic or artistic activities which you feel must be scheduled between 4:30 p.m. and 6:30 p.m. must be cleared with the University Registrar. These requests must be in writing either as a memo or through email. All requests must include the course relationship, intent for the requested meeting, and the reason why the meeting cannot be held either before 4:30 p.m. or after 6:30 p.m.

Any further clarification of this policy can be addressed to the Associate Vice President and Director of Enrollment Services.

University Services

Carnegie Mellon University provides many services to students to help them thrive on and off campus, and in and out of the classroom. The university's service-oriented departments and offices focus on executing critical administrative functions to provide daily services to students, families, the campus community, and visitors. Listed below are some of the services offered by the university.

Academic Advising

Carnegie Mellon recognizes the vital role of academic advising in undergraduate education. The university assigns an academic advisor to each student, and makes certain that all advisors have clear, timely, and accurate information concerning programs, policies, procedures, and resources. In addition to having assigned academic advisors, students often develop relationships with faculty and staff members who serve as academic mentors.

Institutional Statement on Advising

Academic advising is integral to the educational mission of Carnegie Mellon. Advising is an intentional process, grounded in teaching and learning, and provides each student with guidance for developing and achieving meaningful educational, professional, and personal goals. Successful advising at Carnegie Mellon depends upon a shared understanding of, and commitment to, the advising process, by students, advisors, and the university. Academic advisors engage students in learning, promote students' academic success, and foster students' personal, ethical, and intellectual growth, all of which will carry into their roles as citizens and lifelong learners.

The Student's Role

Seeking advice is an important part of how students begin to make decisions about their academic and professional futures. Each major and department has an advising system which may be different from one another. It is important that students find out early from their first year advisor how the advising system for all their four years at Carnegie Mellon works.

Students are responsible for understanding the importance of their relationships with advisors; seeking out advisors, contacts, and information on a regular basis; knowing the requirements of their individual degree programs; and taking final responsibility for making their own decisions based on the best information and advice available.

The Advisor's Role

To achieve the goals of academic advising at Carnegie Mellon, advisors, along with their advising programs, are responsible for being knowledgeable of, and communicating, the requirements of the academic programs in which they advise; monitoring students' progress towards degree completion; being available to meet with students on a regular basis; assisting students in finding the appropriate institutional and community resources; involving students in the academic and career planning process and the exploration of options and resources; and engaging in developmental activities to stay informed of issues that impact student success.

Academic Development

Location: Cyert Hall, Suite B5
Phone: 412-268-6878
acad-dev@andrew.cmu.edu
www.cmu.edu/acadev (https://www.cmu.edu/acadev)

Academic Development is the place to go for help with academic work. We offer peer tutoring, academic coaching in study skills, supplemental instruction and EXCEL collaborative learning groups for traditionally difficult courses. Our programs are available to all Carnegie Mellon University students and are designed to help both students who are having academic difficulties and those who just want to improve their academic performance. The peer tutoring, study skills, supplemental instruction and EXCEL components of Academic Development utilize group and individualized instruction to accommodate the diverse learning styles and skill levels of the student population.

Our services include:

Academic Coaching

Academic Coaching is an assistance program that helps students acquire more effective and efficient study skills. The program is designed to help both students who are having academic difficulty and students who just want to improve their study skills. Student Academic Coaches (ACs) conduct group workshops throughout the semester and weekly individualized sessions that focus on like time managements, taking notes and exam preparation.

EXCEL Groups

EXCEL groups are offered for a select number of traditionally difficult courses. Groups meet weekly throughout the term and are facilitated by trained student leaders who have already completed the course and earned an A. The groups are comprised of up to nine students and are formed on an as-needed basis, with multiple groups per course. Sessions are interactive and geared specifically to the group members.

Peer Tutoring

Peer tutoring is a program designed to assist students with their coursework and it is available in two formats: weekly tutoring appointments or walk-in tutoring.

Supplemental Instruction (SI)

Supplemental Instruction (SI) is an academic enrichment program that is offered in traditionally difficult courses. SI discussion and review sessions are facilitated by trained student SI Leaders who have already completed the course and received an A in it. SI sessions are held twice weekly for one hour; additional sessions are held prior to exams. Attendance is voluntary and registration is not necessary.

Disability Resources & Equal Opportunity

Catherine Getchell, *Director of Disability Resources*
Location: Margaret Morrison Plaza, A30, 5136 Margaret Morrison St., Pittsburgh, PA 15213
Phone: 412-268-6121
access@andrew.cmu.edu
www.cmu.edu/disability-resources

Disability Resources provides responsive and reasonable accommodations to students who self-identify as having a disability, including physical, sensory, cognitive and emotional disabilities. Through our office, the university can provide counsel, support services and accommodations to ensure that all students, regardless of ability, have equal access to the world-class education, campus programs and activities offered by CMU. We work to ensure that qualified individuals receive reasonable accommodations as guaranteed by the Americans with Disabilities Act (ADA) and Section 504 of the Rehabilitation Act of 1973.

Students are also welcome to discuss concerns about support for disabilities with members of the admission staff, housing office and/or health/psychological services. Upon enrollment, students with disabilities should contact the Office of Disability Resources to discuss their needs and to develop a Student Individual Accommodation Plan. Accommodations are made with the intent to maintain the academic integrity of each course and the academic program as a whole, while also meeting assessed needs.

Equal Opportunity / Affirmative Action Policy

Carnegie Mellon is committed to equal employment opportunity for all and to affirmative action. Diversity is a source of strength for Carnegie Mellon and affirmative action is one of the tools that we use to achieve and sustain diversity. All personnel actions are administered in accordance with the university's commitment to non-discrimination and in compliance with applicable federal, state and local laws, statutes, orders and regulations. View the University Policy on Equal Employment Opportunity / Affirmative Action (https://www.cmu.edu/policies/administrative-and-governance/equal-opportunity-affirmative-action-ada.html).

Computing Services

Stan Waddell, *Associate Vice President & Chief Information Officer*
Location: Cyert Hall 285
Phone: 412-268-4357

it-help@cmu.edu
www.cmu.edu/computing

Computing Services maintains and supports computing resources for the campus community, including the campus wired and wireless networks, public printing, computer labs, email, and software catalog.

Visit the Computing Services (http://www.cmu.edu/computing) website to explore the services available to you, including how to:

- get started with computing at Carnegie Mellon
- practice safe computing
- set up file storage and collaboration
- connect your computer or mobile/gaming devices to the network
- access software
- manage your email
- use public printers and computer labs.

For help, contact the Computing Services Help Center at 412-268-4357 (HELP) or it-help@cmu.edu.

Fellowships & Scholarships Office

Stephanie Wallach, *Director*
Location: Cyert Hall A64, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-5702
Fax: 412-268-6159
fso-general@andrew.cmu.edu
www.cmu.edu/fso

The Fellowships and Scholarships Office (FSO) works with current Carnegie Mellon undergraduate students – as well as alumni – in fulfilling their intellectual and professional goals by pursuing nationally competitive scholarships and fellowships. We promote awareness of external scholarship and fellowship opportunities, advising, writing support, overall management of the process, and interview preparation.

Fellowships and scholarships are competitive, merit-based monetary awards that support a wide range of purposeful activities. These include research, internships, projects and study abroad. Eligibility depends on the particular award.

For current graduate students, there are some specific awards the FSO will help facilitate: Knight Hennessey, Fulbright, Soros, Luce, Hertz and Schwarzman.

Within the parameters of each scholarship, we advise students on each award and help them navigate the range of choices. We work with students on various iterations of their applications and oversee the process, including letters of recommendation. Where appropriate, we will manage a campus selection process. If students are selected for an interview as part of the scholarship competition, we will help prepare them and organize campus committees for mock interviews.

Visit the FSO website (https://www.cmu.edu/fso) for information about fellowships and scholarships, and if interested, make an appointment with an FSO representative through Handshake.

Honor Societies

Phi Beta Kappa Society

Carnegie Mellon shelters a chapter of the Phi Beta Kappa Society, sponsored by the three colleges (Dietrich College of Humanities and Social Sciences, Mellon College of Science, and the School of Computer Science) that comprise the University's “arts and sciences” equivalent. The chapter's name is “Upsilon of Pennsylvania,” and was formally installed in April of 1995.

Founded in 1776 at the College of William and Mary in Williamsburg, Va., Phi Beta Kappa is the nation's oldest honorary society, with chapters at 276 of the foremost institutions of higher education across the country. Almost all members are elected by the chapters from among candidates for degrees in liberal arts and sciences, usually from the top 10% of the graduating class.

Membership in Phi Beta Kappa key has become a universally recognized mark of academic achievement in the liberal arts and sciences. The key's venerable pointing finger proclaims for all to see the wearer's commitment to Phi Beta Kappa's ancient principles (represented in the three stars) — friendship, morality and learning. The society's name is formed by the first letters of the phrase *Philosophia Biou Kybernetes*, Philosophy (wisdom) is the Guide of Life. In line with the conviction that the test of education lies not in what people know but in what they are, the objectives of humane learning encouraged by Phi Beta Kappa include not merely knowledge but also intellectual honesty and tolerance, a broad range of intellectual interests and understanding.

The Carnegie Mellon chapter is active in sponsoring visiting speakers, on-campus roundtables that focus on current issues, community service activities, scholarship opportunities, student research involvement, and the like.

The Honor Society of Phi Kappa Phi

The Honor Society of Phi Kappa Phi has been an important presence on campus since 1933. Phi Kappa Phi, a national honor society that began in 1897 at the University of Maine, takes its name from the initial letters of its adopted motto, Philosophia Krateito Photon, “Let the love of wisdom rule humanity.” Phi Kappa Phi recognizes and honors persons of good character who have excelled in scholarship, in all fields of study. Members are nominated by their department or their school or college and then invited to join the society.

To be eligible, seniors must be in the top ten (10) percent of their class and juniors in the upper seven and one-half (7.5) percent of their class at the time of invitation. Graduate students, alumni, faculty and staff are also eligible for nomination. The chapter inducts new members once a year, each spring, and provides information to its members on all sorts of opportunities, including study abroad, internships, and graduate fellowships, recognition and awards.

Intercultural Communication Center

Location: 350 Posner Hall, 3rd floor, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-4979
eslhelp@andrew.cmu.edu
www.cmu.edu/icc

The Intercultural Communication Center (ICC) is a support service offering programs designed to equip nonnative English speakers, both international students and students who attended high school in the U.S., with the skills needed to succeed in academic programs at Carnegie Mellon. In addition to developing academic language skills, students can learn more about the culture and customs of the U.S. classroom. The center offers:

- 1-1 Consultations to help students develop specific aspects of academic language, such as pronunciation and presenting
- Seminars and workshops to develop stronger academic language and cross-cultural communication, such as Three Keys for Better Presentations, Writing Academic Emails, and Participating in Classes
- Videos and materials to help students develop language and cultural awareness

Visit ICC's website (https://www.cmu.edu/icc) to join the mailing list for program information.

Teacher Certification

Carnegie Mellon offers a teacher certification program in the school of music but does not offer a degree in education or teacher certification program in other academic areas. Students can take relevant classes through several departments on campus to develop skills and knowledge that will help them to prepare for a career in K-12 education. There are several pathways to a teaching career and interested students can contact Judith Hallinen, Assistant Vice Provost for Educational Outreach, at jh4p@andrew.cmu.edu to discuss opportunities and programs that can be pursued.

Undergraduate Research Office

Stephanie Wallach, *Assistant Vice Provost for Undergraduate Education*
Location: Cyert Hall A64, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-5702
Fax: 412-268-6159
www.cmu.edu/uro

Conducting research as an undergraduate is an especially valuable way to get to know faculty members; explore an area of interest in depth; turn classroom theory into practical hands-on experience; get a feel for graduate school; learn skills for the workplace; and have some fun at the same time. The Undergraduate Research Office (URO) supports students conducting independent research and creative projects in every field at the university — whether they join an existing lab or project or whether they set out on their own.

All undergraduates at Carnegie Mellon are eligible to participate in Undergraduate Research Office programs. The term “research” is defined broadly as “research, scholarly, or artistic activities that lead to the production of new knowledge; to increased problem solving capabilities, including design and analysis; to original critical or historical theory and interpretation; or to the production of art or artistic performance." Students from all fields and at all levels are encouraged to participate in the research process at least once, and hopefully many times, in their undergraduate careers. This is true whether they are planning to attend graduate school or to seek out a position in the private or public sectors.

Advising and Information Services

The staff of the Undergraduate Research Office are available to discuss project ideas; suggest possible faculty mentors (required); read and comment on proposal drafts; and generally facilitate the research process. In addition, the URO typically runs two proposal writing workshops each semester to assist students in preparing their proposals. Support from the URO is a competitive process and requires the students to submit strong proposals

Small Undergraduate Research Grants (SURG)

Undergraduates in good academic standing are eligible to apply for a Small Undergraduate Research Grant (SURG). Awards are made twice each year based on submitted project proposals. A panel of faculty and administrators from each of the colleges serves on the selection committee and will generally consider requests up to $500 for individual student projects or $1000 for a group project. Grants may be used to purchase supplies and materials, rent time on laboratory equipment, pay subjects in an experiment, or even travel to another city to collect data. Budgets are required as part of the SURG proposals. Deadlines are October for the Spring grant period and in March for the Summer and Fall grant periods.

Summer Undergraduate Research Fellowship (SURF)

These fellowships are designed to allow students a 8–10 week summer of supported research at Carnegie Mellon in close collaboration with a faculty advisor. Students receive a fellowship of $3,500 as a stipend to cover any of their expenses. The deadline for submission of proposals coincides with the regular SURG deadline in March.

Undergraduate Research Symposium: Meeting of the Minds

The undergraduate research symposium, known as "Meeting of the Minds," is an annual event that brings our campus together to celebrate the diverse, creative,and ground-breaking research that takes place among undergraduates. Students share their research findings through poster, oral, and artistic presentations. Many participate in award competitions sponsored by various corporations, departments, individuals, and organizations. All students funded through the URO are required to attend, but it is also open to other students, including senior thesis presenters. Approximately 650 students participate each year. Meeting of the Minds takes place during early May at the University Center.

Presentation Awards

Students whose work has been accepted for presentation at an academic conference are eligible to apply for a Presentation Award. These awards, up to $250, help defray costs of conference registration, transportation, and accommodation.

University Libraries

Keith Webster, *Dean of University Libraries and Director of Emerging and Integrative Media Initiatives*
Location: Hunt Library, 4909 Frew St., Pittsburgh, PA 15213
Phone: 412-268-2444
www.library.cmu.edu

The University Libraries is an essential academic partner, whose services, expertise, and collections are at the heart of the work of CMU. The Libraries strengthen the work of the CMU academic community to ensure its transformative impact on our campus and beyond. Offering digital resources, research support, enhanced learning spaces – and so much more – Hunt, Sorrells, Mellon and CMU-Q libraries enrich the CMU student experience and benefit all members of the our community.

Build and Expand Digital Resources

The libraries create digital resources by scanning archival & rare collections; licensing specialized resources to support campus research; and purchasing perpetual access to online journals, electronic books and specialized web resources.

Showcase Research Excellence

The library provides digital infrastructure exposing faculty publications & research to be visible to the world. The Libraries contribute to author publication charges that enable current faculty research to appear in open access journals and monographs.

Enhance Learning Spaces

Learning in the library requires both individual and group focused learning environments as well as technology to maximize the learning experience. Technology enhancements range from flat screen displays to tools for using visualization software.

Online Access

From the Libraries' home page (www.library.cmu.edu), students and eligible campus community members can access:

- CAMEO library catalog – Use CAMEO to find out where materials are located in libraries on campus. See whether items are checked out, on reserve, or available to be borrowed.
- My Library Account – Renew books, put books on hold, see a list of what you have checked out, see fines
- Course Reserves – Find required materials that your professors have reserved for classes to use
- Research Help – Learn about key resources in your subject area, including the CMU librarian who is a subject specialist for your school or college
- Ask a Librarian – Interactive reference service staffed by CMU librarians (chat, IM, email, phone, or in-person)
- AND MUCH MORE - Library collections, articles and databases, E-Journals A-Z, library catalogs

"Library Catalogs" link to online catalogs for the University of Pittsburgh Library System, The Carnegie Library of Pittsburgh, and other local libraries. We are partners with Pitt and The Carnegie; you can get library cards and borrow directly from these nearby libraries.

University Police

Thomas Ogden, *Chief*
Location: 300 South Craig Street, Room 199, Pittsburgh, PA 15213
campuspd@andrew.cmu.edu
www.cmu.edu/police

The Carnegie Mellon University Police Department provides police services 24 hours a day, seven days a week, 365 days a year. Police officers are responsible for patrolling all university owned or leased property. In addition to patrol, officers will respond and investigate crimes and other emergencies that are in progress or have already occurred.

The success of the Patrol Unit is largely dependent on the eyes and ears of the community it serves. Immediate notification facilitates a rapid response. All emergencies on campus, including fire and medical, should be reported immediately to University Police. If you see suspicious activity or a crime in progress, call the University Police immediately by calling 412-268-2323.

Students are responsible for their personal property as well as the property of groups to which they belong. Insurance against loss, theft, or damage to such property occurring in the residence hall or elsewhere on campus must be arranged for by students or their parents through an insurance agent.

University Police makes available on its website a wide range of information about the university's security practices. View more information about the shuttle and escort service, community outreach, current investigations, crime prevention and safety education, and other programs and services by visiting www.cmu.edu/police.

Carnegie Mellon University publishes an annual campus security and fire safety report describing the university's security, alcohol and drug, sexual assault and fire safety policies, and containing statistics about the number and type of crimes committed on the campus, and the number and cause of fires in campus residence facilities during the preceding three years. You can obtain a copy by contacting the Carnegie Mellon Police Department at 412-268-2323. The annual security and fire safety report also is available online at www.cmu.edu/police/annualreports.

Department of Athletics and Physical Education

Josh Centor, Associate Vice President of Student Affairs and Director of Athletics, Physical Education & Recreation
Location: Skibo Gymnasium, Tech and Frew Streets, Pittsburgh, PA, 15213
Phone: 412-268-1236
jcentor@andrew.cmu.edu
www.cmu.edu/athletics

Intercollegiate Athletics

Carnegie Mellon emphasizes excellence in its intercollegiate athletic programs, as well as in its classrooms. The University strongly believes that academic and athletic excellence can successfully coexist. Intercollegiate athletics are important in student life and make a positive impact on the educational experience. Experience as a student athlete additionally provides benefits in professional and social endeavors following graduation.

Carnegie Mellon sports teams have competed intercollegiately since the early 1900s. In the past 15 years, the program has experienced extensive success. The Tartans have won 86 conference championships and competed in over 132 national championships since 1976. This success has been achieved while meeting all of the academic requirements of demanding programs and without athletic scholarships.

In 1986, Carnegie Mellon became a charter member of the University Athletic Association (UAA), a eight-team league of similar institutions with regard to academic and athletic programs. The UAA, a national association which geographically reaches as far north as Massachusetts, as far south as Atlanta and as far west as St. Louis and Chicago, sponsors intercollegiate competition in 23 sports including 12 for men and 11 for women. UAA members include Brandeis University, Case Western Reserve University, Carnegie Mellon University, Emory University, New York University, the University of Chicago, the University of Rochester and Washington University in St. Louis.

Carnegie Mellon, like the other seven UAA members, is a member of the National Collegiate Athletic Association (NCAA). Its intercollegiate teams compete on the Division III level, which prohibits athletic scholarships and operates under the true meaning of amateurism. Student-athletes who play at the varsity level are students first and athletes second. All students, both athletes and non-athletes, are treated equally with regard to admission and financial aid policies. Carnegie Mellon fully supports a policy of equity in resources and opportunities for women and men.

The university fields competitive teams in 19 sports. The Tartans compete in football, men's and women's golf, men's and women's soccer, men's and women's cross-country, men's and women's tennis, women's volleyball, men's and women's basketball, men's and women's swimming and diving, men's and women's indoor and outdoor track and field, and softball.

Carnegie Mellon's intercollegiate programs have consistently produced winners. The Tartans' football team has won 15 conference championships, had a string of 35 consecutive winning seasons from 1975-2009, and has appeared in the NCAA Division III Championship playoffs six times. The Tartans have also played in three straight ECAC Bowl games. In 1979, Carnegie Mellon was awarded the Lambert Trophy as the best small college team in the northeast. In 2017, senior running back Sam Benger became the fourth Tartan named as a finalist for the William V. Campbell Trophy, an award that recognizes an individual as the absolute best scholar-athlete in the nation amongst all divisions.

The men's cross country team won its most recent conference championship in 2016 and has had a student-athlete or team compete at nationals for 17 straight seasons. In 2017, the women's cross country team made its fourth appearance at the national meet and first since 1998 when the Tartans placed fourth nationally.

The volleyball team recorded back-to-back trips to the NCAA Tournament in 2016 and 2017 and reached their highest AVCA national ranking in program history when they held the sixth spot for two weeks during the 2017 season. The women's soccer team made its sixth straight appearance in the NCAA tournament in 2017 and in 2012 advanced to the national quarterfinals. The men's soccer team has competed in the NCAA tournament four of the last six seasons.

The women's basketball team made post season play in two of the last three seasons. In 2015-16, the Tartans advanced to the Sweet 16 of the NCAA tournament for the first time in school history. The following season, 2016-17, senior Lisa Murphy was selected as the Jostens Trophy award winner. The award is a symbol of excellence for the Division III student-athlete; it is an honor given to the top women's basketball player for their excellence on the court, in the classroom and in the community.

A freshman computer science major on the men's tennis team won the NCAA National Singles Title in 2000 with a sophomore claiming the ITA National Small College Championship title in 2013. The women's tennis team also produced an ITA National Small College Champion when a sophomore won the singles title in 2006. Both men's and women's swimming and diving and track and field teams annually qualify a number of athletes for the national championships. Swimming has produced a combined nine national champions while the men's track and field team won the indoor and outdoor conference championships in 2017. In the spring of 2018, the women's golf team, competing in its fourth year of varsity competition, finished fifth at the NCAA Division III Championships.

Carnegie Mellon has accumulated 138 Academic All-America honors given out by the College Sports Information Directors of America (CoSIDA) since 1976. Eighty-eight have earned the honor since the 2004-05 season. The Tartans have also produced 12 NCAA Postgraduate Scholars since 2007-08, which is a scholarship that is awarded to student-athletes who excel academically and athletically and who are in their final year of intercollegiate athletics competition.

To provide excellence throughout the athletic programs, the department employs full-time coaches in all varsity sports. Intercollegiate competition begins with the first football and soccer games in early September and ends with the NCAA track and field, golf, tennis and softball championships in late May. Students with athletic skills in any of the above mentioned sports are welcome to become members of the team. Participation is open to all students.

Recreation

In addition to providing for its more formal programs and teams, Carnegie Mellon's athletic facilities are available for use by individual students on an extensive seven-day per week schedule.

The Cohon University Center has facilities for swimming, basketball, volleyball, badminton, squash, and racquetball, as well as cardio and strength equipment. Skibo Gymnasium is an indoor facility for recreation basketball and badminton. Gesling Stadium provides outdoor soccer, football and track facilities. Tennis courts, located between the University Center and Margaret Morrison, are lighted for night play. During the school year, they are open for use by students, faculty and staff.

These facilities are available to students, faculty and staff who have a valid Carnegie Mellon ID card. For hours, contact the Athletic Office at 412-268-1236, or visit our website (http://athletics.cmu.edu/landing/index).

Physical Education

The Department of Physical Education provides an elective program with an emphasis on personal fitness and lifetime recreation, thus preparing students for physical activity after the college years. Most classes are offered on a mini-course system with each class running seven weeks in length.

This program of more than 40 courses is designed for all students, from the beginner to those students who have already developed some skill. Courses include weight training, personal fitness, racquetball, tennis, golf, weight training, karate, aerobic fitness, and yoga. The department offers a wide variety of diversity in our course offerings. Instruction is also provided in several team sports. Carnegie Mellon also provides courses for American Red Cross certification in the four levels of swimming and lifeguard training.

Intramural Sports

For those who seek another level of competition or just like to participate and have fun, the Intramural Program provides recreation and relaxation for all students, faculty and staff, regardless of the degree of their natural athletic skills. The university prides itself on an intramural program which annually involves 6,000 students. Men and women, both graduate and undergraduate, compete in more than 20 different activities. Major sports include flag football, soccer, volleyball, floor hockey. basketball, and softball. A few of our popular tournaments are ultimate frisbee, dodgeball, tennis, and badminton.

Through participation in this program, students are able to keep physically fit, put to good use various learned skills, and develop leadership, team play and sportsmanship. Intramural activities, like all sports endeavors, contribute to physical development, good health, and a sound state of mind, while providing keen competition and team spirit. In addition, intramural sports possess an inherent flexibility that allows for a limited commitment of time in light of academic priorities. The intramural program permits students from all departments to meet and socialize on an informal basis.

Fitness and Wellness

The university is well aware that fitness is a vital contributor to an individual's well-being and productivity. For this reason the department is committed to providing the entire campus community with the opportunity and resources to keep fit for the new century.

The Fitness and Wellness program provides educational services, programs, workshops and seminars. Programs include cardio-respiratory fitness, muscular strength, blood pressure and stress reduction. Workshops include the topics of nutrition, weight control, stress management and lower back care and prevention. The Group X program provides over 70 exercise classes per week ranging from yoga and pilates to zumba and indoor cycling.

Faculty

SHANNON AGNEW, Assistant Women's Soccer Coach – Bachelor of Arts, University of Tampa; Carnegie Mellon, 2012–

GARY ALDRICH, Associate Head Track & Field Coach/Instructor – M.S., Slippery Rock University,Carnegie Mellon, 2006–

MICHAEL BELMONTE, Assistant Men/Women Tennis – History, Duquesne; Carnegie Mellon, 2010–

TERRY BODNAR, Assistant Football Coach/Instructor – M.S., Indiana University of PA,Carnegie Mellon, 1984–

BRANDON BOWMAN, Head Men's Soccer Coach – B.S., Centre College; Carnegie Mellon, 2017–

JOSH CENTOR, Assistant Director of Athletics – B.A., Brandeis University,Carnegie Mellon, 2008–

ALAN DEGENNARO, Strength and Conditioning CoachCarnegie Mellon, 2011–

SARA GAUNTNER, Assistant Director of Athletics for Instructional Programs & Recreation & Aquatics Director/Instructor – M.S., Duquesne University,Carnegie Mellon, 2005–

ANDREW GIRARD, Head Men's and Women's Tennis Coach/Instructor – B.S., Michigan Tech University,Carnegie Mellon, 2003–

ALICIA GORMAN, Diving Coach, Director of Acquatics – B.S., University of Tennessee; Carnegie Mellon, 2017–

ANDREW HELMS, Assistant Football Coach – B.S., Carnegie Mellon University; Carnegie Mellon, 2017–

JACQUIE HULLAH, Head Women's Basketball CoachCarnegie Mellon, 2011–

KIM KELLY, Head Women's Volleyball Coach/Instructor – MBA, Mt. St. Mary's University,Carnegie Mellon, 2005–

MATTHEW KINNEY, Head Swimming and Diving Coach/Instructor – M.S., Western Illinois,Carnegie Mellon, 2007–

RICHARD LACKNER, Head Football Coach/Instructor – B.A., Carnegie Mellon,Carnegie Mellon, 1979–

JEFF SIMMONS, Assistant Football Coach/Instructor – B.A., Geneva College; Carnegie Mellon, 2010–

PATTYE STRAGAR, Operations Manager for Fitness and Aquatics/Instructor – B.S., Northwestern University; Carnegie Mellon, 2003–

YON STRUBLE, Head Men's Soccer Coach/Instructor – M.S., Georgia State; Carnegie Mellon, 2010–

TONY WINGEN, Head Men's Basketball Coach/Associate Athletic Director/ Instructor – M.Ed., Springfield College; Carnegie Mellon, 1990–

Department of Athletics and Physical Education Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

69-005 Rec Sports
Fall and Spring: 3 units
Rec sports is a class that will incorporate sports from our intramural program. The class will focus on a variety sports including: flag football, soccer, basketball, dodgeball, softball and additional recreational games.

69-101 Racquetball
Fall and Spring: 3 units
This course is designed to aid in developing the fundamental skills involved in racquetball. Techniques, rules and strategy are stressed. It is hoped that the student will develop a reasonable level of proficiency to enable participation on a leisure-time basis.

Course Website: http://www.cmu.edu/athletic/

69-102 Weight Training
Fall and Spring: 3 units
This course is designed to provide the opportunity for the inexperienced student to learn the effectiveness of a carefully planned weight-training program as a method of body development and the contributing benefit to performance in many sports.

69-103 Advanced Recovery & Restoration
Spring: 3 units
This course is designed to provide the opportunity for the physically active student to learn the effectiveness of a carefully planned recovery and restoration techniques as a method of body development and the contributing benefit to performance in many sports.

69-104 Practical Application of Sports Nutrition for Competitive Athletes
Spring: 3 units
This course will cover the following topics: macronutrient overview, specific overview of fats, carbohydrates, and protein, vitamin and minerals, nutritional needs for strength/power and endurance athletes, pre/during/post training nutritional needs for strength/power and endurance athletes, and other topics. FOR UNDERGRAD STUDENTS ONLY.

69-105 Agility & Circuit Training
Spring: 3 units
This course is designed to train the entire body combining fitness and core body work. We will do jumping and agility exercises to increase explosiveness and foot speed. Circuit training will be used to strengthen your core, arm, and leg muscles and will provide a cardiovascular workout.

69-106 Intro to Recreation
Fall: 3 units
This is a basic level class for first-year students only. This class is designed to teach students various fitness and recreational activities available to them on campus.

69-107 Walking for Fitness
Fall: 3 units
This course is an aerobic conditioning activity. A fast paced walk that is less wear and tear on your joints than what a running program will do.

69-110 Personal Fitness
Fall and Spring: 3 units
This course will be a conditioning course prescribed partially by the individual with assistance from the instructor to insure that the desired results will be achieved or at least pursued correctly. Individual goals will be the main concern. Stretching, aerobics, weight training and nutrition will be discussed.

69-112 Fitness Fusion
Fall and Spring: 3 units
A fun power-packed workout designed to introduce all aspects of fitness. This class combines simple exercises including cardio endurance with dynamic balance and stabilization. The class will fuse fitness while maximizing the benefits offered by training with concise, innovative, and effective exercises for the whole body. Every few weeks another aerobic activity will be added. We will start slowly so you can experience progressions and advance your training. During the fusion of strength, core, and flexibility, we will use a variety of "toys" to enhance your fun and fitness while fusing the total package of mind, body, and spirit.

69-113 Beginning Karate
Fall and Spring: 3 units
Beginning Karate teaches traditional Tang Soo Do (Korean Karate) by Master C. S. Kim and assistant instructors with specific standards and goals designed to help each student maximize potential as an individual, as well as a martial artist. Students will learn stretching and basic stances as well as blocking, punching, kicking, knee and elbow strikes, and open-handed techniques such as knife-hands. Proper etiquette will also be taught.

69-114 Intermediate Karate
Fall and Spring: 3 units
Intermediate Karate teaches a higher level of the traditional martial arts with specific standards and goals designed to help each student maximize potential as an individual, as well as a martial artist. Through traditional Tang Soo Do (Korean Karate) taught by Master C. S. Kim and assistant instructors, you will find many opportunities to gain specific knowledge which will apply not only in your martial arts training, but also in the improvement of your daily quality of life.

69-120 Topics in Health and Physical Activity
Fall and Spring: 3 units
This is a weekend course set for March 29th from 4:00 pm-7:00 pm and March 30/31 from 9:00 am-2:00 pm. The course times will be sent via email before the course begins. This course is designed to expose students to a comprehensive overview of what it means to be healthy, including: stress management strategies, healthy eating habits, importance of sleep, and the benefits of various exercise methods. The course will be presented using both a traditional lecture style, and hands-on practice. A few outside speakers will be brought in to speak in their area of expertise. Students should come prepared to exercise.

69-129 Rape Agression Defense Systems (RAD)
Fall and Spring: 3 units
Self Defense for Women - is a course specifically designed to increase women's awareness of potential sexual assault and to provide physical techniques to respond to such an act. It is intended for women only because it is believed that the presence of males in class (other than instructors or other authorized persons) can alter the emotional and physical responses of women to class material and thereby hinder their ability to reach course objectives. It is of the utmost importance that women be able to maximize their opportunity to learn in the company of like-minded students. The core of the course is based upon the principles of the Rape Aggression Defense System (R.A.D.)which was conceived and developed by Larry N. Nadeau. His goal in developing R.A.D. is also its motto: "To develop and enhance the options of self-defense, so they may become viable considerations to the woman who is attacked." This course is composed of three sections: risk reduction principles, physical defense techniques, and simulation. Risk reduction principles include a thorough review of personal self-awareness & the environment, whether in the home, neighborhood, or unfamiliar community. Physical defense techniques include the introduction to bodily strikes with hands, kicks with the feet, and defenses against grabs & holds. Simulation is the activity that attempts to incorporate, via physical demonstration, all emotional & physical techniques that have been taught through the acting out of scenarios involving instructors (padded/protected) as attackers, and students (padded/protected) responding to the assault.

69-130 Beginning Tennis
Fall and Spring: 3 units
This course is designed to familiarize the student with the rules of tennis and to develop the skills needed to become proficient for recreational play. During the first half of the course, all tennis strokes will be covered and reviewed in detail. The second half of the course will focus mostly on competitive games and match-play.

69-131 Volleyball
Spring: 3 units
This course is designed to familiarize the student with the rules of volleyball and to develop the skills needed to become proficient for recreational play.

69-132 Advanced Tennis
Fall: 3 units
This course will consist mainly of tennis drills and discussions related to singles, doubles, and match strategy. In addition to being able to successfully execute all tennis strokes, students should also already have significant tennis match experience.

69-134 Beginning Golf
Fall and Spring: 3 units
This course is designed to give the student all the skills necessary to play a satisfactory game of golf. The long game, the short game and putting are covered. It is a leisure time sport that is challenging and can be used by the student for the rest of his/her life.

69-135 Soccer Skills
Spring: 3 units
This course is designed to familiarize the student with the rules of soccer and to develop the skills needed to become proficient for recreational play.

69-136 Basketball Skills
Fall and Spring: 3 units
This course is designed to familiarize the student with the rules of basketball and to develop the skills needed to become proficient for recreational play.

69-137 Ultimate Frisbee
Fall: 3 units
This class is designed to teach basic Frisbee skills. This class is a great conditioning/cardio class with high energy. It is a fun team game to play.

69-139 Indoor Soccer Skills
Spring: 3 units
This course is designed to familiarize the student with the rules of soccer and to develop the skills needed to become proficient for recreational play.

69-140 Squash
Fall and Spring: 3 units
This course is designed to aid in developing the fundamental skills involved in squash. Techniques, rules and strategy are stressed.

69-141 Beginning Soccer
Spring: 3 units
This class is designed for beginner soccer players. This class will teach you soccer skills and techniques to become a better player.

69-142 Beginning Fencing
Spring: 6 units
This course will cover the basic skills needed for fencing with the foil. Footwork, attacks, and defenses will be practiced. Competition rules and strategies will be discussed. Students will fence each other and the instructor in almost every class.

69-143 Floor Hockey/Dodgeball
Spring: 3 units
This class is designed to teach two team sports that are fun and great exercise. Both classes will be taught basic skills to succeed in the games.

69-144 Diamond Sports
Spring: 3 units
This course is designed to familiarize the student with the rules of softball and wiffleball and to develop the skills needed to become proficient for recreational play. Students will play each other or the instructor in almost every class.

69-145 Beginning Softball
Fall and Spring: 3 units
Students will learn beginning softball skills-throwing, hitting, running

69-146 Team Handball
Fall: 3 units
Team Handball or European Handball - This is an introductory level class that will cover the basics of the sport including the rules, organization, and basic game play. Students will be expected to learn the rules and participate in play on a daily basis.

69-150 Beginning Swimming
Fall: 3 units
This basic course is designed to equip the non-swimmer with fundamental skills and knowledge to assure reasonable safety in, on or about the water. Areas covered include the basic swimming strokes, basic diving, safe and efficient entry into the water, and some elementary forms of rescue.

69-151 Introduction to Yoga
Fall and Spring: 3 units
This course is designed for the beginning yoga student who wants to gain a solid foundation of yoga poses and the benefits a yoga practice has to offer. The course is also for those who have experience in Yoga and want to practice and improve their basic skills.

69-153 Lifeguard Training
Spring: 3 units
This class is the American Red Cross Lifeguard Training course. Students who complete certification will be eligible to be employed as lifeguards. Attendance is required. There will be a $90.00 fee for this class from the American Red Cross. This fee will be deducted from the student's account once the status of the student is "enrolled and attending this class."

69-155 Cardio Fitness/Sculpt
Fall and Spring: 3 units
A total body fitness class for men and women that incorporates stretching for flexibility, exercises for strength and movement to increase cardiovascular improvement.

69-156 First Aid/CPR
Spring: 3 units
A basic course in treatment and care of injuries in emergency situations. Topics will include legal liability, prevention of injuries, nutrition and cardiovascular conditioning. The course will conclude with theoretical and practical application of cardiopulmonary resuscitation. Upon completion of the course students will receive Red Cross Certification. There will be a fee for this class of $15.00. This fee will be deducted from the student's account.

69-157 Swimming Stroke Improvement
Fall: 3 units
This course is designed to provide the student with the opportunity to learn the elements of good swimming. A wide range of strokes, basic diving, safety, endurance, and versatility in the water will be covered for all students. Experienced swimmers will have the opportunity to perfect their strokes.

69-160 Swim-Fit
Fall and Spring: 3 units
Must be able to complete a 1000 yard swim (40 laps) prior to entering the class ; this is not a learn-to-swim class. Pre and post timed swims, deep water treading, lap swimming interval training. Average workout is around 2000 yards.

69-165 Cycling Core
Fall and Spring: 3 units
Indoor cycling classes are riding on a stationary bike while getting a great workout, experiencing several styles of training, and listening to music. All are welcome—beginner to advanced—you set the workout pace to various intensities. This course is for those participants who want to gain knowledge and experience of riding for endurance, speed work, race training, strength training, and/or visionary riding. Each class will be formatted to take the rider to their levels of advancement—beginner to advanced—all doing the same workout. Bikes are provided. No prior bike experience is necessary. No special footwear required—bike shoes are welcome—and tennis shoes at least are a must. Come along for the ride of a lifetime while having fun and getting into shape.

69-167 Beginning Ballroom Dance
Spring: 2 units
This class provides an overview of six American Style Ballroom Dances: Foxtrot, Waltz, Tango, Cha Cha, Rumba, Swing. Participants will learn three or four basic step patterns in each dance, the timing of each pattern, leading and following principles and the unique characteristics of each dance. At the end of this course, participants will be able to dance comfortably at a social dance. It is recommended that suede bottomed dance shoes be worn, but not required.

69-175 African-Brazil Dance
Fall: 2 units
This class incorporates African-Modern dance technique (specifically elements of Dunham and Horton technique) and applies it to dance movements from West Africa, Haiti, and /or Brazil. Students will build strength, alignment, and stamina while experiencing the joy of dancing to the exciting and mesmerizing music of these regions. Open to non-drama and drama majors.

69-176 Non-Majors Jazz
Spring: 3 units
This class is designed for those students who would like to continue their study in jazz but are not enrolled in the CFA department. They will learn the basics and progression movements in the area of jazz dancing. This is for all levels of participants.

69-195 Emergency Medical Technician 1
Fall and Spring: 12 units
The Emergency Medical Technician provides students with a basic knowledge of Emergency Medicine, and enables students to take the National Registry EMT Certification exam and become certified at the state and national level. This course is cross-enrolled through the Community College of Allegheny County (CCAC) and will require registration with CCAC on the first day of class. This will require a fee, which has yet to be determined. Due to state laws and classroom hours requirements, all lectures are mandatory with very few exceptions. This class will meet on around 2 Saturdays, which will be announced on the first day of class. This class is also offered in two parts. The first part (69-195) is offered during mini-2 and the second part (69-195) is offered during the full spring semester. You must attend both parts in order to be eligible to take the National Registry EMT Certification exam. Please email info@cmuems.org with any questions you might have.

Reserve Officers' Training Corps (ROTC)

Department of Aerospace Studies (Air Force ROTC)

Lt Col Diana Bishop, *Detachment 730 Commander*
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The local AFROTC program is administered by the Department of Aerospace Science at the University of Pittsburgh. This program is available to undergraduate students at fourteen “cross-town” universities via enrollment through agreement with the University of Pittsburgh. Students must have at least six semesters (three full academic years) of school remaining to successfully complete AFROTC graduation requirements. Upon successful completion of university academic and ROTC requirements, students will earn a commission as a Second Lieutenant in the US Air Force.

Students will complete one or two years in the General Military Course (GMC) before competing for an enrollment allocation into a four-week summer leadership training program. After completion of the summer training program, students are enlisted into the Professional Officer Course (POC), where they will take on role leading anywhere from 10–50 of their fellow cadets in weekly activities. *Students are under NO contractual obligation to the Air Force until entering the POC or accepting an Air Force scholarship.* In addition to the academic portion of the curriculum, each student attends a weekly two-hour, hands-on “laboratory” that tests both their followership and leadership abilities amongst their peers. This lab is used to practice various leadership and management techniques and groom students into future military leaders. Three and three-and-a-half year scholarships are available to qualified students in certain areas of study. Most AFROTC scholarships cover tuition plus lab fees, books, plus each scholarship awardee receives a tax free monthly stipend that ranges between $300–500 per month.

Department of Military Science (Army ROTC)

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The Army Reserve Officers’ Training Corps (ROTC) program supporting Carnegie Mellon University is located at the University of Pitts-burgh. It exists to train the future officer leadership of the United States Army and offers opportunities and challenges that can put college students on the fast track to success in life. ROTC provides a combination of academics and important hands-on training, in addition to physical and mental challenges that will help students succeed in college and beyond. Through the training in ROTC, students will develop the confidence, self-esteem, motivation and leadership skills they will need regardless of their career plans.

The Four-Year Program

The traditional Four-Year program is divided into two parts. The Basic Course is taken in the freshman and sophomore years. There is no commitment for non-scholarship students at this level. Upon success-ful completion of the Basic Course, students are eligible for the Advanced Course, taken in the junior and senior years. At the beginning of the Advanced Course, students will decide whether or not they wish to become officers in the Army and enter into a formal contract. During the summer between the junior and senior years, students are required to attend the the Leader Development and Assessment Course (LDAC). Upon successful completion of a University degree and the Army ROTC program, students are commissioned into the United States Army as a Second Lieutenant.

The Two-Year Program

If the first two years of ROTC are not taken, students can attend the Leader’s Training Course (LTC) during the summer between the sophomore and junior year. This camp will qualify students to begin the Advanced Course in their junior year or in the first year of a two-year graduate program. Or, if students have served in the active duty military, attended a military academy for one year, participated in JROTC for three years or belong to a Army National Guard or Army Reserve unit, they already qualify for entrance into the Advanced Course.

The Alternative Entry Program

The Alternative Entry Program is designed for academic junior students with no prior qualifying military training but are otherwise qualified. This option allows students to contract into the Advanced Course without receiving placement credit for the basic course. Students accepted into this program must complete the Leader’s Training Course and the Leader Development and Assessment Course during the summer months.

Curriculum

Freshman Year		Units
30-101	Introduction to Military Leadership - Fall	5
30-102	Foundations of Leadership- Spring	5

Sophomore Year		Units
30-201	Leadership Dynamics and Application- Fall	5
30-202	Applications in Leadership and Combat Power-Spring	5

Junior Year		Units
30-301	Basic Leader Planning and Combat Operations-Fall	5
30-302	Advanced Leader Planning and Combat Operations- Spring	5
Leadership Development & Assessment Course (six-week required summer camp)		

Senior Year		Units
30-401	Progressive Leadership Theory and Applications-Fall	5
30-402	Transition to the Profession of Arms- Spring	5

Army ROTC Scholarships

Army ROTC offers four, three and two year full scholarships with additional annual allowances of $900 for books and a monthly stipend. High school, undergraduate and incoming two-year graduate students are eligible to apply. For application and information call ROTC at the University of Pittsburgh at (412) 624-6254/6197.

The Simultaneous Membership Program (SMP)

This program allows students to become members of the Army National Guard or the Army Reserves while enrolled in Army ROTC. Students in the Advanced Course who are SMP are paid for their Guard/Reserve training. The benefit of this program is that students in the Advanced Course are able to act as Army officers in their National Guard or Reserve unit, receiving valuable leadership experience.

Summer Programs

Leadership Development & Assessment Course
This 35-day camp is a requirement for all contracted students. Students attend the summer between their junior and senior year. Students are placed in various leadership positions throughout Camp and their skills and abilities will be tested and evaluated in preparation of a commission in the United States Army. All expenses are paid by the Army. Students are paid while attending.

Leader’s Training Course
This 35-day camp is taken as a prerequisite for entry into the Advanced Course if the Basic Course cannot be fulfilled. It is taken the summer before the junior year. All expenses are paid by the Army. Students are paid while attending.

Army Adventure Training
ROTC students may participate in Airborne School, Air Assault School, Northern Warfare School and Mountain Warfare School the summer before the sophomore and junior year. These courses range from two to four weeks and students must arrive in top physical condition. All expenses are paid by the Army.

Extracurricular Activities

Rangers: Army ROTC students are eligible to participate in the Cadet Ranger Club. The Club conducts physically and mentally challenging extracurricular training to promote fitness, teamwork, self-confidence and fellowship. Training includes physical fitness, rappelling, rope bridging, tactics, hiking, climbing, weapons training and orienteering.
Scabbard & Blade: National Honor Society consisting of cadets/midshipmen from Army, Air Force and Naval ROTC.
Rho Tau Chi: Military fraternity established for the members of the various branches of ROTC. Purpose is to draw together cadets to increase communication and feelings of goodwill between the Cadet Corps and the community. Cadets participate in a variety of community service projects.
Color Guard: Dedicated group of Army ROTC cadets who train and perform to present the American flag and Army colors at football and basketball games and various community events.

Department of Naval Science (Naval ROTC)

Mike Danko, *ROTC and Veterans Affairs Coordinator*
Captain William McKinney, *Commanding Officer*
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The Department of Naval Science was established 16 December 1987. Its mission is to prepare young men and women mentally, morally, and physically, and to instill in them the highest qualities of duty, honor, and loyalty, in preparation for leadership positions in the naval service.

Carnegie Mellon’s Naval Reserve Officers Training Corps (NROTC) is designed for young men and women who are seeking a challenging academic experience and who desire to serve their country as officers in the Navy or Marine Corps after graduation.

NROTC midshipmen lead the same campus life as other Carnegie Mellon students. They make their own arrangements for room and board, choose a preferred area of study and participate in extracurricular activities. Midshipmen wear civilian clothes to classes but wear uniforms one day of the week. NROTC students are active in all facets of university life; many are in positions of leadership in student government, on varsity and intramural sports teams, in campus clubs, and other student organizations. The NROTC program seeks students who are bright, ambitious, enthusiastic leaders whose lives are enriched by their education at Carnegie Mellon and by their involvement in NROTC.

Four-Year Scholarship Program

The four-year scholarship program provides full tuition and university fees, $750 for textbooks per year, uniforms, and a $250 per month tax-free subsistence allowance to students during their freshman year. This stipend then increases to $300 during their sophomore year, $350 for their junior year and $400 for their senior year. Midshipmen must complete the university-approved curriculum of their choice, including courses in calculus and calculus-based physics (Navy Option Only), and specified courses in naval science subjects. Paid summer training periods are also provided. Scholarships are awarded on the basis of a nationwide competition before the start of the freshman year. Midshipmen commissioned through the scholarship programs become officers in the Navy or Marine Corps and incur a four-year active duty obligation in a selected area of the naval service.

College (Non-Scholarship) Programs in NROTC
Qualified students may participate in NROTC as college program (non-scholarship) midshipmen and earn commissions in the Navy or Marine Corps Reserve upon graduation. The active duty obligation for this program is three years. Students receive all naval science textbooks and uniforms. Additionally, if awarded advanced standing during their junior and senior years, they receive a tax-free subsistence monthly allowance of $350 and $400 respectively. A paid summer training period is provided between the junior and senior year. College program students may compete for three- and two-year scholarships described in the following paragraph.

College Program Three- and Two-Year Scholarships
Three-year scholarships are available on a competitive basis to those qualifying college program (non-scholarship) NROTC students who have demonstrated leadership and academic excellence during their freshman or sophomore year and are nominated for the scholarship by the Professor of Naval Science. Scholarship benefits are identical to those provided by the four-year scholarship program. Active duty obligation is four years upon commissioning in a selected area of the naval service.

Two-Year National Scholarship Program
Sophomores who have not participated in the NROTC program may apply for a nationally competitive two-year NROTC scholarship. The two-year scholarship program provides the same benefits as the four-year program for a period of 20 months. Students must apply for this program no later than February of their sophomore year. Students selected for this program attend the Naval Science Institute during the summer before their junior year to complete required naval science course material. A paid summer training period is provided between the junior and senior years. Commissionees incur a four-year active duty obligation upon graduation in a selected area of the naval service.

Curriculum

The sequence of naval science courses is the same for all officer candidates for the first three semesters. Midshipmen accepted into the Marine Corps option program will have curriculum variations starting with their third year. Additionally, some candidates may be required to complete courses in American military affairs, national security policy, English, mathematics, and/or the physical sciences. Descriptions of the course requirements for each candidate classification (scholarship/college program) may be obtained from the Department of Naval Science office.

All scholarship and college program students are required to attend a weekly 1.5 hour Naval Laboratory (32-100) where professional orientation, military drill, physical fitness, and leadership are emphasized. Guest speakers from the Fleet are frequent participants in these laboratories. Naval Science courses are open to all students. Since these are required courses for NROTC students, they will be given priority in enrollment. Remaining spaces will be filled through the normal university registration process.

Naval Professional Academic Courses

Freshman Year		Units
32-100	Naval Laboratory	3
32-101	Introduction to Naval Science	6
32-102	Seapower and Maritime Affairs	6

Sophomore Year		Units
32-200	Naval Laboratory	3
32-201	Leadership & Management	9
32-212	Navigation *	9

Junior Year		Units
32-300	Naval Laboratory	3
32-310	Evolution Of Warfare **	9
32-311	Naval Ship Systems I-Engineering *	9
32-312	Naval Ship Systems II-Weapons *	9

Senior Year		
32-400	Naval Laboratory	3
32-402	Leadership and Ethics	9
32-410	Amphibious Warfare/Operations & The Fundamentals of Maneuver Warfare **	9
32-411	Naval Operations and Seamanship *	9

Footnotes:
* Required of students in the Navy Option
** Required of students in the Marine Option
All other courses are required of all students in the program.

Naval ROTC Faculty

JEFF CORAN, Captain, USN – M.S., Rensselaer Polytechnic Institute; Carnegie Mellon, 2014–

ROTC Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

Aerospace Studies-ROTC Courses

31-101 Foundations of the United States Air Force
Fall: 3 units
AS100 is a survey course designed to introduce cadets to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-102 Foundations of the United States Air Force
Spring: 3 units
AS100 is a survey course designed to introduce cadets to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-105 Air Force Leadership Laboratory
All Semesters
The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-106 Air Force Leadership Laboratory
All Semesters
The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-107 Air Force Leadership Laboratory
All Semesters
The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-108 Air Force Leadership Laboratory
All Semesters
The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-201 The Evolution of Air and Space Power
Fall: 3 units
The AS200 course designed to examine general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values with the use of operational examples and historical Air Force leaders and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-202 The Evolution of Air and Space Power
Spring: 3 units
The AS200 course designed to examine general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values with the use of operational examples and historical Air Force leaders and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-301 Air Force Leadership Studies
Fall: 9 units
AS300 is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

31-302 Air Force Leadership Studies
Spring: 9 units
AS300 is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

31-401 National Security Affairs and Preparation for Active Duty
Fall: 9 units
AS400 examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

31-402 National Security Affairs and Preparation for Active Duty
Spring: 9 units
AS400 examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

Military Science-ROTC Courses

30-101 Introduction to Military Leadership
Fall: 5 units
In this course, students will be introduced to the fundamentals of Army leadership, management and basic military skills. The course emphasizes the Army's "Principles of Leadership" and familiarizes the student with rifle marksmanship, orienteering and map reading, rappelling, basic lifesaving skills and the wear of the Army uniform. In addition, students will enhance their time management, decision-making and physical fitness abilities. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-102 Foundations of Leadership
Spring: 5 units
This course is a continuation of the subjects and skills taught in 30101. In addition to extending the student's abilities in the areas of leadership, orienteering and map reading, lifesaving and other basic military concepts, the course also introduces the student to the employment of military units. Individual topics covered include the Army's emerging technological enhancements, the Army organization and structure and the wartime policies and principles. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-201 Leadership Dynamics and Application
Fall: 5 units
In this course, students will delve more deply ino the Army's leadership and management techniques, including the application of those techniques in faculty-supervised practical exercises. The course also seeks to enhance the student's abilities in orienteering and map reading, terrain analysis, advanced lifesaving techniques and physical fitness. Students are introduced to the values that define the United States Army as an American institution, and each student continues to enhance his or her physical development under the supervision of the faculty. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-202 Applications in Leadership and Combat Power
Spring: 5 units
This course continues the study of the topics covered in 30201 and focuses upon practical application of the leadership and management techniques learned in the fall semester. The student develops and applies advanced map reading, terrain analysis, problem-solving and decision-making skills in practical exercises. Additionally, the student is introduced to the Army's formal orders process, used to maneuver and sustain Army forces on the modern battlefield. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-301 Basic Leader Planning and Combat Operations
Fall: 5 units
This course offers an in-depth analysis and focused practical application of leadership and management techniques. The emphasis in the course is on leader development and the goal is to enhance the student's ability to perform effectively in a stressful decision-making environment. As such, time management, decision-making, advanced military skills, troop-leading procedures and advanced physical training are emphasized. The course requires participation in a demanding physical training program to prepare contracted students for the Army's R.O.T.C. Leader Development and Assessment Course (LDAC). Each student must participate in field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students. Veterans with two or more years of service may enroll with approval.

30-302 Advanced Leader Planning and Combat Operations
Spring: 5 units
This course builds upon the foundation laid in the fall semester with the objective of fully preparing contracted students for participation in the Army's challenging R.O.T.C. Leader Development and Assessment Course (LDAC). The course extends and enhances the student's leadership, management, communication, fitness and basic military skills in preparing the student for commissioning as an officer in the United States Army. Practical exercises are used to reinforce all of the skills that the student has developed over the course of the military science instruction. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students. Veterans with two or more years of service may enroll with approval.

30-401 Progressive Leadership Theory and Applications
Fall: 5 units
This course is the first of two semester courses that serve as a capstone designed to transition the student from cadet to U.S. Army officer. Students are assigned to command and staff positions within the cadet battalion, corresponding to those found in United States Army units. Students perform the duties of the staff or command as assigned and interact with the other cadets as part of a functioning command organization. In addition to studying the operations and organizations of the U.S. Army, students are required to plan and execute the required training and activities in leading the underclasss cadets. A variety of topics of current interest are covered. Guest speakers are commonly invited to discuss their military experiences or their perspectives on military-related topics. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students.

30-402 Transition to the Profession of Arms
Spring: 5 units
This capstone course completes the transition from cadet to Army officer and concludes with the student's commissioning into the United States Army. During the semester, students continue to act in accordance with their assigned staff and command responsibilities and they prepare for their duties as a Lieutenant in the Army. This course covers personal and performance counseling, evaluation of subordinate leaders and team-building skills as well as military justice and discipline. Students bring to bear all of the skills and knowledge that they have accrued over the prior semesters in the Department of Military Science. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students.

Naval Science - ROTC Courses

32-100 Naval Laboratory
Fall and Spring: 3 units
Military drill, physical fitness, and leadership seminars.

32-101 Introduction to Naval Science
Fall: 6 units
A general introduction to the naval profession and to concepts of Seapower. Instruction emphasizes the mission, organization, and warfare components of the Navy and Marine Corps. Included is an overview of officer and enlisted ranks and rates, training and education, and career patterns. The course also covers naval courtesy and customs, military justice, leadership, and nomenclature. This course exposes the student to the professional competencies required to become a naval officer.

32-102 Seapower and Maritime Affairs
Spring: 6 units
This course surveys US naval history from its European origins to the present with emphasis on major developments and the geopolitical forces shaping these developments. Also included is discussion of the theories and writings of naval historian and strategist Alfred Thayer Mahan. The course will finish by covering present day concerns in seapower and maritime affairs including the economic and political issues of merchant marine commerce, the law of the sea, the navy and merchant marine of the former Soviet Union (FSU), and a comparison of US and FSU maritime strategies to include the rise and decline of the Soviet Navy.

32-200 Naval Laboratory
Fall and Spring: 3 units
Military drill, physical fitness, and leadership seminars.

32-201 Leadership & Management
Fall: 9 units
This course is a comprehensive advanced-level study of organizational behavior and management. Topics include a survey of the management functions of planning, organizing, and controlling; an introduction to individual and group behavior in organizations; an extensive study of motivation and leadership. Major behavioral theories are explored in detail. Practical applications are explored by the use of experiential exercises, case studies, and laboratory discussions. Other topics developed include decision-making, communication, responsibility, authority and accountability.

32-212 Navigation
Spring: 9 units
An in-depth study of piloting and an introduction to celestial navigation theory. Students learn piloting skills including the use of charts, visual and electronic aids, and the theory and operation of magnetic and gyro compasses. Students develop practical skills in both piloting and celestial navigation. Other topics include tides, currents effects of wind and weather, plotting, use of navigation instruments, types and characteristics of electronic navigation systems, and the typical day's work in navigation. Also included is a study of the international and inland rules of the nautical road, relative motion, vector analysis theory, and relative motion problems.

32-300 Naval Laboratory
Fall and Spring: 3 units
Military drill, physical fitness, and leadership seminars.

32-310 Evolution Of Warfare
Spring: 9 units
This course is to provide the student with a very basic understanding of the art and concepts of warfare from the beginning of recorded history to the present day. The intent of the curriculum is to familiarize the student with an understanding of the threads of continuity and the interrelations of political, strategic, operational, tactical, and technical levels of war from the past, while bringing into focus the application of these same principles and concepts to the battlefields of today and the future.

32-311 Naval Ship Systems I-Engineering
Fall: 9 units
A detailed study of ship characteristics and types including ship design, hydrodynamic forces, stability, compartmentalization, propulsion, electrical and auxiliary systems, interior communications, ship control, and damage control. Included are basic concepts of the theory and design of steam, gas turbine, internal combustion, and nuclear propulsion. Shipboard safety and firefighting are also discussed.

32-312 Naval Ship Systems II-Weapons
Spring: 9 units
This course outlines the theory and employment of weapons systems. The student explores the processes of detection, evaluation, threat analysis, weapon selection, delivery, guidance and explosives. Fire control systems and major weapon types are discussed, including capabilities and limitations. The physical aspects of radar and underwater sound are described in detail. The facets of command, control, and communications are explored as a means of weapons system integration.

32-400 Naval Laboratory
Fall and Spring: 3 units
Military drill, physical fitness, and leadership seminars.

32-402 Leadership and Ethics
Spring: 9 units
The study of naval junior officer responsibilities. The course exposes the student to a study of ethics, decision making and responsibility as well as counseling methods, military justice administration, naval human resources management, directives and correspondence, naval personnel administration, material management and maintenance and supply systems. This capstone course in the NROTC curriculum builds on and integrates the professional competencies developed in prior course work and professional training.

32-410 Amphibious Warfare/Operations & The Fundamentals of Maneuver Warfare
Fall: 9 units
A historical survey of the development of amphibious doctrine and the conduct of amphibious operations. Emphasis is placed on the evolution of amphibious warfare in the twentieth century, especially during World War II. Focus is applied to four main themes: political/strategic situation, sea-to-land transitions, tactics ashore, and development of amphibious technology. Present day potential and limitations on amphibious operations, including the rapid deployment force concept, are explored.

32-411 Naval Operations and Seamanship
Fall: 9 units
Designed as an introduction to naval operations and shipboard evolutions, vessel behavior and characteristics in maneuvering, applied aspects of ship handling, and afloat communications. This course builds upon the information presented in Navigation 32-212, Engineering 32-311, and Weapons Systems 32-312. An understanding of the nautical rules of the road, relative motion and vector analysis are utilized in discussion regarding the conduct of naval operation to include formation tactics and ship employment. The student will also be introduced to the various components of naval warfare and their role in sea control and power projection missions within naval and joint operations.

Degrees Offered

With cutting-edge brain science, path-breaking performances, innovative start-ups, driverless cars, big data, big ambitions, Nobel and Turing prizes, hands-on learning, and a whole lot of robots, CMU doesn't imagine the future, we create it. Carnegie Mellon offers a wide range of programs in seven schools and colleges, and has consistently ranked high in a number of disciplines (https://www.cmu.edu/about).

To browse the primary degrees offered , select a school or college below. For a list of minors, please see Undergraduate Options (p. 25).

College of Engineering

Interdepartmental

- M.S. in Energy Science, Technology and Policy
- M.S. in Energy Science, Technology and Policy (Applied Studies)
- M.S. in Energy Science, Technology and Policy and Integrated Study in Computer Science
- M.S. in Engineering and Technology Innovation Management

Biomedical Engineering

- B.S. in an engineering discipline with an additional major in Biomedical Engineering (p. 84)
- M.S. in Biomedical Engineering
- M.S. in Biomedical Engineering and Integrated Study in Computer Science
- Ph.D. in Biomedical Engineering
- Ph.D. in Biomedical Engineering and Engineering and Public Policy

Chemical Engineering

- B.S. in Chemical Engineering (p. 95)
- M. of Chemical Engineering
- M. of Chemical Engineering & Colloids, Polymers and Surfaces
- M.S. in Chemical Engineering
- M.S. in Chemical Engineering and Colloids, Polymers and Surfaces
- M.S. in Chemical Engineering and Integrated Study in Computer Science
- M.S. in Colloids, Polymers and Surfaces
- Ph.D. in Chemical Engineering

Civil and Environmental Engineering

- B.S. in Civil Engineering (p. 102)
- M.S. in Advanced Infrastructure Systems
- M.S. in Civil Engineering
- M.S. in Civil and Environmental Engineering
- M.S. in Civil & Environmental Engineering and Integrated Study in Computer Science
- M.S. in Civil and Environmental Engineering/M. of Business Administration (jointly with the Tepper School of Business)
- M.S. in Computational Mechanics
- M.S. in Environmental Engineering
- M.S. in Environmental Management and Science
- Ph.D. in Advanced Infrastructure Systems
- Ph.D. in Civil Engineering
- Ph.D. in Civil and Environmental Engineering
- Ph.D. in Civil and Environmental Engineering and Engineering and Public Policy (jointly with the Department of Engineering and Public Policy)
- Ph.D. in Computational Mechanics
- Ph.D. in Environmental Engineering
- Ph.D. in Environmental Management and Science

Electrical and Computer Engineering

- B.S. in Electrical and Computer Engineering (p. 110)
- B.S. in Music and Technology (jointly with the Department of Music and the School of Computer Science)
- M.S. in Electrical and Computer Engineering
- M.S. in Electrical & Computer Engineering and Integrated Study in Computer Science
- M.S. in Software Engineering (Silicon Valley Campus)
- Master of Science in Software Engineering - Development Management (Silicon Valley Campus)
- Ph.D. in Electrical and Computer Engineering

Engineering and Public Policy

- B.S. in an engineering discipline with an additional major in Engineering and Public Policy (p. 125)
- B.S. in CFA, DC, MCS, or SCS and an additional major in Science, Technology and Public Policy (p. 126)
- M.S. in Engineering and Public Policy
- Ph.D. in Engineering and Public Policy
- Ph.D. in Engineering and Public Policy and an engineering discipline
- Ph.D. in Engineering & Public Policy and Language & Information Technologies
- Ph.D. in Engineering and Public Policy and Statistics (jointly with the Department of Statistics)

Information and Communication Technology

- M.S. in Information Technology (CMU Africa campus only)

Information Networking Institute

- M.S. in Information Networking
- M.S. in Information Security
- M.S. in Information Technology - Information Security
- M.S. in Information Technology - Mobility
- M.S. in Information Technology - Software Management

Materials Science and Engineering

- B.S. in Materials Science and Engineering (p. 138)
- M.S. in Additive Manufacturing
- M.S. in Computational Materials Science and Engineering
- M.S. in Materials Science
- M.S. in Materials Science and Engineering
- M.S. in Materials Science & Engineering and Integrated Study in Computer Science
- Ph.D. in Materials Science
- Ph.D. in Materials Science and Engineering

Mechanical Engineering

- B.S. in Mechanical Engineering (p. 151)
- M.S. in Computational Design and Manufacturing
- M.S. in Mechanical Engineering
- M.S. in Mechanical Engineering - Advanced Study
- M.S. in Mechanical Engineering - Research
- Ph.D. in Mechanical Engineering

College of Fine Arts

Architecture

- B. of Architecture (p. 191) (5-year program)
- B.A. in Architecture
- M. of Advanced Architectural Design
- M. of Architecture
- M.S. in Architecture
- M.S. in Building Performance and Diagnostics
- M.S. in Computational Design
- M.S. in Sustainable Design
- M.S. in Sustainable Design (Advanced Studies)
- M.S. in Sustainable Design (Applied Studies)
- M. of Tangible Interaction Design
- M. of Urban Design
- D. of Professional Practice in Advanced Architectural Design
- D. of Professional Practice in Architecture

- Ph.D. in Architecture
- Ph.D. in Building Performance and Diagnostics
- Ph.D. in Computational Design

Art

- B.F.A. in Art (p. 208)
- M.F.A. in Art

Design

- B. of Design (p. 220)
- M.A. in Design
- M. of Design in Design for Interactions
- M. of Design in Interaction Design
- M. of Professional Studies in Design for Interactions
- D. of Design
- Ph.D. in Communication De
- Ph.D. in Design

Drama

- B.F.A. in Drama (p. 238)
- M.F.A. in Costume Design
- M.F.A. in Costume Production
- M.F.A. in Directing
- M.F.A. in Dramatic Writing
- M.F.A. in Lighting Design
- M.F.A. in Scene Design
- M.F.A. in Sound Design
- M.F.A. in Stage and Production Management
- M.F.A. in Technical Direction
- M.F.A. in Video and Media Design

Music

- B.F.A. in Music (Composition) (p. 267)
- B.F.A. in Music Performance (p. 267) (various disciplines)
- B.S. in Music and Technology (p. 271) (jointly with the Department of Electrical and Computer Engineering and the School of Computer Science)
- M. Music in Composition
- M. Music in Music Education
- M. Music in Performance (various disciplines)
- M.S. in Music and Technology (jointly with the Department of Electrical and Computer Engineering and the School of Computer Science)

Dietrich College of Humanities and Social Sciences

Interdepartmental

- B.S. in Economics and Mathematical Sciences (p. 515) (jointly offered by the Undergraduate Economics Program and the Department of Mathematical Sciences)
- B.S. in Economics and Politics (p. 305) (jointly offered by the Undergraduate Economics Program and Institute for Politics and Strategy)
- B.S. in Economics and Statistics (p. 515) (jointly offered by the Department of Statistics and Data Science and the Undergraduate Economics Program)
- B.A./B.S.in Ethics, History, and Public Policy (p. 518) (jointly offered by the Departments of History and Philosophy)
- B.S. in Information Systems (p. 384)
- B.A. in Linguistics (p. 520) (jointly offered by the Departments of English, Modern Languages, Philosophy, and Psychology)
- B.S. in Neuroscience (p. 786) (jointly offered by the Department of Biological Sciences and the Center for the Neural Basis of Cognition)
- B.S. in Psychology and Biological Sciences (p. 520) (jointly offered by the Departments of Psychology and Biological Sciences)
- B.S. in Statistics and Machine Learning (p. 500) (jointly offered by the Department of Statistics and Data Science and the School of Computer Science)

Center for the Neural Basis of Cognition

- Ph.D. in Neural Computation
- Ph.D. in Neural Computation and Machine Learning
- Ph.D. in Neural Computation and Statistics

Economics (jointly offered by Dietrich College and Tepper School of Business unless otherwise noted)

- B.A. in Economics (p. 302)
- B.S. in Economics (p. 303)
- Ph.D. in Economics (Tepper only)
- Ph.D. in Economics and Public Policy (Tepper only, jointly with Heinz College)

English

- B.A. in Creative Writing (p. 316)
- B.A. in Film and Visual Media (p. 317)
- B.A. in Literature and Culture (p. 318)
- B.A. in Professional Writing (p. 319)
- B.S. in Technical Writing and Communication (p. 321)
- M.A. in Global Communication and Applied Translation
- M.A. in Literary and Cultural Studies
- M.A. in Professional Writing
- M.A. in Rhetoric
- Ph.D. in Literary and Cultural Studies
- Ph.D. in Rhetoric

History

- B.A. in Global Studies (p. 359)
- B.A./B.S. in Social and Political History (p. 357)
- M.A. in History
- Ph.D. in History

Modern Languages

- B.A. in Chinese Studies (p. 409)
- B.A. in French and Francophone Studies (p. 411)
- B.A. in German Studies (p. 412)
- B.A. in Hispanic Studies (p. 413)
- B.A. in Japanese Studies (p. 415)
- B.A. in Russian Studies (p. 416)
- M.A. in Applied Second Language Acquisition
- M.A. in Second Language Acquisition
- Ph.D. in Second Language Acquisition

Philosophy

- B.A. in Philosophy (p. 449)
- B.S. in Logic and Computation (p. 448)
- M.A. in Philosophy
- M.S. in Logic, Computation and Methodology
- Ph.D. in Logic, Computation and Methodology
- Ph.D. in Philosophy
- Ph.D. in Pure and Applied Logic

Politics and Strategy

- B.S. in International Relations and Politics (p. 393)
- M.S. in International Relations and Politics

Psychology

- B.A./B.S. in Psychology (p. 466)
- B.S. in Cognitive Science (p. 469)
- Ph.D. in Cognitive Neuroscience
- Ph.D. in Psychology
- Ph.D. in Psychology and Behavioral Decision Research (jointly with the Department of Social and Decision Sciences)

Social and Decision Sciences

- B.A. in Behavioral Economics, Policy, and Organizations (p. 482)
- B.S. in Decision Science (p. 483)
- B.S. in Policy and Management (p. 485)
- M.S. in Behavioral Decision Research
- M.S. in Social and Decision Sciences
- Ph.D. in Behavioral Decision Research
- Ph.D. in Behavioral Economics (jointly with Tepper School of Business)
- Ph.D. in Behavioral Marketing and Decision Research (jointly with Tepper School of Business)
- Ph.D. in Psychology and Behavioral Decision Research (jointly with the Department of Psychology)
- Ph.D. in Social and Decision Sciences

Statistics and Data Science

- B.S. in Statistics (p. 495)
- B.S. in Statistics (Mathematical Sciences Track)
- B.S. in Statistics (Statistics and Neuroscience Track)
- B.S. in Statistics and Machine Learning (p.)
- M. of Statistical Practices
- Ph.D. in Neural Cognition and Statistics (jointly with the Center for the Neural Basis of Cognition)
- Ph.D. in Statistics
- Ph.D. in Statistics and Engineering and Public Policy (jointly with the Department of Engineering and Public Policy)
- Ph.D. in Statistics and Machine Learning (jointly with the Department of Machine Learning)
- Ph.D. in Statistics and Public Policy (jointly with the Heinz College)

H. John Heinz III College

School of Information Systems & Management

Information Security

- M.S. in Information Security Policy and Management

Information Systems

- M. of Information Systems Management
- M. of Information Systems Management in Business Intelligence and Data Analytics
- Ph.D. in Information Systems and Management

Information Technology

- M.S. in Information Technology (Business Intelligence and Data Analytics)
- M.S. in Information Technology (IT Management)
- M.S. in Information Technology (Information Security and Assurance)
- M.S. in Information Technology (Software Design and Management)

School of Public Policy & Management

Arts Management

- M. of Arts Management (jointly with the College of Fine Arts)
- M. of Arts Management (jointly with the College of Fine Arts) and Graduate Degree in Innovation and Organization of Culture and the Arts (jointly with the University of Bologna's School of Economics)
- M. of Arts Management (jointly with the College of Fine Arts) and J.D. (jointly with the University of Pittsburgh School of Law)

Entertainment Industry Management

- M. of Entertainment Industry Management (jointly with the College of Fine Arts)

Health Care Policy and Management

- M.S. in Health Care Analytics and Information Technology
- M.S. in Health Care Policy and Management
- M.S. in Health Care Policy and Management and M.B.A. (jointly with Tepper School of Business)

Medical Management

- M. of Medical Management

Public Management

- M. of Public Management

Public Policy and Management

- M.S. in Public Policy and Management
- M.S. in Public Policy and Management (Data Analytics)
- M.S. in Public Policy and Management and M.B.A. (jointly with Tepper School of Business)
- M.S. in Public Policy and Management and J.D. (jointly with the University of Pittsburgh School of Law)
- M.S. in Public Policy and Management and M. of Divinity (jointly with the Pittsburgh Theological Seminary)
- Ph.D. in Economics and Public Policy (jointly with the Tepper School of Business)
- Ph.D. in Machine Learning and Public Policy (jointly with the School of Computer Science)
- Ph.D. in Public Policy and Management
- Ph.D. in Statistics and Public Policy (jointly with Dietrich College of Humanities and Social Sciences)

Adelaide, South Australia Campus

- M.S. in Information Technology
- M.S. in Public Policy and Management

Mellon College of Science

Interdepartmental

- Ph.D. in Molecular Biophysics and Structural Biology

Biological Sciences

- B.A. in Biological Sciences (p. 547)
- B.S. in Biological Sciences (p. 544)
- B.S. in Biological Sciences/Neuroscience Track (p. 546)
- B.S. in Biological Sciences and Psychology (p. 547) (jointly with the Department of Psychology)
- B.S. in Neuroscience (p. 547) (jointly with the Department of Psychology)
- M.S. in Biological Sciences
- Ph.D. in Biological Sciences

Chemistry

- B.A. in Chemistry (p. 564)
- B.S. in Chemistry (p. 562)
- B.S. in Chemistry/Biological Chemistry Track (p. 566)
- M.S. in Chemistry
- M.S. in Colloids, Polymers, and Surfaces (jointly with the Department of Chemical Engineering)
- Ph.D. in Chemistry

Mathematical Sciences

- B.S. in Mathematical Sciences (p. 584)
- M.S. in Algorithms, Combinatorics, and Optimization
- M.S. in Mathematical Sciences
- M.S. in Computational Finance (jointly with the Department of Statistics, the H. John Heinz III College, and the Tepper School of Business)
- D.A. in Mathematical Sciences
- Ph.D. in Algorithms, Combinatorics, and Optimization
- Ph.D. in Mathematical Finance
- Ph.D. in Mathematical Sciences
- Ph.D. in Pure and Applied Logic (jointly with the Department of Philosophy and the School of Computer Science)

Physics

- B.A. in Physics (p. 605)
- B.S. in Physics (p. 603)

- M.S. in Physics
- Ph.D. in Applied Physics
- Ph.D. in Physics

School of Computer Science

SCS College-Wide

- B.S. in Artificial Intelligence (p. 633)

Computer Science

- B.S. in Computer Science (p. 639) (jointly with the Institute for Software Research)
- B.S. in Music and Technology (p. 271) (jointly with the Departments of Electrical and Computer Engineering and Music)
- M.S. in Computer Science
- M.S. in Computer Science - Foundational Studies
- M.S. in Computer Science - Research
- M.S. in Computer Science - Research Thesis
- M.S. in Computer Science (5th Year Scholars Program only)
- Ph.D. in Algorithms, Combinatorics and Optimization (jointly with the Department of Mathematical Sciences and Tepper School of Business)
- Ph.D. in Computer Science
- Ph.D. in Pure and Applied Logic (jointly with the Department of Mathematical Sciences and the Department of Philosophy)

Computational Biology Department

- B.S. in Computational Biology (p. 636)
- M.S. in Automated Science - Biological Experimentation
- M.S. in Computational Biology
- Ph.D. in Computational Biology

Human-Computer Interaction

- M. of Human-Computer Interaction
- M. of Human-Computer Interaction (5th Year Scholars Program only)
- M. of Educational Technology & Applied Learning Sciences (jointly with the Dietrich College of Humanities and Social Sciences)
- M.S. in Product Management (jointly with Tepper School of Business)
- Ph.D. in Human-Computer Interaction

Institute for Software Research

- M. of Software Engineering in Embedded Systems
- M. of Software Engineering in Scalable Systems
- M. of Software Engineering in Software Engineering
- M.S. in Information Technology - Privacy Engineering
- Ph.D. in Societal Computing
- Ph.D. in Software Engineering

Language Technologies Institute

- M.S. in Artificial Intelligence and Innovation
- M.S. in Intelligent Information Systems
- M.S. in Intelligent Information Systems - Advanced Study
- M.S. in Language Technologies
- M. of Computational Data Science
- Ph.D. in Language and Information Technologies

Machine Learning

- M.S. in Machine Learning
- M.S. in Machine Learning (5th Year Scholars Program only)
- Ph.D. in Machine Learning
- Ph.D. in Machine Learning & Public Policy (jointly with the Heinz College)
- Ph.D. in Neural Computation and Machine Learning (jointly with Center for Neural Basis of Cognition)
- Ph.D. in Statistics and Machine Learning (jointly with the Dietrich College of Humanities and Social Sciences)

Robotics Institute

- M.S. in Computer Vision
- M.S. in Robotics
- M.S. in Robotics (5th Year Scholars Program only)
- M.S. in Robotic Systems Development
- Ph.D. in Robotics

David A. Tepper School of Business

Business Administration

- B.S. in Business Administration (p. 743)

Economics (jointly with Dietrich College of Humanities and Social Sciences)

- B.A. in Economics (p. 762)
- B.S. in Economics (p. 763)
- B.S. in Economics and Mathematical Sciences (p. 764) (jointly offered by Dietrich College, the Department of Mathematical Sciences, and Tepper School of Business)
- B.S. in Economics and Politics (p. 305) (jointly offered by the Undergraduate Economics Program and Institute for Politics and Strategy)
- B.S. in Economics and Statistics (p. 767) (jointly offered by the Tepper School of Business and the Department of Statistics and Data Science)

Industrial Administration

- M. of Business Administration (M.B.A.)
- M.B.A./M.S. in Public Policy Management (jointly with Heinz College)
- M.B.A./M.S. in Civil and Environmental Engineering (in association with Carnegie Institute of Technology)
- M.B.A. and J.D. in Law (jointly with the University of Pittsburgh Law School)
- M.B.A/M.S. in Health Care Policy Management (jointly with Heinz College)
- M.B.A/M.S in Software Engineering (jointly with the School of Computer Science)
- M.S. in Business Analytics
- M.S. in Computational Finance (jointly with Dietrich College, the Mellon College of Science, and Heinz College)
- M.S. in Product Management
- Ph.D. in Accounting
- Ph.D. in Algorithms, Combinatorics, and Optimization (jointly with the School of Computer Science and Department of Mathematical Sciences)
- Ph.D. in Economics
- Ph.D. in Finance
- Ph.D. in Information Systems
- Ph.D. in Management of Manufacturing and Automation (with Robotics Institute)
- Ph.D. in Marketing
- Ph.D. in Operations Management and Manufacturing
- Ph.D. in Operations Research
- Ph.D. in Organizational Behavior and Theory
- Ph.D. in Economics and Public Policy (jointly with Heinz College)
- Ph.D. in Strategy, Entrepreneurship, and Technological Change (jointly with the Department of Social and Decision Sciences, Heinz College, and the Department of Engineering and Public Policy)

University-Wide, Interdisciplinary, and Joint Degree Programs

Architecture-Engineering-Construction Management Program

- M.S. in Architecture-Engineering-Construction Management (jointly with the Department of Civil and Environmental Engineering and the School of Architecture)
- Ph.D. in Architecture-Engineering-Construction Management (jointly with the Department of Civil and Environmental Engineering and the School of Architecture)

BXA Intercollege Degree Programs

- B. of Computer Science and Arts (p. 791) (jointly with the School of Computer Science and the College of Fine Arts)
- B. of Humanities and Arts (p. 795) (jointly with the Dietrich College of Humanities and Social Sciences and the College of Fine Arts)
- B. of Science and Arts (p. 815) (jointly with the Mellon College of Science and the College of Fine Arts)
- B.S. in an engineering discipline with an additional major in Engineering and Arts (p. 820) (jointly with the College of Engineering and College of Fine Arts)

Communication Planning and Information Design Program

- M. Design in Communication Planning and Information Design (jointly with the School of Design and the Department of English)

Computational Finance Program

- B.S. in Computational Finance (p. 781) (jointly with the Dietrich College of Humanities and Social Sciences, Heinz College, Mellon College of Science and Tepper School of Business)
- M.S. in Computational Finance (jointly with the Dietrich College of Humanities and Social Sciences, Heinz College, Mellon College of Science and Tepper School of Business)

Entertainment Technology Center

- M. of Entertainment Technology

Integrated Innovation Institute

- M. of Integrated Innovation for Products and Services
- M. of Integrated Innovation for Products and Services - Advanced Study
- M.S. in Software Management (Silicon Valley campus)
- M.S. in Technology Ventures

Science and Humanities Scholars Program

- B.A./B.S. in various disciplines (p.) (jointly with the Dietrich College of Humanities and Social Sciences and the Mellon College of Science)

Carnegie Mellon University in Qatar

Qatar Biological Sciences

- B.S. in Biological Sciences

Qatar Business Administration

- B.S. in Business Administration

Qatar Computer Science

- B.S. in Computer Science
- B.S. in Computational Biology

Qatar Information Systems

- B.S. in Information Systems

Schools/Colleges

The intersection of fields is a Carnegie Mellon University specialty. Renowned faculty at the university's seven schools/colleges explore side by side with students, collaborating on research, tackling society's biggest challenges and delivering work that matters. In addition to the hundreds of programs offered by the schools and colleges, CMU also offers dozens of interdisciplinary programs (p. 781), which are designed especially for students who want to work beyond just one discipline.

College of Engineering

Jonathan Cagan, Interim Dean, George Tallman and Florence Barrett Ladd Professor

Annette M. Jacobson, Associate Dean for Undergraduate Studies

Kurt Larsen, Assistant Dean for Undergraduate Studies

Treci Bonime, Assistant Dean for Undergraduate Studies

Location: Scaife Hall 110
https://engineering.cmu.edu

Carnegie Institute of Technology (CIT), the engineering college of the university, has three main activities - undergraduate education, graduate education, and research. Its continuing goal has been to maintain excellence in all these activities. The degree to which this goal has been achieved is attested to by the demand for its graduates, the success of its alumni, the quality of its students and faculty, the adoption elsewhere of its innovations, and the national and international recognition it receives in educational and research activities.

The college offers the degree of bachelor of science in chemical engineering, civil engineering, electrical and computer engineering, mechanical engineering, and materials science and engineering.
All of these programs are accredited by ABET, www.abet.org (http://www.abet.org).

An engineering student may also choose to pursue a minor in one of the CIT designated minor programs, or a double major in engineering and public policy or biomedical engineering, or to design a minor, additional major or dual-degree programs with other non-engineering departments.

Educational Objectives

The overarching objective of our engineering curriculum is to provide our students an education that enables them to be productive and fulfilled professionals throughout their careers. Our more specific, measurable objectives for graduates of our engineering curriculum are the following:

- Graduates recognize that they acquired a high quality, rigorous technical education from the College of Engineering at Carnegie Mellon.
- Graduates, in addition to their technical knowledge, recognize that they have acquired a broader body of knowledge that allows them to understand the larger context of the problems that they must address during their career.
- Graduates use their technical foundation and their broader base of knowledge to be successful in a diverse collection of individual careers inside and outside of the engineering profession.

From its earliest days, Carnegie Institute of Technology (CIT) has considered undergraduate education to be the key element in the development of future leaders. In this regard, CIT has adopted a plan for education that is designed to equip students with the capacity to learn and to continue the process of self-education throughout their lives. The present curriculum incorporates this philosophy by providing the opportunity for both breadth in a number of engineering, science, humanities and fine arts areas as well as depth in a major area of concentration. To achieve these goals, our flexible curriculum has been designed to allow students to customize their program to suit their needs and to help each student acquire:

- A thorough and integrated understanding of fundamental knowledge in fields of a students' major interest and the ability to use this knowledge;
- Competence in the orderly way of thinking, which professionals and scientists have always used in reaching sound, creative conclusions, with the goal that after graduation the student can, by such thinking, reach decisions both as a professional and as a citizen;
- An ability to learn independently with scholarly orderliness, so that after graduation the student will be able to grow in wisdom and keep abreast of the changing knowledge and problems of the profession and the society in which he or she participates;
- The philosophical outlook, breadth of knowledge, and sense of values which will increase the student's understanding and enjoyment of life and enable each student to recognize and deal effectively with the human, economic, ethical and social aspects of professional problems; and
- The ability to communicate ideas to others in a comprehensive and understandable manner.

The curriculum encourages students to confront professional problems, accomplished through team and problem-oriented courses, as well as courses which emphasize design or individual projects. These classes stress creativity and independent thought and require the student to define the problem, propose a solution or a design in the presence of technical and socioeconomic constraints, to make judgments among alternative solutions, and to explore innovative alternatives to more conventional solutions.

First Year for Engineering Students

The Carnegie Mellon engineering education is based on engineering and science fundamentals that give students the skills to face new and challenging situations. The first year in engineering provides a broad foundation upon which students build a curriculum in their eventual major. Since students in CIT do not select a major until the end of the first year, all first year students share a common experience consisting of introductory courses in the engineering majors (one each semester), calculus, physics, other science courses which complements specific introductory engineering courses, and courses in the liberal arts, fine arts, business, and social sciences. This curriculum helps make an informed decision about a final major. Below is an examples of a standard schedule for a first-year engineering student.

Fall Semester	
Introductory Engineering Elective	12
Restricted Technical Elective	9-12
Differential and Integral Calculus	10
General Education	9
Computing @ Carnegie Mellon	3

Spring semester	
Introductory Engineering Elective	12
Restricted Technical Elective	10
Integration, Differential Equations, Approximation	10
General Education Course	9

Notes:

1. Each semester every CIT department offers its Introductory Engineering Elective. Every first year CIT student must select one such course each semester.

2. Each Introductory Engineering Elective requires a specific Restricted Technical Elective (as a pre- or co-requisite) as given below:

Introductory Engineering Course	**Restricted Technical Elective**
Biomedical Engineering	**03-121**
Chemical Engineering	**09-105**
Civil & Environmental Engineering	**33-141**
Electrical & Computer Engineering	**15-110 or 15-112**
Engineering & Public Policy	**33-141**
Mechanical Engineering	**33-141**
Materials Science & Engineering	**33-141**

3. All students must complete 33-141 Physics I for Engineering Students by the end of the first year. Therefore, if a student chooses to take Introduction to Chemical Engineering (with 09-105 as a co-requisite) during one semester and Introduction to Electrical and Computer Engineering (with 15-110 as a co-requisite), the student must take 33-141 in place of the General Education requirement in the Spring semester of the first year and take the General Education course in a subsequent semester. Alternatively, a student entering the university with AP credit in a required first year course may substitute 33-141 in its place.
4. CIT students must complete the First-Year Writing requirement in their freshman year. View more information (p. 77).

General Education Programs

The environment in which today's engineering graduates will find themselves working is evolving rapidly. Technical innovation is becoming ever more critical to retaining a competitive edge. This is true for individuals, for firms and for nations. Start-ups, as well as established companies, have significant international opportunities but also face more competition in a global economy. Seizing these opportunities and dealing with the associated challenges requires an understanding of the global context in which engineers work, as well as understanding multi-disciplinary approaches to technological innovation across cultures.

The College of Engineering has developed General Education Requirements designed to ensure that our students are ready to work effectively in the global economy, and become the innovators and leaders of tomorrow.

Classes of 2021 - Later

All requirements for 2021+ remain the same as 2016-2020 except the following changes:

All undergraduate students must complete the First-Year Writing requirement — **the Department of English does not accept any Advanced Placement exemptions.** This requirement can be completed in two different ways:

Option 1: Enroll in one of two full-semester courses (9 units each)
76-101 Interpretation and Argument (Students for whom English is a second language may need to take 76-100 Reading and Writing in an Academic Context first. The English department will contact those students.)
76-102 Advanced First Year Writing: Special Topics: (by invitation only)

Option 2: Enroll in two of three half-semester "mini" courses* (4.5 units each)
76-106 Writing about Literature, Art and Culture:
76-107 Writing about Data
76-108 Writing about Public Problems

*Minis should be completed back-to-back within a single semester.

General Education Electives (3 total)

At least 27 units from any non-technical academic courses from the Dietrich College, College of Fine Arts, and the Tepper School of Business excluding those listed on the General Education Exclusions page (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/exclusions.html). Courses from this list of non-technical courses outside of the Dietrich College or the College of Fine Arts (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/non-dietrich-cfa-courses.html#undefined) may also be counted. **A maximum of 18 units of these units may be fulfilled via AP/IB/Cambridge exam credit.**

For category course lists reference the CIT General Education website (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education).

Classes of 2016 - 2020

Complete the following requirements to graduate (72 units):

1. 76-101 Interpretation and Argument (some students may need to take 76-100 first)
2. One course from the following list:

73-230	Intermediate Microeconomics	9
84-104	Decision Processes in American Political Institutions	9
85-102	Introduction to Psychology	9
79-104	Global Histories	9
one other PPC or SDM course (defined below) or a 100-level Modern Language course		

Students must complete each of the categories (descriptions of categories follow below). **This is a 9-unit requirement. Any course taken on this list that is below 9 units must be combined with an additional course to total at least 9 units in order to complete this requirement.**

Note that the units from one course cannot be split to count for two General Education categories (eg PPC and General Education Elective).

- **Innovation & Internationalization (I&I)**
  - 9 units from the I&I list of courses (which could be two 4.5 unit courses);
- **Peoples, Places, and Cultures (PPC)** [1]
  - 9 units from the PPC list; or a 9-12 unit course in a modern language at the 200+ level (Students can receive exemption through an approved study abroad program. These students would have three General Education Electives to complete instead of two.)
- **Social Analysis and Decision Making (SDM)**
  - 9 units from the SDM list of courses (which could be two 4.5 unit courses)
- **Writing and Expression (W&E)**
  - 9 units from the W&E list of courses (in addition to 76-101)
- **General Education Electives (2 total)**
  - At least 18 units (any combination) from the four categories: I&I, PPC, SDM or W&E, or non-technical academic courses (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/non-dietrich-cfa-courses.html) from the Dietrich College or the College of Fine Arts excluding those listed on the CIT website under General Education Exclusions (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/exclusions.html).

Experiential Learning (EL)

- 6 EL points by participating in a variety of approved activities in the following timeframe:
  - 2 points sophomore fall semester (39-210)
  - 2 points sophomore spring semester (39-220)
  - 2 points junior fall semester (39-310)

Category Descriptions

People, Places and Cultures (PPC)

PPC courses are designed to help you gain better understanding of the diversity of the world in which we live, and the way in which societal factors interact to shape that world.

Social Analysis and Decision Making (SDM)

SDM courses are focused on helping you to gain an understanding of different ways in which individuals and societies approach and make decisions.

Innovation and Internationalization (I&I)

I&I courses are intended to provide a broad perspective regarding the creation of pioneering ideas and their outcomes in a global context.

Experiential Learning (EL)

Being curious and constantly looking for inspiration are critical parts of lifelong learning. To be successful as an engineer and as a citizen, your education must not stop when you graduate from Carnegie Mellon. The EL requirement aims to encourage a habit of lifelong learning about innovation and the growing internationalization in engineering and, indeed of many other aspects of the modern world. The goal of this requirement is to help inspire the habits of being open to new ideas as successful, innovative engineers.

To do that, during both semesters of your sophomore year, and the first semester of your junior year, we require you to choose a few related activities that are not part of your formal course work. Examples could include:

- Attending approved seminars and then submitting a one page write up of your thoughts on what you heard;
- Holding an official leadership position (i.e., President, Vice President, Secretary, Treasurer) in a Carnegie Mellon sponsored organization

Additional Majors and Dual Degrees in CIT

A major is defined as a program that must be completed for the granting of a degree. Additional majors comprise a single degree with majors in two separate areas; for example, the degree of Bachelor of Science in Chemical Engineering and an additional major in English. Although the additional major requires the completion of two designated programs, they may have overlapping requirements that can be met simultaneously. The general principle used to measure eligibility for a Carnegie Institute of Technology additional major is that the major (core) requirements of both departments must be completed. Finally, although the student is formally enrolled as an undergraduate in one of the departments (the parent department, which is responsible for scheduling and other administrative actions for the student), the student should apply for the additional major through the second department and coordinate requirements with both departments.

The additional major is to be distinguished from a dual degree program, which results in two separate bachelor's degrees; for example, Bachelor of Science in Chemical Engineering and a Bachelor of Arts in English. The dual degree, though, requires a minimum of 90 units of work in addition to the units required for the first degree. The second degree may be earned in Bachelor of Science or Bachelor of Arts degree programs.

Requirements for students wishing to complete Additional Majors in CIT

Note: This applies to **all** students.

The student must satisfactorily pass all requirements of the regular and complete program (with the permissible exceptions) leading to a degree in CIT. The minimum number of units required for the additional major is the number required by the parent department or major.

The student takes and satisfactorily completes the courses specified by a second department, usually using elective space available in the first program.

The second department, on the basis of the specified number of courses plus the courses comprising the parent department's regular degree requirements, then certifies that the student has completed the requirements for a major in the second department.

Equivalent technical electives may be substituted at the discretion of the departments/colleges.

Non-technical courses in the curricula can be used to meet the requirements of the second major. But if the second major is not a Dietrich College department, the program must include a minimum of 72 units of General Education courses to meet CIT requirements for graduation.

Designated Minors Offered by CIT

(for engineering students)

Undergraduate students in the Carnegie Institute of Technology (CIT) can elect to complete an interdisciplinary Designated Minor in addition to their primary major. Designated minors have been added to the curriculum to provide the student with technical elective content in areas related to the research expertise of our faculty. Students may select a designated minor from the following list:

- Audio Engineering
- Automation and Control
- Biomedical Engineering*
- Colloids, Polymers and Surfaces
- Electronic Materials
- Global Engineering
- Manufacturing Engineering
- Material Science and Engineering
- Mechanical Behavior of Materials

* Also available for non-CIT students

Complete descriptions of the designated minors can be found at CIT Designated Minors (http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/undergraduatedesignatedminors/.html).

To declare a CIT Designated Minor, please contact the director listed for each minor.

Minors for Non-Engineering Students

Students in a non-engineering discipline can also declare certain CIT minors:

- Biomedical Engineering
- Engineering Studies
- Technology and Policy

A full listing of curriculum for these minors when taken by non-engineering students can be found at CIT Minors for Non-Engineering Students (p. 163).

Academic Standards

Grading Practices

For undergraduate grading regulations, please see Undergraduate Academic Regulations (p. 29).

CIT Dean's Honor List

Each semester, Carnegie Institute of Technology recognizes students who have earned outstanding academic records by naming them on the dean's honor list. The criterion for such recognition is a semester quality point average of at least 3.75 while completing at least 36 factorable units and earning no incomplete grades.

Transfer into CIT Departments

Undergraduate students admitted to colleges other than CIT who wish to transfer into a CIT department during their first year should consult with an advisor in the Undergraduate Studies Office in the CIT Dean's Office. Students admitted to CIT but excluded from certain departments must also consult with the CIT Dean's Office if they wish to transfer into a restricted CIT department.

First-year students can apply for transfer after mid-semester grades for the spring semester have been posted. At that time, a decision will be based on availability of space and the student's academic performance.

CIT undergraduate students beyond the first year wishing to transfer into another CIT department may apply if they are in good academic standing and if there is room in the department of their choice. If the demand for any department exceeds the space available, then the department will admit students based on a comparative evaluation of all applicants at the end of each semester, up to the limit of available space.

Undergraduate students not in CIT who wish to transfer into a CIT department beyond the first year will be considered for transfer on a rolling space available/academic performance basis.

Criteria for all applicants include space in the department, good academic standing, and successful completion of or being currently enrolled in at least one introductory to engineering course (minimally the one of the target major), the appropriate science co-requisite, math (21-120, 21-122) and Physics 1 (33-141, 33-111, or 33-131).

Procedure for transfer of students from another university into CIT departments: A student first applies through the Office of Admission. If the Office of Admission believes the applicant is acceptable, the student's record is sent to the CIT Undergraduate Studies Office for evaluation and a decision on acceptance/rejection is made in consultation with the target department.

Academic Actions

In order to maintain good academic standing, CIT students must attain at least minimum quality point averages for each semester (as well as cumulatively) and also maintain adequate progress toward completing graduation requirements. Minimum quality point averages for good academic standing are 1.75 each semester in the freshman year and 2.00 thereafter. "Adequate academic progress towards graduation" generally means that students are successfully completing approximately 45-55 units per semester so that at the end of eight semesters they will have accumulated the minimum units required for graduation, have a cumulative QPA of at least 2.00, and have completed all degree requirements.

When a student fails to meet minimum performance criteria, it normally results in an academic action. Depending on the circumstances, one of the following actions is taken: academic probation, continued probation, suspension, or drop. These academic actions are recommended by the college's departments, based on the guidelines described below, and adjudicated by the CIT Undergraduate Studies Office. However, the sequence of the academic actions is not automatic in all cases. Decisions may be based on unique individual student performance and circumstances, and are not determined solely on the basis of grades and quality point averages.

Probation

A student is on academic probation when performance either for the semester or cumulatively fails to meet the minimum standard. The term of academic probation is one semester, and signifies to the student the college's insistence that academic performance return to at least the minimum acceptable level. A student is removed from academic probation and returned to good academic standing when both the semester and cumulative quality point averages meet at least the stated minimum, and when adequate academic progress* toward completing graduation requirements is being made.

A first-year student who earns fewer than 27 units per semester, or who has a semester grade point average below 1.75 for either the first or second semester will be placed on academic probation*.

A student in the third or subsequent semester, who earns fewer than 27 units per semester or fewer than 108 units over three consecutive semesters (excluding summers) or who has a semester grade point average below 2.00 will be placed on academic probation*.

Probation Continued

A student who is currently on probation but whose record indicates that the standards are likely to be met by the end of the next semester may be continued on probation at the discretion of the associate dean.

Suspension

A first year student on probation, who earns a semester grade point average below 1.75 or completes less than 27 units for that probationary semester will be suspended*.

A student on probation in the third or subsequent semester, who earns a semester grade point average below 2.00, fewer than 27 units per semester for that probationary semester or fewer than 108 units over the last three consecutive semesters (excluding summers) will be suspended*.

The typical period of academic suspension is two semesters, during which a student on academic suspension is expected to reflect on the circumstances leading up to the suspension, identify the issues that prevented achieving academic success, take actions that address these issues, demonstrate sufficient readiness to return to the university and successfully resume his or her studies.

Two months prior to the end of that suspension period, a student may petition to return to school (on probation) by completing the following steps:

- Writing a formal petition, requesting to return and receiving permission in writing from the CIT associate dean for undergraduate studies.
- Completing a Return from Leave of Absence form from Enrollment Services; and
- Providing transcripts and clearance forms if the student has been in a program at another college or university even though academic credit earned may not transfer back to Carnegie Mellon unless prior approval from the Associate/Assistant Dean is given.

Drop

The most severe academic action occurs when a student is dropped from the college, and is not permitted to re-enroll. This normally results when a student, already on final academic probation, continues to perform at levels below the minimum set by the college for good academic standing, and does not show indication of being able to reach an acceptable level of performance or maintain adequate academic progress toward completing graduation requirements. It is also an option when, in unusual cases, a student has performed poorly, and has been unresponsive to outreach efforts by college and/or university offices seeking to offer help and support.

*Note: students with accommodations approved by the Office of Disability Resources, the Counseling and Psychological Services Center or the Dean of Student Affairs may petition for an exception to adequate academic progress rules.

Students who are suspended, dropped, take a leave of absence or withdraw are required to vacate the campus (including residence halls and Greek houses) within a maximum of two days after the action and to remain off the campus for the duration of the time specified. This action includes debarment from part-time or summer courses at the university for the duration of the period of the action.

Graduation Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their department with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshman and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some departments may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

1. All mathematics (21-xxx) courses **required*** for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.

2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

***Elective mathematics courses are not included in this policy**

Students must be recommended for a degree by the faculty of CIT.

A candidate must meet the residence requirement of having completed at least 180 units at Carnegie Mellon University.

Students must meet all financial obligations to the university before being awarded a degree.

Modification of Graduation Requirements: A student may seek permission to modify graduation requirements by petition to the CIT College Council.

CIT Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

39-109 Grand Challenge Freshman Seminar: Climate Change
Fall and Spring: 9 units
Climate change is considered by many the most serious social, political, and environmental issue of the 21st century. As human activities increase the level of greenhouse gases in the atmosphere, scientists have established the reality of climate change and have estimated its impacts on human society and the natural world. Despite the scientific consensus on its existence, causes, and consequences, a substantial number of Americans and citizens of other countries still question these conclusions and a small but vocal group of doubters continue to challenge the science and scientific consensus on climate change. In spite of some social division over these issues, governments at local, national, and international levels have made concerted efforts to craft policies to address climate change. These policies have shifted over time as the information, attitudes, and technology associated with climate change have evolved. In this course, we will explore the challenges and complexities of climate change by investigating the subject from a variety of angles: scientific, political, rhetorical, cultural, economic, technological, and ethical. Over the course of the semester, well inquire: What is climate change? How do scientists know it is happening? Why is there public debate over it? What solutions are available? And what are the pros and cons of the different solutions?

39-210 Experiential Learning I
Fall and Spring
The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT sophomores, requires the student to choose and experience activities for development and growth that are not part of formal course work. The activities are chosen from a list provided on the CIT Undergraduate Studies website.

39-220 Experiential Learning II
Fall and Spring
The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT sophomores, requires the student to choose and experience activities for development and growth that are not part of formal course work. The activities are chosen from a list provided on the CIT Undergraduate Studies website.
Prerequisite: 39-210

39-245 Rapid Prototype Design
All Semesters: 9 units
This course provides an introduction to rapid design through virtual and physical prototyping. The class covers the engineering design process, problem solving methods, interdisciplinary team work, current industrial practice, and manufacturing process capabilities. The course emphasizes hands on learning. Sophomores have priority while registering for this course. Juniors and seniors will be put on the waitlist, then released once sophomores have registered.

39-250 CIT Undergraduate Projects
Fall
This course number is to be used for Fall CIT freshman research projects only. Student must complete a CIT Undergraduate Project Approval form (located in Scaife Hall 110) and submit for approval. The form must include a complete description and a signature approval from the research advisor/instructor. If the project is approved, the CIT Undergraduate Studies Office will add the course to the student's fall schedule.

39-251 CIT Undergraduate Projects
Spring
This course number is to be used for Spring CIT freshman research projects only. Student must complete a CIT Undergraduate Project Approval form (located in Scaife Hall 110) and submit for approval. The form must include a complete description and a signature approval from the research advisor/instructor. If the project is approved, the CIT Undergraduate Studies Office will add the course to the student's fall schedule.

39-310 Experiential Learning III
Fall and Spring
The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT juniors, requires the student to choose and experience activities for development and growth that are not part of formal course work. The activities are chosen from a list provided on the CIT Undergraduate Studies website.
Prerequisite: 39-220

39-402 Leadership Development Seminar
All Semesters: 9 units
This course is designed for CIT juniors and seniors committed to further developing their leadership skills and potential for sustained impact in the future. The course will be substantive and engaging, while less technically challenging, outright, than thought provoking, edifying, and enjoyable, ideally. The course will build on the foundation of six key leadership pillars, identified by CIT to hone a student's professional and personal development to serve others, and to seek out and nurture opportunities to heighten one's capacity as a person and leader who is: VISIONARY, with clear goals for yourself, your organizations and communities, and others in whose lives you are a part, including the broader society; ETHICAL, with core values and steadfastness in the face of competing objectives, and the resilience to deal with conflicts without moral compromise; ENGAGING, with empathy, attentive interpersonal attributes, outstanding formal and informal communication skills, and the capacity to inspire; TACTICAL, with an ability to operationalize big ideas and bring them to fruition, creating the ideal environment for individual and group success; TECHNICAL, based on your own high-level skill set and the ego strength for inclusion of others with complementary realms of expertise; REFLECTIVE, manifesting in the honest appraisal of personal and organizational success against metrics, and the ability to redirect based on assessment.

39-447 CIT Undergraduate Interdisciplinary Design Project
All Semesters
This course is to be used for undergraduate research projects involving a significant interdisciplinary design component. It can be added by permission only through collaboration with the student, project advisor, and the CIT Dean's Office. For projects that are not interdisciplinary in nature, students should refer to the research number specific to the department in which the research is being completed.

39-499 Summer Curricular Practical Training
Summer: 3 units
The college of engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. CIT students interested in registering their internship for course credit on their transcript may enroll in this course. To do so, students must complete a CIT Internship form (located in Scaife Hall 110) and submit for approval. The CIT Undergraduate Studies Office will add the course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 1-2 page report of their work experience, and a 1-2 page evaluation from the company supervisor to the CIT Undergraduate Office. After the reports has been reviewed and approved, a "P" grade will be assigned. This process should be used by international students interested in Curricular Practical Training (CPT) or by any other engineering undergraduate wishing to have their internship experience reflected on their official University transcript. International students should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website.

39-500 Honors Research Project
All Semesters
Juniors who have an accumulated QPA of at least 3.5 receive an invitation to participate in the program. This course, open by invitation only, will provide the opportunity for close interaction with a faculty member through independent honors research in a number of disciplinary and interdisciplinary areas, as part of the CIT Honors Research Program. Students will work on their projects during their senior year, earning the equivalent of 18-24 units. Students are required to register for CIT Honor Research Project 39-500. To receive CIT College Honors, a student must complete at least 18 units in 39-500 on the same research topic and submit a 1-page executive summary of your research. Lastly, students must present their research findings at the Undergraduate Research Symposium, "Meeting of the Minds" in May. Although "Meeting of the Minds" is open to any undergraduate research initiatives occurring on campus, it is a requirement for College of Engineering Honors Research students.

Course Website: https://tinyurl.com/cithonorsresearch

39-601 Special Topics: Additive Manufacturing Processing and Product Development
Fall: 12 units
Introduction to additive manufacturing (AM) processing fundamentals and applications using Solidworks 3-D CAD software and a variety of polymer and metal AM machines. Includes a brief history of AM processing, a review of and technical fundamentals of current AM processes, a study of the current AM market, and future directions of the technology. Lab Sessions will support an open-ended product development project. Lectures on metals AM will address current research impacting industry. Students will also perform a literature review of papers on the state of the art. Basic Solidworks knowledge required.

39-602 Additive Manufacturing and Materials
Fall and Spring: 12 units
This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

39-603 Additive Manufacturing Laboratory
Spring: 12 units
Hands-on laboratory projects will teach students about all aspects of metals additive manufacturing (AM). Students will learn how to use SOLIDWORKS for part design, create and transfer design files to the AM machines, run the machines to build parts, perform post-processing operations, and characterize AM parts. Student will work in teams and complete three separate lab projects, each utilizing a different material system, part design, AM process/machine, post-processing steps and characterization methods. A major lab report and presentation will be required for each of the three lab projects. The course includes weekly lectures to complement the laboratory component. Priority for enrollment will be given to students who have declared the Additive Manufacturing Minor.
Prerequisites: 27-765 or 24-632 or 39-601 or 27-503 or 39-602

39-605 Engineering Design Projects
Fall: 12 units
In this project course, students work in multidisciplinary teams to design products or processes. The course is open to juniors, seniors and graduate students from all parts of the campus community. Each project is sponsored by an industry, government or non-profit partner, and is of real commercial interest to that partner. Students work directly with their partner throughout the semester to establish goals and requirements, evaluate their design as it progresses, and produce a final report, presentation, and, if appropriate, a prototype. Design reviews, held twice during the semester, give students a chance to present their preliminary designs and receive feedback and advice. In completing their designs, teams must consider not only the functionality of their designs, but also the look, feel, appearance, and societal impact. Skills built in this course will include: developing the product statement, establishing goals and constraints for the product, project management, and generating and evaluating design alternatives. As some projects may span multiple semesters with new groups of students, careful documentation of project work is emphasized. Students may take this course for either one or two semesters.

39-606 Engineering Design Projects
Spring: 12 units
In this project course, students work in multidisciplinary teams to design products or processes. The course is open to juniors, seniors and graduate students from all parts of the campus community. Each project is sponsored by an industry, government or non-profit partner, and is of real commercial interest to that partner. Students work directly with their partner throughout the semester to establish goals and requirements, evaluate their design as it progresses, and produce a final report, presentation, and, if appropriate, a prototype. Design reviews, held twice during the semester, give students a chance to present their preliminary designs and receive feedback and advice. In completing their designs, teams must consider not only the functionality of their designs, but also the look, feel, appearance, and societal impact. Skills built in this course will include: developing the product statement, establishing goals and constraints for the product, project management, and generating and evaluating design alternatives. As some projects may span multiple semesters with new groups of students, careful documentation of project work is emphasized. Students may take this course for either one or two semesters.

39-647 Special Topics in Design
All Semesters
This course is to be use for Interdisciplinary Engineering Design Independent Study. It can be added by permission only through collaboration with the student, Independent Study project advisor, and the CIT Dean's Office.

39-648 Rapid Design and Prototyping of Computer Science
Spring: 12 units
This course deals with rapid prototyping, manufacture, and applications of a new generation of wearable computers, with head-mounted display. The design of wearable computers is a multidisciplinary process including: Electronic design, mechanical design, software development, and human-computer interaction. Two classes of wearable computers will be further developed: embedded, custom designed VuMan series, and general purpose Navigator series. Electronic design includes the custom designed computer board, electronic interfacing, and power supply. Industrial designers and mechanical engineers team to design and manufacture with in-house facilities a variety of conformable/lightweight housings. A software development environment and user interface builders support software and application development. Current applications include: Global Position Sensing, Hypertext documents, speech recognition, wireless communications, and digital imaging.

39-660 Masters EST&P Project
Fall and Spring
This project course is designed for EST&P students who are working on an independent investigation on a project related to energy with the advice and approval of the program advisor and/or affiliated faculty member. Summary report, presentation or poster on work accomplished must be submitted at completion of semester. Once you have determined a suitable topic area, found an engineering faculty member who has agreed to supervise the project work, send the EST&P project approval form to the EST&P director for enrollment. Variable units. Restricted to EST&P students

39-699 Career & Professional Development for Engineering Masters Students
Fall and Spring: 3 units
This professional development course is designed to engage, educate and empower engineering Masters Students to create and manage career opportunities, as well as to develop the professional skills necessary to be successful in a job search and internship/first year of employment. Open to College of Engineering masters students, this seminar style course will support professional development in the following areas: self-assessment/awareness, resume creation, personal introduction development, job search planning, interviewing, networking, career fair success, entrepreneurship, and internship/employment readiness, etc. Assignments will be actionable and relevant to the job search, enabling students to immediately apply classroom learning. Assignments and active classroom participation will determine pass/fail grade.

Department of Biomedical Engineering

Professor Bin He, Department Head
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Professor Conrad M. Zapanta, Associate Department Head for Undergraduate Education
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Biomedical Engineering Overview

Biomedical engineering education at Carnegie Mellon University reflects the belief that a top biomedical engineer must be deeply trained in both a traditional engineering practice and biomedical sciences. The unique additional major program leverages extensive collaborations with sister departments in the College of Engineering and with major medical institutions in Pittsburgh. This collaborative approach, combined with a rigorous engineering education, confers unique depth and breadth to the education of Biomedical Engineering graduates.

Students who elect Biomedical Engineering as a major must also declare a major in one of the traditional engineering disciplines: Chemical Engineering, Civil & Environmental Engineering, Electrical & Computer Engineering, Materials Science & Engineering, or Mechanical Engineering.

The curriculum, demanding but readily feasible to complete in four years, is highly rewarding to motivated students.

Common Requirements for the Additional Major

The Biomedical Engineering additional major program takes advantage of curricular overlaps between Biomedical Engineering and traditional engineering majors, such that the dual major can be completed in four years with only a modest increase in course requirements. The requirements for Biomedical Engineering consist of the core, the tracks, and the capstone design course. The core exposes students to basic facets of biomedical engineering to lay a foundation. The tracks allow students to build depth in a specific aspect of biomedical engineering. The capstone design (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/Resources/undergrad_design.html) project engages students in teamwork to develop real-world applications.

The additional major in Biomedical Engineering should be declared at the same time when declaring a traditional engineering major.

Course Requirements for the Additional Major

Minimum units required for additional major: 93–102

Students majoring in Biomedical Engineering must meet **three** sets of requirements:

1. Biomedical Engineering (BME)
2. A traditional engineering discipline, and
3. College of Engineering General Education (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education) sequence.

The Quality Point Average (QPA) for courses that count toward the additional major must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted toward the additional major.

The course requirements for the BME portion of the additional major are as follows:

Core Courses

(all required)

		Units
03-121	Modern Biology- Fall and Spring	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering- Fall and Spring	12
42-201	Professional Issues in Biomedical Engineering- Fall and Spring	3
42-202	Physiology- Fall and Spring	9
42-203	Biomedical Engineering Laboratory- Fall and Spring #	9
42-302	Biomedical Engineering Systems Modeling and Analysis- Fall and Spring	9
42-401	Foundation of BME Design-Fall*	6
42-402	BME Design Project- Spring	9
		66

\# Also known as 03-206 for Health Professions Program (http://www.cmu.edu/hpp) students.

* 42-401 serves as the precursor/pre-requisite for 42-402 BME Design Project.

Tracks (Completion of one track is required)

- Biomaterials and Tissue Engineering (BMTE (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/bmte_track.html))
- Biomechanics (BMEC (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/bmec_track.html))
- Biomedical Signal and Image Processing (BSIP (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/bsip_track.html))
- Cellular and Molecular Biotechnology (CMBT (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/cmbt_track.html))
- Neuroengineering (Neuro (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/neuro_track.html))
- Self-Designed Biomedical Engineering (SBME (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/sbme_track.html))

Biomaterials and Tissue Engineering (BMTE) Track

Overview

The BMTE track addresses issues at the interface of materials science, biology and engineering. The topics include the interactions between materials and cells or tissues, the effects of such interactions on cells and tissues, the design of materials for biological applications, and the engineering of new tissues.

Targets

The BMTE track is ideal for students interested in combining the education of Biomedical Engineering with Materials Science & Engineering or with Chemical Engineering. Both provide the necessary foundation in chemistry and/or materials science. Students of this track may develop careers in biotechnology, tissue engineering, biopharmaceuticals, and medical devices that leverage materials properties.

Requirements

In addition to the Biomedical Engineering core courses, students in the BMTE Track must take the following combination of **three** courses:

- One (1) **Required** BMTE elective
- Two (2) BMTE Electives (either **Required** or **Additional**)

BMTE Electives

Required BMTE Electives (must take one of the following)

42/27-411	Engineering Biomaterials- Fall	9
42-612/27-520	Tissue Engineering- Spring	12
42-670	Special Topics: Biomaterial Host Interactions in Regenerative Medicine- Fall	12

Additional BMTE Electives

03-320	Cell Biology	9
42-613	Polymeric Biomaterials- Spring	9
42-620	Engineering Molecular Cell Biology- Fall	12
42-624	Biological Transport and Drug Delivery- Spring	9
42-673	Special Topics: Stem Cell Engineering- Fall, every other year	9
42-676	Bio-nanotechnology: Principles and Applications	9
42-x00	BME Research* or 39-500 Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as BMTE track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as BMTE track electives.

Sample schedules can be found on the BMTE (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/bmte_track.html) page on the BME website.

Biomechanics (BMEC) Track

Overview

The BMEC track addresses the application of solid or fluid mechanics to biological and medical systems. It provides quantitative understanding of the mechanical behavior of molecules, cells, tissues, organs, and whole organisms. The field has seen a wide range of applications from the optimization of tissue regeneration to the design of surgical and rehabilitation devices.

Targets

The BMEC track is ideally suited to the combined education of Biomedical Engineering and Mechanical Engineering or Civil & Environmental Engineering. Both provide the necessary foundation in the underlying physical principles and their non-Biomedical Engineering applications. This track may also appeal to students of Electrical & Computer Engineering who are interested in biomedical robotics. Education in biomechanics enables students to pursue careers in medical devices or rehabilitation engineering.

Requirements

In addition to the Biomedical Engineering core courses, students in the BMEC Track must take must take the following combination of **three** courses:

- One (1) **Required** BMEC Elective
- Two (2) BMEC Electives (either **Required** or **Additional**)

BMEC Electives

Required BMEC Electives (must take at least one of the following)

42-341	Introduction to Biomechanics- Fall	9
42-645/24-655	Cellular Biomechanics- Intermittent	9
42-646	Molecular Biomechanics- Intermittent	9
42-648	Cardiovascular Mechanics- Spring	12

Additional BMEC Electives

33-441/03-439	Introduction to BioPhysics- Fall	10
42-444	Medical Devices- Fall and Spring	9
42-447	Rehabilitation Engineering- Fall	9
42-640/24-658	Image-Based Computational Modeling and Analysis- Spring	12
42-643	Microfluids- Intermittent	12
42-647	Continuum Biomechanics: Solid and Fluid Mechanics of Physiological Systems	12
42-x00	BME Research* or 39-500 Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics, newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives.

Sample schedules can be found on the BMEC (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/bmec_track.html) page on the BME website.

Biomedical Signal and Image Processing (BSIP) Track

Overview

The BSIP track addresses biomedical phenomena based on the information embedded in sensor-detected signals, including digital images and nerve electrical pulses. Students in this track will gain understanding of the technologies involved in acquiring signals and images, the mathematical principles underlying the processing and analysis of signals, and the applications of signal/image processing methods in basic research and medicine.

Targets

This track aligns most naturally with a combined education of Biomedical Engineering and Electrical & Computer Engineering, which lays a solid foundation in signal processing principles. This track prepares students for careers in medical imaging or smart prosthetics. It also interfaces with many clinical practices including radiology, neurology/neurosurgery, and pathology.

Requirements

In addition to the Biomedical Engineering core courses, students in the BSIP Track must take the following combination of **three** courses:

- One (1) **Required** BSIP elective
- Two (2) BSIP Electives (either **Required** or **Additional**)

BSIP Electives

Required BSIP Electives (must take at least one of the following)

42-431	Introduction to Biomedical Imaging and Image Analysis	12
42-630	Introduction to Neuroscience for Engineers-Spring	12
42-631	Neural Data Analysis- Fall	9
42-632	Neural Signal Processing- Spring	12

Additional BSIP Electives

03-534	Biological Imaging and Fluorescence Spectroscopy- Spring	9
15-386	Neural Computation- Spring	9
16-725	(Bio)Medical Image Analysis- Spring	12
18-491	Fundamentals of Signal Processing [1]	12
42-426	Biosensors and BioMEMS- Intermittent	9
42-437	Biomedical Optical Imaging-Fall	9
42-447	Rehabilitation Engineering- Fall	9
42-640/24-658	Image-Based Computational Modeling and Analysis- Spring	12
42-682	Bioinstrumentation and Measurement	12

42-x00	BME Research* or 39-500 Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	

[1] Please consult the BSIP (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/bsip_track.html)page on the BME website for additional information.

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics, newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives.

Sample schedules can be found on the BSIP (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/bsip_track.html) page on the BME website.

Cellular and Molecular Biotechnology (CMBT) Track

Overview

The CMBT track emphasizes fundamentals and applications of biochemistry, biophysics, and cell biology, and processes on the nanometer to micrometer size scale. Students in this track acquire understanding of the molecular and cellular bases of life processes, and build skills in quantitative modeling of live cell-based biotechnologies and in technologies that exploit the unique properties of biomolecules in non-biological settings.

Targets

The CMBT track is ideally suited for the combined education of Biomedical Engineering and Chemical Engineering, which provides a strong core of chemistry and molecular processing principles. The track may also interest students of Mechanical Engineering, Materials Science & Engineering, or Civil & Environmental Engineering who have an interest in molecular aspects of Biomedical Engineering. The CMBT track prepares students for careers in bio/pharmaceutical, medical diagnostics, biosensors, drug delivery, and biological aspects of environmental engineering.

Requirements

In addition to the Biomedical Engineering core courses, students in the CMBT Track must take the following combination of **three** courses:

- One (1) **Required** CMBT Elective
- Two (2) CMBT Electives (either **Required** or **Additional**)

CMBT Electives

Required CMBT Electives (must take at least one of the following)

42-620	Engineering Molecular Cell Biology- Fall	12
42-623	Cellular and Molecular Biotechnology- Intermittent	9
42-624	Biological Transport and Drug Delivery- Spring	9

Additional CMBT Electives

03-320	Cell Biology	9
42/06-622	Bioprocess Design	9
42-643	Microfluids-Intermittent	12
42-645/24-655	Cellular Biomechanics- Intermittent	9
42-646	Molecular Biomechanics- Intermittent	9
42-673	Special Topics: Stem Cell Engineering- Fall, every other year	9
42-676	Bio-nanotechnology: Principles and Applications- Fall	9
42-x00	BME Research* or 39-500 Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics, newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives.

Sample schedules can be found on the CMBT (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/cmbt_track.html) page on the BME website.

Neuroengineering (Neuro) Track

Overview

The Neuroengineering (Neuro) track uses engineering techniques to examine, understand, and apply the properties of complex neural systems. Areas of interest include the research and development of neuroengineering technologies for sensing, interfacing, imaging, and modulating the nervous systems. Examples of applications include brain-computer interfaces for use in paralysis, neural stimulation device design for sensory and motor prostheses and basic science research, and neural recording and imaging devices.

Targets

This track aligns most naturally with a combined education of Biomedical Engineering and Electrical & Computer Engineering, which lays a solid foundation in signal processing principles. This track prepares students for careers in brain-computer interfaces, neural stimulators, and neuroprosthetics.

Requirements

In addition to the Biomedical Engineering core courses, students in the BMEC Track must take must take the following combination of **three** courses:

- One (1) **Required** Neuro Elective
- Two (2) Neuro Electives (either **Required** or **Additional**)

Neuro Electives

REQUIRED Neuro ELECTIVES (MUST TAKE AT LEAST ONE OF THE FOLLOWING)

42-631	Neural Data Analysis	9
42-632	Neural Signal Processing	12
Other courses as approved		

ADDITIONAL Neuro ELECTIVES

42-437	Biomedical Optical Imaging- Fall	9
42-630	Introduction to Neuroscience for Engineers- Spring	12
42-676	Bio-nanotechnology: Principles and Applications- Fall	9
18-370	Fundamentals of Control	12
18-460	Optimization	12
15-386	Neural Computation	9
42-x00	BME Research* or 39-500 Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12
Other courses as approved		

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics, newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives.

Sample schedules can be found on the Neuro (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/neuro_track.html) page on the BME website.

Self-Designed Biomedical Engineering (SBME) Track

The SBME track is aimed at helping highly motivated students who have a strong sense of career direction that falls beyond the scope of regular Biomedical Engineering tracks, and allows students to choose courses relevant to the theme from across the University. Students are allowed to design the "track" portion of the curriculum in consultation with the faculty. Example themes include medical robotics, neural engineering, or computational biomedical engineering.

Requirements

In addition to the Biomedical Engineering core requirements, students must take **three** elective courses of at least 9 units each. These elective courses must form a coherent theme that is relevant to biomedical engineering. In addition, at least one of the elective courses must be judged by the Biomedical Engineering Undergraduate Affairs Committee to have substantial biological or medical content.

If undergraduate research is part of the SBME track, the research project must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Petition Procedure

1. Students wishing to pursue a self-designed track should first consult with the Biomedical Engineering Undergraduate Affairs Committee. Contacts for the Committee are Prof. Robert Tilton (https://www.cmu.edu/bme/People/Faculty/profile/rtilton.html) (committee chair), and Prof. Conrad Zapanta (https://www.cmu.edu/bme/People/Faculty/profile/czapanta.html) (Biomedical Engineering Associate Head of Undergraduate Affairs).
2. A SBME track proposal must be submitted electronically to Prof. Conrad Zapanta (https://www.cmu.edu/bme/People/Faculty/profile/czapanta.html) at least three weeks prior to Pre-Registration during the spring of the sophomore year. The proposal must include:
   - The three courses of the designed track, including catalog descriptions and when these courses are expected to be taken.
   - A justification of how these courses form a coherent theme relevant to biomedical engineering.
   - Two alternative courses that may substitute for one of the proposed courses, in case the original course is not available.
3. Once approved, the student must sign an agreement listing the theme and the three courses comprising the SBME track.
4. In the event that issues beyond the student's control, such as course scheduling or cancellation, prevent the student from completing the approved course plan, the student may petition the Biomedical Engineering Undergraduate Affairs Committee to
   - Substitute a course with another course that fits the approved theme, OR
   - Complete one of the regular tracks (all classes)

Minor in Biomedical Engineering

Professor Conrad M. Zapanta, *Associate Department Head of Undergraduate Education*
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www.bme.cmu.edu

The minor program is designed for engineering students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is also open to students of all colleges and is popular among science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. Students pursuing the minor may contact the BME Associate Head for Undergraduate Education (https://www.cmu.edu/bme/People/Faculty/profile/czapanta.html) (http://www.bme.cmu.edu/people/staff.html#ADH)for advice. Students interested in declaring Biomedical Engineering minor should contact either the BME Associate Head for Undergraduate Education (https://www.cmu.edu/bme/People/Faculty/profile/czapanta.html)or the Biomedical Engineering Undergraduate Program Coordinator (https://www.cmu.edu/bme/People/Administration).

Requirements

Minimum units required for minor: 57

03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
42-xxx	BME Elective (>= 9 units), Any course offered by the Department of Biomedical Engineering numbered 42-300 or higher and worth at least 9 units	
xx-xxx	Elective I (>= 9 units) #	
xx-xxx	Elective II (>= 9 units) +	

Some Special Topics, newly offered or intermittently offered 42-xxx may be acceptable as electives. Students should consult with their advisors and petition the Biomedical Engineering Undergraduate Affairs Committee for permission to include such courses.

Notes

\# Elective I cannot be a required course in the student’s major. It may be

1. Any required or additional track elective course selected from any of the five Biomedical Engineering tracks. See the online catalog (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/Resources/catalog.html) for a listing of courses.
2. Any 42-xxx course with a 42-300 or higher number and worth at least 9 units.
3. 42-203 Biomedical Engineering Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). The course has a limited capacity and priority is given to students who have declared the Additional Major in Biomedical Engineering.**
4. One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units.

\+ Elective II must be a Biomedical Engineering Required or additional track elective.

** Priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.

Full-Time Faculty

ABBOTT, ROSALYN, Assistant Professor of Biomedical Engineering – Ph.D., University of Vermont, 2011;

BARATI FARIMANI, AMIR, Assistant Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., University of Illinois at Urbana-Champaign, 2015;

BARTH, ALISON L., Professor, Biological Sciences, and Biomedical Engineering – Ph.D., University of California, Berkeley, 1997;

BEHRMANN, MARLENE, George A. and Helen Dunham Cowan Professor of Cognitive Neuroscience Center for the Neural Basis of Cognition and Department of Psychology Professor, Biomedical Enegineering – Ph.D., University of Toronto, 1991;

BETTINGER, CHRISTOPHER J. , Professor of Biomedical Engineering and Materials Science & Engineering – Ph.D., Massachusetts Institute of Technology, 2008;

BRUCHEZ, MARCEL P. , Professor of Biological Sciences, Chemistry, and Biomedical Engineering – Ph.D., University of California, Berkeley, 1998;

CAI, YANG, Associate Research Professor, Biomedical Engineering – Ph.D., West Virginia University, 1997;

CAMPBELL, PHIL G. , Research Professor, Institute of Complex Engineering Systems, Biomedical Engineering, Biological Sciences, Materials Science & Engineering – Ph.D., The Pennsylvania State University, 1985;

CHALACHEVA, P. SANG, Assistant Teaching Professor of Biomedical Engineering – Ph.D., University of Southern California, 2014;

CHAMANZAR, MAYSAM , Assistant Professor, Electrical and Computer Engineering, Biomedical Engineering – Ph.D., Georgia Institute of Technology, 2012;

CHASE, STEVEN M., Associate Professor of Biomedical Engineering and Center for the Neural Basis of Cognition – Ph.D., Johns Hopkins University, 2006;

CHOSET, HOWIE, Professor, Robotics Institute, Biomedical Engineering, and Electrical & Computer Engineering – Ph.D., California Institute of Technology , 1996;

COHEN-KARNI, TZAHI (ITZHAQ), Associate Professor of Biomedical Engineering and Materials Science & Engineering – Ph.D., Harvard University, 2011;

COOK, KEITH, Professor and Associate Department Head of Graduate Studies of Biomedical Engineering – Ph.D., Northwestern University, 2000;

DAHL, KRIS N., Professor of Chemical Engineering, Biomedical Engineering, and Materials Science & Engineering – Ph.D., University of Pennsylvania, 2004;

DOMACH, MICHAEL M. , Professor of Chemical Engineering and Biomedical Engineering – Ph.D., Cornell University, 1983;

FEDDER, GARY K., Howard M. Wilkoff Professor, Institute for Complex Engineering Systems, Biomedical Engineering, Electrical & Computer Engineering, Robotics Institute – Ph.D., University of California, Berkeley, 1994;

FEINBERG, ADAM W., Arthur Hamerschlag Career Development Professor; Professor of Biomedical Engineering and Materials Science & Engineering – Ph.D., University of Florida, 2004;

GALEOTTI, JOHN, Systems Scientist, Robotics Institute and Assistant Professor of Biomedical Engineering – Ph.D, Carnegie Mellon University, 2007;

GEYER, HARMUT, Associate Professor, Robotics Institute and Biomedical Engineering – Ph.D., Friedrich-Schiller-University of Jena, Germany, 2005 ;

GITTIS, ARYN, Associate Professor, Biological Sciences, and Biomedical Engineering – Ph.D., University of California, San Diego, 2008;

GROVER, PULKIT, Associate Professor, Electrical & Computer Engineering, Center for Neural Basis of Cognition, and Biomedical Engineering – Ph.D., University of California, Berkeley, 2010;

HALILAJ, ENI, Assistant Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., Brown University, 2015;

HE, BIN, Trustee Professor and Department Head, Biomedical Engineering – Ph.D., Tokyo Institute of Technology, 1988;

KAINERSTORFER, JANA M., Assistant Professor of Biomedical Engineering – Ph.D., University of Vienna, 2010;

KASS, ROBERT, Maurice Falk Professor, Statistics, Department of Machine Learning, Center for the Neural Basis of Cognition, and Biomedical Engineering Interim co-Director, Center for the Neural Basis of Cognition – Ph.D., University of Chicago, 1980;

KELLY, SHAWN, Adjunct Associate Professor of Biomedical Engineering – Ph.D., Massachusetts Institute of Technology, 2003;

KUHLMAN, SANDRA , Associate Professor, Biological Sciences, and Biomedical Engineering – Ph.D., University of Kentucky, 2001;

LEDUC, PHILIP R., Professor of Mechanical Engineering, Biomedical Engineering, and Biological Sciences – Ph.D., Johns Hopkins University, 1999;

LOESCHE, MATHIAS , Professor of Physics and Biomedical Engineering – Ph.D., Technical University of Munich, 1986;

MAJIDI, CARMEL, Associate Professor of Mechanical Engineering and Biomedical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2007–

MINDEN, JONATHAN S. , Professor of Biological Sciences and Biomedical Engineering – Ph.D., Albert Einstein College of Medicine, 1985;

MITCHELL, TOM M., E. Fredkin University Professor, Computer Science, Robotics, Language Technologies, and Biomedical Engineering – Ph.D., Stanford University, 1979;

MOURA , JOSE M. F., University Professor of Electrical & Computer Engineering and Biomedical Engineering – Ph.D., Massachusetts Institute of Technology, 1975;

MURPHY, ROBERT F., Ray and Stephanie Lane Professor of Computational Biology and Professor of Biological Sciences, Biomedical Engineering, and Machine Learning – Ph.D., California Institute of Technology, 1980;

OZDOGANLAR, BURAK , Ver Planck Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., University of Michigan, 1999;

PANAT, RAHUL, Associate Professor, Mechanical Engineering, Civil & Environmental Engineering, Materials Science & Engineering, and Biomedical Engineering – Ph.D., University of Illinois at Urbana-Champaign, 2004;

RABIN, YOED, Professor of Mechanical Engineering and Biomedical Engineering – D.Sc., Technion - Israel Institute of Technology, 1994;

REN, XI (CHARLIE), Assistant Professor of Biomedical Engineering – Ph.D., Peking University, 2011;

RIVIERE, CAMERON N., Associate Research Professor, Robotics Institute and Biomedical Engineering – Ph.D., Johns Hopkins University, 1995;

RUSSELL, ALAN J., Highmark Distinguished Career Professor, Institute of Complex Engineering Systems and Biomedical Engineering – Ph.D., University of London, 1987;

SCHNEIDER, JAMES W., Professor of Chemical Engineering and Biomedical Engineering – Ph.D., University of Minnesota, 1998;

SHIMADA, KENJI, Theodore Ahrens Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., Massachusetts Institute of Technology, 1993;

SHINN-CUNNINGHAM, BARBARA, Director, Carnegie Mellon Neuroscience Institute Professor, Center for the Neural Basis of Cognition, Biomedical Engineering, Psychology, and Electrical & Computer Engineering – Ph.D., Massachusetts Institute of Technology, 1994;

SIMKO (PALCHESKO), RACHELLE, Special Faculty - Researcher – Ph.D., Duquesne University, 2011;

SMITH, MATTHEW, Associate Professor, Biomedical Engineering and Center for the Neural Basis of Cognition – Ph.D., New York University, 2003;

SYDLIK, STEFANIE, Assistant Professor of Chemistry and Biomedical Engineering – Ph.D., Massachusetts Institute of Technology, 2012;

TAYLOR, REBECCA, Ph.D. – Assistant Professor of Mechanical Engineering and Biomedical Engineering, Stanford University, 2013;

TILTON, ROBERT D. , Chevron Professor; Professor, Biomedical Engineering and Chemical Engineering – Ph.D., Stanford University, 1991;

TRUMBLE, DENNIS, Associate Research Professor, Biomedical Engineering and Center for the Neural Basis of Cognition – Ph.D., Carnegie Mellon University, 2010;

VERSTYNEN, TIMOTHY, Associate Professor, Psychology, Center for the Neural Basis of Cognition and Biomedical Engineering – Ph.D., University of California, Berkeley, 2006;

WANG, YU-LI, Mehrabian Professor of Biomedical Engineering – Ph.D., Harvard University, 1980;

WASHBURN, NEWELL R. , Associate Professor of Biomedical Engineering, Chemistry, and Materials Science & Engineering – Ph.D., University of California, Berkeley, 1998;

WAYNE, ELIZABETH, Assistant Professor, Biomedical Engineering and Chemical Engineering – Ph.D., Cornell University, 2015;

WEBSTER-WOOD, VICTORIA , Assistant Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., Case Western Reserve University, 2017;

WHITEHEAD, KATHRYN A, Associate Professor of Chemical and Biomedical Engineering – Ph.D., University of California, Santa Barbara, 2007;

YTTRI, ERIC, Assistant Professor, Biological Sciences, Center for the Nneural Basis of Cognition, Biomedical Engineering – Ph.D., Washington University in St Louis, 2011;

YU, BYRON, Professor of Biomedical Engineering and Electrical & Computer Engineering – Ph.D., Stanford University, 2007;

ZAPANTA, CONRAD M., Teaching Professor and Associate Head of Undergraduate Education of Biomedical Engineering – Ph.D., The Pennsylvania State University, 1997;

ZHANG, YONGJIE JESSICA, Associate Professor of Mechanical Engineering and Biomedical Engineering – Ph.D., University of Texas at Austin, 2005;

ZHENG, SIYANG, Associate Professor, Biomedical Engineering and Electrical and Computer Engineering – Ph.D., California Institute of Technology, 2007;

Department of Biomedical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

42-101 Introduction to Biomedical Engineering
Fall and Spring: 12 units
This course will provide exposure to basic biology and engineering problems associated with living systems and health care delivery. Examples will be used to illustrate how basic concepts and tools of science & engineering can be brought to bear in understanding, mimicking and utilizing biological processes. The course will focus on four areas: biotechnology, biomechanics, biomaterials and tissue engineering and biosignal and image processing and will introduce the basic life sciences and engineering concepts associated with these topics. Pre-requisite OR co-requisite: 03-121 Modern Biology.

42-200 Sophomore BME Research Project
Fall and Spring
Research projects for sophomores under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-201 Professional Issues in Biomedical Engineering
Fall and Spring: 3 units
This course exposes students to many of the issues that biomedical engineers face. It provides an overview of professional topics including bioethics, regulatory issues, communication skills, teamwork, and other contemporary issues. Outside speakers and case studies will describe real world problems and professional issues in biotechnology and bioengineering, and progress toward their solution. Prerequisite or co-requisite: 42-101 Introduction to Biomedical Engineering

42-202 Physiology
Fall and Spring: 9 units
This course is an introduction to human physiology and includes units on all major organ systems. Particular emphasis is given to the musculoskeletal, cardiovascular, respiratory, digestive, excretory, and endocrine systems. Modules on molecular physiology tissue engineering and physiological modeling are also included. Due to the close interrelationship between structure and function in biological systems, each functional topic will be introduced through a brief exploration of anatomical structure. Basic physical laws and principles will be explored as they relate to physiologic function. Prerequisite or co-requisite: 03-121 Modern Biology, or permission of instructor.
Prerequisites: 03-121 or 03-151

42-203 Biomedical Engineering Laboratory
Fall and Spring: 9 units
This laboratory course is designed to provide students with the ability to make measurements on and interpret data from living systems. The experimental modules reinforce concepts from 42-101 Introduction to Biomedical Engineering and expose students to four areas of biomedical engineering: biomedical signal and image processing, biomaterials, biomechanics, and cellular and molecular biotechnology. Several cross-cutting modules are included as well. The course includes weekly lectures to complement the experimental component. Prerequisites: 42-101 Introduction to Biomedical Engineering and 03-121 Modern Biology. Pre-med students should register for 03-206. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering.
Prerequisites: 42-101 and (03-151 or 03-121)

42-300 Junior BME Research Project
Fall and Spring
Research projects for sophomores under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-302 Biomedical Engineering Systems Modeling and Analysis
Fall and Spring: 9 units
This course will prepare students to develop mathematical models for biological systems and for biomedical engineering systems, devices, components, and processes and to use models for data reduction and for system performance analysis, prediction and optimization. Models considered will be drawn from a broad range of applications and will be based on algebraic equations, ordinary differential equations and partial differential equations. The tools of advanced engineering mathematics comprising analytical, computational and statistical approaches will be introduced and used for model manipulation.
Prerequisites: 21-260 or 06-262 or 18-202

42-341 Introduction to Biomechanics
Fall: 9 units
This course covers the application of solid and fluid mechanics to living tissues. This includes the mechanical properties and behavior of individual cells, the heart, blood vessels, the lungs, bone, muscle and connective tissues as well as methods for the analysis of human motion.
Prerequisites: 06-261 or 24-231 or 12-355

42-400 Senior BME Research Project
Fall and Spring
Research projects for sophomores under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-401 Foundation of BME Design
Fall: 6 units
This course sequence introduces Biomedical Engineering students to the design of useful biomedical products to meet a specific medical need. Students will learn to identify product needs, how to specify problem definitions and to use project management tools. Methods to develop creativity in design will be introduced. The course sequence is comprised of two parts: 42-401 is offered in the Fall semester and provides the students the opportunity to form project teams, select and define a project, create a development plan, and complete an initial prototype. 42-402 is offered in the Spring semester is a full semester course and completes the plan that was developed in the fall semester. This course culminates in the completion of multiple prototypes, a poster presentation, and a written report. Prerequisite: Senior standing in Biomedical Engineering. Co-requisite: 42-101.
Prerequisite: 42-101

42-402 BME Design Project
Spring: 9 units
This course sequence introduces Biomedical Engineering students to the design of useful biomedical products to meet a specific medical need. Students will learn to identify product needs, how to specify problem definitions and to use project management tools. Methods to develop creativity in design will be introduced. The course sequence is comprised of two parts: 42-401 is offered in the Fall semester and provides the students the opportunity to form project teams, select and define a project, create a development plan, and complete an initial prototype. 42-402 is offered in the Spring semester is a full semester course and completes the plan that was developed in the fall semester. This course culminates in the completion of multiple prototypes, a poster presentation, and a written report. Prerequisite: 42-401

42-411 Engineering Biomaterials
Fall: 9 units
This course will cover structure-processing-property relationships in biomaterials for use in medicine. This course will focus on a variety of materials including natural biopolymers, synthetic polymers, and soft materials with additional treatment of metals and ceramics. Topics include considerations in molecular design of biomaterials, understanding cellular aspects of tissue-biomaterials interactions, and the application of bulk and surface properties in the design of medical devices. This course will discuss practical applications of these materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies. Open only to juniors or seniors in CIT, or by permission of instructor.
Prerequisites: 27-215 or 06-221 or 24-221

42-426 Biosensors and BioMEMS
Intermittent: 9 units
This course emphasizes the principles of biomolecule-based sensing, including molecular recognition, biomolecular binding kinetics and equilibrium; methods of detection and signal transduction, including optical, colorimetric, fluorescence, potentiometric, and gravimetric techniques; statistical principles of high throughout screening; microfluidic and microarray device design principles and fabrication technologies; molecular motors. Prerequisites: 03-231 OR 03-232 Biochemistry.
Prerequisite: 03-232

42-431 Introduction to Biomedical Imaging and Image Analysis
Fall: 12 units
This course gives an overview of tools and tasks in various biological and biomedical imaging modalities, such as microscopy, magnetic resonance imaging, x-ray computed tomography, ultrasound and others. Students will be exposed to the major underlying principles in modern imaging systems as well as state of the art methods for processing biomedical images such as deconvolution, registration, segmentation, pattern recognition, etc. The discussion of these topics will draw on approaches from many fields, including physics, statistics, signal processing, and machine learning. As part of the course, students will be expected to complete an independent project. Students will have the opportunity to visit laboratory to see real biomedical imaging devices in action. Prerequisites: 18-290 Signals and Systems or permission of the instructor, working knowledge of Matlab, and some image processing experience. Cross-listed courses: 18-496
Prerequisites: 18-290 and 42-202

42-437 Biomedical Optical Imaging
Fall: 9 units
Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. NOTE: 42-437 is intended for undergraduates only. Pre-requisite: 33-107 Physics II for Engineering Students or permission of the instructor.
Prerequisite: 33-142

42-444 Medical Devices
Fall: 9 units
This course is an introduction to the engineering, clinical, legal and regulatory aspects of medical device performance and failure. Topics covered include a broad survey of the thousands of successful medical devices in clinical use, as well as historical case studies of devices that were withdrawn from the market. In-depth study of specific medical devices will include: cardiovascular medicine, orthopedics, and general medicine. We will study the principles of operation (with hands-on examples), design evolution, and modes of failure. Additional lectures will provide basic information concerning biomaterials used for implantable medical devices (metals, polymers, ceramics) and their biocompatibility, mechanisms of failure (wear, corrosion, fatigue, fretting, etc.). The level of technical content will require junior standing for MCS and CIT students, a degree in science or engineering for non-MCS or non-CIT graduate students, or permission of the instructor for all other students.

42-447 Rehabilitation Engineering
Fall: 9 units
Rehabilitation engineering is the systematic application of engineering sciences to design, develop, adapt, test, evaluate, apply, and distribute technological solutions to problems confronted by individuals with disabilities. This course surveys assistive technologies designed for a variety functional limitations - including mobility, communication, hearing, vision, and cognition - as they apply to activities associated with employment, independent living, education, and integration into the community. This course considers not only technical issues in device development, but also the psychosocial factors and market forces that influence device acceptance by individuals and the marketplace. Open only to students with junior standing who have had at least one engineering class or by permission of instructor.

42-474 Special Topics: Introduction to Biophotonics
Fall: 9 units
Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. NOTE: 42-474 is intended for undergraduates only. Pre-requisite: 33-107 Physics II for Engineering Students or permission of the instructor.
Prerequisite: 33-107

42-612 Tissue Engineering
Spring: 12 units
This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Pre-requisite: Knowledge in cell biology and biomaterials, or permission of instructor

42-613 Polymeric Biomaterials
Spring: 9 units
This course will cover aspects of polymeric biomaterials in medicine from molecular principles to device scale design and fabrication. Topics include the chemistry, characterization, and processing of synthetic polymeric materials; cell-biomaterials interactions including interfacial phenomena, tissue responses, and biodegradation mechanisms; aspects of polymeric micro-systems design and fabrication for applications in medical devices. Recent advances in these topics will also be discussed.

42-620 Engineering Molecular Cell Biology
Fall: 12 units
Cells are not only basic units of living organisms but also fascinating engineering systems that exhibit amazing functionality, adaptability, and complexity. Applying engineering perspectives and approaches to study molecular mechanisms of cellular processes plays a critical role in the development of contemporary biology. At the same time, understanding the principles that govern biological systems provides critical insights into the development of engineering systems, especially in the micro- and nano-technology. The goal of this course is to provide basic molecular cell biology for engineering students with little or no background in cell biology, with particular emphasis on the application of quantitative and system perspectives to basic cellular processes. Course topics include the fundamentals of molecular biology, the structural and functional organization of the cell, the cytoskeleton and cell motility, the mechanics of cell division, and cell-cell interactions. Pre-requisites: 21-260 Differential Equations, or 06-262 Mathematical Methods of Chemical Engineering, or 18-202 Mathematical Foundations of Electrical Engineering. Advanced undergraduate or graduate student standing is required. Prior completion of 03-121 Modern Biology is suggested but not required. Proficiency in basic computation such as MATLAB programming is expected.
Prerequisites: 18-202 or 21-260 or 06-262

42-622 Bioprocess Design
Spring: 9 units
This course is designed to link concepts of cell culture, bioseparations, formulation and delivery together for the commercial production and use of biologically-based pharmaceuticals; products considered include proteins, nucleic acids, and fermentation-derived fine chemicals. Associated regulatory issues and biotech industry case studies are also included. The format of the course is a mixture of equal parts lecture, open discussion, and participant presentation. Course work consists of team-oriented problem sets of an open-ended nature and indivudual-oriented industry case studies. The goals of the course work are to build an integrated technical knowledge base of the manufacture of biologically based pharmaceuticals and U.S. biotechnology industry. Working knowledge of cell culture and modern biology, biochemistry and differential equations is assumed. Pre-requisite: 42-321 Cellular and Molecular Biotechnology or both 03-232 Biochemistry and 06-422 Chemical Reaction Engineering, or instructor permission.
Prerequisites: 06-422 or 42-321 or 03-232

42-623 Cellular and Molecular Biotechnology
Fall: 9 units
This course will provide students with an introduction to biotechnology in an engineering context. The focus will be on using microorganisms to prepare therapeutically and technologically relevant biochemicals. Topics to be covered include cellular and microbial metabolism, recombinant DNA methodologies, bioreactor design, protein separation and purification, and systems approaches to biotechnology. Prerequisites: (42-202 Physiology OR 03-121 Modern Biology OR 03-232 Biochemistry) AND (06-262 Mathematical Methods of Chemical Engineering OR 21-260 Differential Equations) OR permission of instructor.

42-624 Biological Transport and Drug Delivery
Spring: 9 units
Analysis of transport phenomena in life processes on the molecular, cellular, organ and organism levels and their application to the modeling and design of targeted or sustained release drug delivery technologies. Coupling of mass transfer and reaction processes will be a consistent theme as they are applied to rates of receptor-mediated solute uptake in cells, drug transport and biodistribution, and drug release from delivery vehicles. Design concepts underlying advances in nanomedicine will be described.

42-630 Introduction to Neuroscience for Engineers
Intermittent: 12 units
The first half of the course will introduce engineers to the neurosciences from the cellular level to the structure and function of the central nervous system (CNS) and include a study of basic neurophysiology; the second half of the course will review neuroengineering methods and technologies that enable study of and therapeutic solutions for diseases or damage to the CNS. A goal of this course is provide a taxonomy of neuroengineering technologies for research or clinical application in the neurosciences.

42-631 Neural Data Analysis
Fall: 9 units
The vast majority of behaviorally relevant information is transmitted through the brain by neurons as trains of actions potentials. How can we understand the information being transmitted? This class will cover the basic engineering and statistical tools in common use for analyzing neural spike train data, with an emphasis on hands-on application. Topics may include neural spike train statistics (Poisson processes, interspike intervals, Fano factor analysis), estimation (MLE, MAP), signal detection theory (d-prime, ROC analysis, psychometric curve fitting), information theory, discrete classification, continuous decoding (PVA, OLE), and white-noise analysis. Each topic covered will be linked back to the central ideas from undergraduate probability, and each assignment will involve actual analysis of neural data, either real or simulated, using Matlab. This class is meant for upper-level undergrads or beginning graduate students, and is geared to the engineer who wants to learn the neurophysiologist's toolbox and the neurophysiologist who wants to learn new tools. Those looking for broader neuroscience application (eg, fMRI) or more focus on regression analysis are encouraged to take 36-746. Those looking for more advanced techniques are encouraged to take 18-699. Prerequisites: undergraduate probability (36-225/227, or its equivalent), some familiarity with linear algebra and Matlab programming

42-632 Neural Signal Processing
Fall: 12 units
The brain is among the most complex systems ever studied. Underlying the brain's ability to process sensory information and drive motor actions is a network of roughly 10^11 neurons, each making 10^3 connections with other neurons. Modern statistical and machine learning tools are needed to interpret the plethora of neural data being collected, both for (1) furthering our understanding of how the brain works, and (2) designing biomedical devices that interface with the brain. This course will cover a range of statistical methods and their application to neural data analysis. The statistical topics include latent variable models, dynamical systems, point processes, dimensionality reduction, Bayesian inference, and spectral analysis. The neuroscience applications include neural decoding, firing rate estimation, neural system characterization, sensorimotor control, spike sorting, and field potential analysis. Prerequisites: 18-290; 36-217, or equivalent introductory probability theory and random variables course; an introductory linear algebra course; senior or graduate standing. No prior knowledge of neuroscience is needed.

42-640 Image-Based Computational Modeling and Analysis
Spring: 12 units
Biomedical modeling and visualization play an important role in mathematical modeling and computer simulation of real/artificial life for improved medical diagnosis and treatment. This course integrates mechanical engineering, biomedical engineering, computer science, and mathematics together. Topics to be studied include medical imaging, image processing, geometric modeling, visualization, computational mechanics, and biomedical applications. The techniques introduced are applied to examples of multi-scale biomodeling and simulations at the molecular, cellular, tissue, and organ level scales.

42-643 Microfluids
Intermittent: 12 units
This course offers an introduction to the emerging field of microfluidics with an emphasis on chemical and life sciences applications. During this course students will examine the fluid dynamical phenomena underlying key components of "lab on a chip" devices. Students will have the opportunity to learn practical aspects of microfluidic device operation through hands-on laboratory experience, computer simulations of microscale flows, and reviews of recent literature in the field. Throughout the course, students will consider ways of optimizing device performance based on knowledge of the fundamental fluid mechanics. Students will explore selected topics in more detail through a semester project. Major course topics include pressure-driven and electrokinetically-driven flows in microchannels, surface effects, micro-fabrication methods, micro/nanoparticles for biotechnology, biochemical reactions and assays, mixing and separation, two-phase flows, and integration and design of microfluidic chips. Pre-requisites: 24-231 or 06-261 or 12-355 or instructor permission.

42-645 Cellular Biomechanics
Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence cell behavior and function, with a focus on the connection between mechanics and biochemistry. Specific topics include: (1) the role of stresses in the cytoskeleton dynamics as related to cell growth, spreading, motility, and adhesion; (2) the generation of force and motion by moot molecules; (3) stretch-activated ion channels; (4) protein and DNA deformation; (5) mechanochemical coupling in signal transduction. If time permits, we will also cover protein trafficking and secretion and the effects of mechanical forces on gene expression. Emphasis is placed on the biomechanics issues at the cellular and molecular levels; their clinical and engineering implications are elucidated. 3 hrs. lec. Prerequisite: Instructor permission. Prerequisites: None. Corequisites: None. Cross Listed Courses: 24-655 Notes: None. Reservations:

42-646 Molecular Biomechanics
Intermittent: 9 units
This class is designed to present concepts of molecular biology, cellular biology and biophysics at the molecular level together with applications. Emphasis will be placed both on the biology of the system and on the fundamental physics, chemistry and mechanics which describe the molecular level phenomena within context. In addition to studying the structure, mechanics and energetics of biological systems at the nano-scale, we will also study and conceptually design biomimetic molecules and structures. Fundamentals of DNA, globular and structured proteins, lipids and assemblies thereof will be covered.

42-647 Continuum Biomechanics: Solid and Fluid Mechanics of Physiological Systems
Spring: 12 units
This course provides a general survey of the solid and fluid mechanics of physiological systems, within the framework of continuum mechanics. The main objective of the course is to understand mathematical modeling of solid materials such as bone and tissues, and fluid mechanics of blood and other biofluids such as synovial fluid, etc. The course as a whole encourages class participation and discussion in a seminar-type fashion. The course begins with a historical review of the subject followed by a review of vector and tensor analysis, before discussing various measures of deformation and stress formulations. The development and understanding of appropriate constitutive models for particular problems are at the core of this course. Both analytical and to some extent experimental results are presented through readings from reports in recent journals and the relevance of these results to the solution of unsolved problems is highlighted. The intent is to provide the basic ideas of continuum mechanics for engineering and science students with little or no background in biomechanics or mathematical modeling, with particular emphasis on the application of quantitative and system perspectives to fluid and solid mechanics problems. In addition to looking at various examples with physiological applications, the last few weeks of the course are dedicated to discussing individually-crafted research projects for the students.

42-648 Cardiovascular Mechanics
Spring: 12 units
The primary objective of the course is to learn to model blood flow and mechanical forces in the cardiovascular system. After a brief review of cardiovascular physiology and fluid mechanics, the students will progress from modeling blood flow in a.) small-scale steady flow applications to b.) small-scale pulsatile applications to c.) large-scale or complex pulsatile flow applications. The students will also learn how to calculate mechanical forces on cardiovascular tissue (blood vessels, the heart) and cardiovascular cells (endothelial cells, platelets, red and white blood cells), and the effects of those forces. Lastly, the students will learn various methods for modeling cardiac function. When applicable, students will apply these concepts to the design and function of selected medical devices (heart valves, ventricular assist devices, artificial lungs).

42-661 Surgery for Engineers
Spring: 9 units
This course explores the impact of engineering on surgery. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. A number of visits to the medical center are anticipated for hands on experience with a number of technologies utilized by surgeons to demonstrate the result of advances in biomedical engineering. These experiences are expected to include microvascular surgery, robotic surgery, laparoscopic, and endoscopic techniques. Tours of the operating room and shock trauma unit will be arranged. If possible observation of an operative procedure will be arranged (if scheduling permits). Invited surgeons will represent disciplines including cardiovascular surgery, plastic and reconstructive surgery, surgical oncology, trauma surgery, minimally invasive surgery, oral and maxillofacial surgery, bariatric surgery, thoracic surgery, orthopedic surgery, and others. The Primary Instructor is Howard Edington, M.D., MBA System Chairman of Surgery, Allegheny Health Network. This course meets once a week for 3 hours. Several sessions will be held at the Medical Center, transport provided. Pre-requisite: Physiology 42-202 and one of the introductory engineering courses, 42-101, 06-100, 12-100. 18-100, 19-101, 24-101, or 27-100 Priority for enrollment is given to BME Graduate students and additional majors, followed by BME minors.

42-663 Computational Methods in BME
Spring: 12 units
This goal of this course is to enable students with little or no programming background to solve simple computational problems in science and engineering. Emphasis will be placed on enabling students to use currently available numerical methods (rather than developing anew) to solve engineering problems. Upon completing the course, the successful student will be able to use basic knowledge regarding computer architecture, data types, binary arithmetic, and programming, to solve sample quantitative problems in engineering. Topics will include: solving linear systems of equations, model fitting using least squares techniques (linear and nonlinear), data interpolation, numerical integration and differentiation, solving differential equations, and data visualization. Specific example computations in each topic above will be drawn from problems in physics, chemistry, as well as signal and image processing, and biomedical engineering. Students will work independently in groups for a final project. Matlab will be used as the programming language/environment for this class, although different languages such as C, Java, and Python will be briefly discussed (time permitting). May count as practicum for practicum-option MS. Pre-requisite: Calculus, multivariate calculus, linear algebra, and differential equations

42-664 Bioinstrumentation
Intermittent: 9 units
This course aims to build the foundation of basic principles, applications and design of bioinstrumentation. Topics covered include biosignals recording, transducers for biomedical application, action potentials EMG, EEG, ECG, amplifiers and signal processing, blood flow and pressure measurements, data acquisition and signal conditioning, spectral analysis of data, filtering, and safety aspects of electrical measurements. Ultimately, students will learn (1) how to apply basic circuit theory to perform measurement of biosignals, (2) be familiar and use common measurement devices, such as multimeter and oscilloscope, (3) be familiar with Op-amps circuits, (4) how to acquire and analyze a signal using time and frequency techniques, and (5) how to filter a signal to remove noise. Pre-requisite: Physics II (E&M)

42-670 Special Topics: Biomaterial Host Interactions in Regenerative Medicine
Fall: 12 units
Special Topics: This course will provide students with hands-on experience in investigating host responses to synthetic and naturally biomaterials used in regenerative medicine applications. Students will gain experience in the analysis of host responses to these biomaterials as well as strategies to control host interaction. Biomaterial biocompatibility, immune interactions, tissue healing and regeneration will be addressed. Students will integrate classroom lectures with laboratory skills evaluating host-material interactions in a laboratory setting. Laboratory characterization techniques will include cell culture techniques, microscopic, cytochemical, immunocytochemical and histological analyses. Prerequisite: junior or senior standing in Biomedical Engineering or consent of the instructor.

42-671 Precision Medicine for Biomedical Engineers
Fall: 9 units
This course explores the opportunities for engineers in precision medicine of complex medical disorders. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. The course will focus on common complex conditions and diseases such as inflammatory bowel disease (IBD), pancreatitis, diabetes mellitus and obesity, rheumatoid arthritis, multiple sclerosis, pain syndrome and pharmacogenetics. Improvement in care of these conditions requires a reverse engineering approach, and new tools because of the complexity and unpredictability of clinical course and best treatments on a case-by-case basis. Currently, the cost of medications for these conditions in Pittsburgh alone is >1 billion, with a large percent of patients receiving less than optimal treatment because of lack of precision medicine tools. The course includes introduction to medical genetics, biomarkers of disease, health records, disease modeling, outcome predictions, therapies, remote monitoring and smart applications. Special lectures on health economics and career opportunities are also planned. Each session will include didactic lectures, workshops and development of applications. Specific engineering topics which may be relevant to each of these specialties as well as topics which span many specialties (for example biodetectors, computational biology, bioinformatics, UI/UX, gaming ideas to connect patients to products, integrated applications) will be presented by various faculty members of the CMU biomedical engineering and other dept. and UPMC/UPitt faculty. Students will gain experience exploring genetic variants associated with common diseases, including the opportunity to explore their own DNA. Instructors: David C. Whitcomb, MD, PhD (UPMC) Philip Empey, PharmD, PhD (UPMC)

42-672 Fundamentals of Biomedical Imaging and Image Analysis
Spring: 12 units
This course introduces fundamentals of biological and medical imaging modalities and related image analysis techniques. It is organized into three units. The first unit introduces fundamental principles of biological imaging modalities, such as fluorescence microscopy, super-resolution microscopy, and electron microscopy. These modalities are used to visualize and record biological structures and processes at the molecular and cellular levels. The second unit introduces fundamental principles of imaging modalities, such as magnetic resonance imaging, x-ray computed tomography, and ultrasound. These modalities are used to visualize and record medical structures and processes at the tissue and organ levels. Recent developments in convergence of biological and medical imaging are briefly discussed. The third section introduces fundamentals of computational techniques used for analyzing and understanding biological and medical images, such as deconvolution, registration, segmentation, tracking, and pattern recognition. The introduction to these topics will draw on concepts and techniques from several related fields, including physics, statistics, signal processing, computer vision, and machine learning. As part of the course, students will complete several independent projects. Students will also have the opportunity to visit laboratories to see some of the actual biomedical imaging devices in action. Prerequisites: 18-290 Signals and Systems or permission of the instructor. Proficiency in basic programming is expected. Knowledge of image processing, computer vision, and/or MATLAB is helpful but not essential.

42-673 Special Topics: Stem Cell Engineering
Intermittent: 9 units
Special Topics: This course will give an overview over milestones of stem cell research and will expose students to current topics at the frontier of this field. It will introduce students to the different types of stem cells as well as environmental factors and signals that are implicated in regulating stem cell fate. The course will highlight techniques for engineering of stem cells and their micro-environment. It will evaluate the use of stem cells for tissue engineering and therapies. Emphasis will be placed on discussions of current research areas and papers in this rapidly evolving field. Students will pick a class-related topic of interest, perform a thorough literature search, and present their findings as a written report as well as a paper review and a lecture. Lectures and discussions will be complemented by practical lab sessions, including: stem cell harvesting and culture, neural stem cell transfection, differentiation assays, and immunostaining, polymeric microcapsules as advanced culture systems, and stem cell integration in mouse brain tissue. The class is designed for graduate students and upper undergraduates with a strong interest in stem cell biology, and the desire to actively contribute to discussions in the class.

42-674 Special Topics: Engineering for Survival: ICU Medicine
Intermittent: 9 units
Special Topics: Engineering for Survival: ICU Medicine The overall learning objective of this class is to expose students to acute care medicine and the fundamentals of acute illness. The lectures review the structure and function of different body systems. Typical modes of failure (disease) are then described and illustrated with examples using actual de-identified cases based on over 30 years of experiences in the intensive care unit (ICU) by Dr. Rosenbloom. Field trips are made to a local critical care and emergency medicine simulation facility at the University of Pittsburgh. An optional opportunity to participate in ICU rounds is also available.
Requirements: Junior standing and higher

42-676 Bio-nanotechnology: Principles and Applications
Fall: 9 units
"Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of biological applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nanomaterials in cancer therapy."

42-678 Medical Device Innovation
Spring: 6 units
The increasing pace of medical discoveries and emerging technologies presents a unique and exciting time for medical devices. Medical devices range from biomaterials that stimulate the body to repair itself to drug eluting stints to robotic surgical systems. Because they seek to improve and prolong human health, there are unique requirements and challenges for medical device development compared to most other industries. This class will look at how medical device innovation is currently practiced as well as the drivers which govern it, such as the FDA, intellectual property, reimbursement, and funding. By the end of this course, students should be able to: (1) obtain a broad understanding of medical devices; (2) identify new product opportunities; (3) understand the drivers that affect medical device development; and (4) develop strategies to address those drivers within the overall medical device development plan.

42-679 Medical Device Realization
Spring: 6 units
This course is a companion to 42-678, Medical Device Innovation, which is a pre-requisite for this course. Medical Device Realization will take the research and early conceptualization work in 42-678and use it to further conceptualize and develop a prototype.
Prerequisites: 42-678 or 49-732

42-681 Engineering and Analysis of Complex Disease Models
Spring: 9 units
One of the key challenges in the fields of tissue engineering and disease modelling is a disconnect between the use of robust bioengineering tools and our limited understanding of pathobiology. The future of these fields depends on biomedical engineers using their technical skill sets to study normal physiology and disease mechanisms. In this class, we will explore current state-of-the-art methods for creating tissue and disease models, including: 2D/3D tissue cultures, bioreactors, organs-on-a-chip, microfluidic models, disease-in-a-dish models (with discussions on coupling multiple tissue systems), animal models of disease, and CRISPR/CAS9. The first few weeks of the semester will focus on learning the state-of-the-art methods with 1 exam as an assessment. The rest of the class will focus on specific disease modules with journal reviews and experts sharing their research on disease models with the class. For assessment, students will read 1 journal article each week and provide a brief critique. In addition, they will write a grant and present to the class methods for creating a disease model of their choice. At the end of the class, students will be able to critically assess and design models of normal and pathobiological disease mechanisms. Prior knowledge of basic physiology is required.

42-682 Bioinstrumentation and Measurement
Fall: 12 units
This course aims to build the understanding of basic concepts and applications of instrumentation used for biomedical research and patient care. The course will follow a fast track, using a flipped format to cover components ranging from simple resistors, capacitors, transistors, sensors, actuators, to operational amplifiers and microcontrollers, using a combination of lectures, guided tutorials, lab exercises, and term projects. Students will gain hands-on skills of how to integrate components into functional instruments, based on physiological measurements such as temperature, humidity, oxygen concentration, blood pressure, and EKG signals. MATLAB programming will be used throughout the course. The course is designed for advanced undergraduate and graduate students with a knowledge in basic physics of electricity and magnetism.

42-683 Introduction to Machine Learning for Biomedical Engineers
Fall: 9 units
This course introduces fundamental concepts, methods and applications in machine learning and datamining. We will cover topics such as parametric and non-parametric learning algorithms, support vector machines, neural networks, clustering, clustering and principal components analysis. The emphasis will be on learning high-level concepts behind machine learning algorithms, and applying them to biomedical-related problems. This course is intended for advanced undergraduate and graduate students in Biomedical Engineering or related disciplines. Students should have experience with high-level programming language such as Matlab, basic familiarity with probability, statistics and linear algebra, and should be comfortable with manipulating vectors and matrices.

42-684 Principles of Immunoengineering and Development of Immunotherapy Drugs
Fall: 9 units
This course will provide context for the application of engineering principles to modulate the immune system to approaches problems in human health. Basic understanding of the components and function of the innate and adaptive immune system. Students will leave with a basic understanding of immunology and of the engineering techniques used to develop and characterize immunotherapy systems. Where appropriate, we will discuss how immunoengineering fits into other disciplines of engineering such as mechanical, chemical, and materials science. Because the purpose of immunoengineering is disease treatment, we will discuss, the therapy pipeline, development of clinical trials and the FDA approval process. Immunotherapy will also be assessed within different disease contexts including cancer, infectious disease, allergies, prosthetics and implants, neuro and musculoskeletal disorders.

42-713 Applied Nanoscience and Nanotechnology
Fall and Spring: 12 units
Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nano materials in cancer therapy. Pre-requisite: Graduate standing. College level chemistry or physical chemistry, and thermodynamics.

42-735 Medical Image Analysis
Spring: 12 units
Students will gain theoretical and practical skills in medical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Student will develop practical experience through projects using the National Library of Medicine Insight Toolkit (ITK), a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with clinicians at UPMC. It is possible that a few class lectures may be videoed for public distribution. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python. Required textbook, "Machine Vision", ISBN: 052116981X; Optional textbook, "Insight to Images", ISBN: 9781568812175.
Prerequisite: 03-121

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

42-737 Biomedical Optical Imaging
Fall: 12 units
Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants.

42-772 Special Topics: Applied Nanoscience and Nanotechnology
Fall: 12 units
Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nano materials in cancer therapy. Pre-requisite: Graduate standing. College level chemistry or physical chemistry, and thermodynamics.

42-773 Special Topics: Inventive Problem Solving in Biomedical Engineering
Fall: 12 units
This course is aimed at discovering inventive solutions to some of medicines most difficult problems. It involves a theory of inventive problem solving known as Triz that teaches the student how to invent on demand. The structure of the course will follow a flipped classroom model: with reading assignments and pre-recorded lectures assigned before class and homework performed in-class. This will allow students to learn the material at their own pace, and to translate theory to practice in a group setting with mentorship of the course instructor and teaching assistant, and teamwork of classmates. Throughout the semester, specific problems will be assigned to the entire class on topics emphasizing cost saving (affordable health care act), medicine for under-resourced settings, and global health. A final project will be required of each student on a topic of choice (with instructor approval.) Each project will have an associated client from industry or healthcare who will serve as outside reviewer. The composition of the class will emphasize biomedical engineering students, but will also invite a limited enrollment of students from the School of Design, Tepper, and Heinz. Accordingly, there will be emphasis on multi-disciplinary teamwork, and networking. In summary, the goals of this course are to: develop formal skills in inventive problem solving, gain proficiency in teamwork and networking, and to actually solve real-world problems in medicine. May count as practicum for practicum-option MS. Pre-requisite: Graduate standing for MCS and CIT students. For non-MCS or CIT graduate students, a degree in a science or engineering. For all other students, permission of the instructor.

42-774 Special Topics: Introduction to Biophotonics
Fall: 12 units
Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. Pre-requisite: Graduate standing. College level physics covering electromagnetism and optics or permission of the instructor.

Department of Chemical Engineering

Anne Skaja Robinson, Head
Office: Doherty Hall 1107
www.cmu.edu/cheme

Chemical engineering is a broad discipline based on chemistry, mathematics, physics and biology. Chemical engineers work collaboratively toward the development and commercialization of new products and processes by applying principles of *chemical engineering science* and *process systems engineering*. Chemical engineering science refers to the data and models that help the chemical engineer understand and predict the transport and transformation of chemicals in processes. Process systems engineering provides methodologies for the systematic design, control, operations and analysis of these processes, as well as their economic evaluation, safety and environmental assessment.

The chemical engineering profession offers challenging and well-compensated careers in numerous industries, including high-technology areas. Chemical engineers design safe, efficient and environmentally friendly chemical processes, supervise the operation of chemical plants, and develop new products and processes. In the chemicals and petroleum industry, chemical engineers develop catalysts and new reaction and separation units to improve yields in the production of fuels and commodity chemicals. Chemical engineers are also found in industries associated with polymers (plastics and resins) and coatings (paint, integrated circuits, magnetic tapes). The pharmaceutical industry recruits chemical engineers who possess expertise in both process engineering and biochemistry/molecular biology. In the semiconductor industry, chemical engineers supervise the processing of complex polymers, chip fabrication and production of thin films. Many consulting companies seek chemical engineers for evaluation of the economic feasibility of industrial projects, and for software development for the design, analysis and operation of chemical processes. Finally, the depth and breadth of coursework makes chemical engineering an excellent preparatory major for students interested in medical and business schools.

The department emphasizes ethical problem-solving techniques in the learning of basic principles in chemical engineering science and process systems engineering. Computing is integrated throughout the curriculum and extensive use is made of software for mathematical modeling and simulation in the department's Gary J. Powers Educational Computer Lab. The Robert Rothfus Laboratory and Lubrizol Analytical Laboratory feature hands-on experiments that illustrate applications in safety, environmental, product development, and computerized data acquisition and control. In addition to several engineering minors, the Colloids, Polymers and Surfaces option is also available, as well as a minor in Manufacturing Management and Consulting, and the double major in Biomedical and Health Engineering.

Program Educational Objectives and Student Outcomes

Program Educational Objectives: The objectives for the program are that within a few years after graduation, graduates will obtain employment or attend graduate school, will advance in their chosen careers, and will be productive and fulfilled professionals. The curriculum and programs are developed to prepare students to attain these educational objectives.

Students majoring in chemical engineering learn the science and engineering that govern chemical processing systems. Fundamental principles, problem solving, systems analysis and design, development of self-confidence, and communication skills are emphasized. Students are made aware of modern tools, industrial needs and societal issues. The curriculum emphasizes the acquisition of knowledge in basic science and mathematics during the first three semesters, acquisition and exercise of knowledge about engineering science in the next three semesters, and acquisition of knowledge and experience with chemical engineering design in the final two semesters. Moreover, lab courses emphasize projects where students work on innovate ideas and decide what equipment to build or use in order to carry out those ideas. This combination of fundamental knowledge and practical skills provides a firm foundation for future learning and career growth. The goal of the department is to produce students who will become leaders in their careers.

Student Outcomes: The Program has adopted the Student Outcomes listed in the 2018-2019 Criteria for Accrediting Engineering Programs. Students who complete the curriculum will have attained the following outcomes:

- an ability to apply knowledge of mathematics, science, and engineering
- an ability to design and conduct experiments, as well as to analyze and interpret data
- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- an ability to function on multidisciplinary teams
- an ability to identify, formulate, and solve engineering problems
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a recognition of the need for, and an ability to engage in, life-long learning
- a knowledge of contemporary issues
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The department offers a number of special programs for students majoring in Chemical Engineering. In addition to the double majors offered by the College of Engineering such as Biomedical Engineering and Engineering & Public Policy, students may choose from a variety of minors in technical areas offered by the College of Engineering. Undergraduate research projects are also available in the areas of bioengineering, complex fluids engineering, environmental engineering, process systems engineering, and catalysis & surface science. The department has recently established the Chemical Engineering Summer Scholars (ChESS) program to support undergraduate research within the department. Students may participate in study abroad programs during their Junior year. In addition to the University program with EPFL in Switzerland and ITESM Monterey in Mexico, the department provides its own exchange programs with Yonsei University in Seoul, Korea, RWTH Aachen in Germany, Universidad Nacional del Litoral in Argentina, and Imperial College in London, Great Britain. Students may also participate in Practical Internships for Senior Chemical Engineering Students, a one-year industrial internship program offered between the Junior and Senior years. Finally, qualified students may enroll in our Master of Chemical Engineering program. This degree is typically completed in the fifth year. However, depending on the number of advanced placement courses and course load at Carnegie Mellon, this degree could be awarded during the B.S. graduation, or after one additional semester.

Curriculum

Minimum units required for B.S. in Chemical Engineering 389

The program in chemical engineering within the Department of Chemical Engineering is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

First Year

Fall		Units
21-120	Differential and Integral Calculus	10
76-xxx	Designated Writing/Expression Course	9
99-101	Computing @ Carnegie Mellon	3
06-100	Introduction to Chemical Engineering	12
09-105	Introduction to Modern Chemistry I	10
		44

Spring		Units
21-122	Integration and Approximation	10
xx-xxx	Introductory Engineering Elective (other than ChE)	12
33-141	Physics I for Engineering Students	12
xx-xxx	General Education Course	9
		43

Second Year

Fall		Units
21-259	Calculus in Three Dimensions	9
06-221	Thermodynamics	9
06-222	Sophomore Chemical Engineering Seminar	1
09-106	Modern Chemistry II	10
xx-xxx	Computer Sci./Physics II *	10-12
xx-xxx	General Education Course	9
39-210	Experiential Learning I	0
		48-50

Spring		Units
06-261	Fluid Mechanics	9
06-262	Mathematical Methods of Chemical Engineering	12
09-221	Laboratory I: Introduction to Chemical Analysis	12
xx-xxx	Physics II/Computer Sci. *	12-10
xx-xxx	General Education Course	9
39-220	Experiential Learning II	0
		54-52

* Computer Science/Physics II: Students should complete 15-110 Principles of Computing or 15-112 Fundamentals of Programming and Computer Science as well as 33-142 Physics II for Engineering and Physics Students by the end of the Sophomore year. The recommended sequence is 33-141 /33-142 for engineering students, however, 33-151/ 33-152 will also meet the CIT Physics requirement.

For those students who have not taken 06-100 as one of the two Introductory Engineering Electives, 06-100 should be taken in the Fall Semester of the Sophomore year. The General Education Course normally taken during that semester may be postponed until the Junior year. These students should consult with their faculty advisors as soon as possible.

At the end of the Sophomore year, a student should have completed the following required basic science and computer science courses:

09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12
99-10x	Computing @ Carnegie Mellon	3

Third Year

Fall		Units
06-321	Chemical Engineering Thermodynamics	9
06-322	Junior Chemical Engineering Seminar	2
06-323	Heat and Mass Transfer	9
09-217	Organic Chemistry I	9
or 09-219	Modern Organic Chemistry	
09-347	Advanced Physical Chemistry	12
xx-xxx	General Education Course	9
39-310	Experiential Learning III	0
		50

Spring		Units
06-361	Unit Operations of Chemical Engineering	9
06-363	Transport Process Laboratory	9
06-364	Chemical Reaction Engineering	9
03-232	Biochemistry I **	9
xx-xxx	Unrestricted Elective	9
xx-xxx	General Education Course	9
		54

Fourth Year

Fall		Units
06-421	Chemical Process Systems Design	12
06-423	Unit Operations Laboratory	9
xx-xxx	Unrestricted Elective	9
xx-xxx	Unrestricted Elective	9
xx-xxx	General Education Course	9
		48

Spring		Units
06-462	Optimization Modeling and Algorithms	6
06-463	Chemical Product Design	6
06-464	Chemical Engineering Process Control	9
xx-xxx	Unrestricted Elective	9
xx-xxx	Unrestricted Elective	9
xx-xxx	General Education Course	9
		48

** Students pursuing a Chemical Engineering/Engineering and Public Policy double major are waived from taking the Biochemistry Elective. They will take 36-220.

Notes:

1. In addition to the graduation requirement of an overall QPA of 2.0 (not counting the First Year), the Department of Chemical Engineering requires a cumulative QPA of 2.0 in all chemical engineering courses (all those numbered 06-xxx).
2. Minimum number of units required for graduation: 389.
3. All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
4. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.
5. Overloads are permitted only for students maintaining a QPA of 3.5 or better during the preceding semester.
6. Electives: To obtain a Bachelor of Science degree in Chemical Engineering, students must complete 06-100 and one other Introductory Engineering Elective. There are also five Unrestricted Electives. Students must discuss choice of electives with their faculty advisors.
7. Undergraduate Research: Independent research projects are available by arrangement with a faculty advisor. Many students conduct these research projects for elective credit by enrolling in 06-200, 06-300, or 06-400 (Sophomore, Junior, or Senior Research Projects) or 39-500 Honors Research Project for eligible Seniors.
8. Advanced undergraduates may also take Chemical Engineering graduate courses (600+ level).

Double Major in Engineering and Public Policy (EPP)

Students may pursue a double major in Chemical Engineering and EPP. This double major is built around electives in Social Analysis, Probability and Statistics courses, and projects. Specific course choices should be discussed with a faculty advisor and an EPP advisor.

Double Major in Biomedical Engineering (BME)

Students may pursue a double major in Chemical Engineering and BME. Specific course choices should be discussed with a faculty advisor and a BME advisor.

Minors with a B.S. in Chemical Engineering

Chemical Engineering students are eligible for any CIT Designated Minor. Those minors that are especially well suited to Chemical Engineers include Audio Engineering, Automation and Controls, Biomedical Engineering, Colloids, Polymers & Surfaces, Electronic Materials, Environmental Engineering, Global Engineering, Manufacturing Engineering, Materials Science and Engineering, Mechanical Behavior of Materials, and Robotics. The minor requirements may be fulfilled with electives. Other minors, such as the Supply Chain Management minor in association with the Tepper

School of Business, are also available outside of CIT. These should be discussed with a faculty advisor.

Colloids, Polymers and Surfaces Minor

Dr. Ilhem Hakem, *Director*
Location: Doherty Hall 3207

The sequence of courses in the Colloids, Polymers and Surfaces (CPS) designated minor provides an opportunity to explore the science and engineering of fine particles and macromolecules as they relate to complex fluids and interfacially engineered materials. These topics are very relevant to technology and product development in industries that manufacture pharmaceuticals, coatings and paints, pulp and paper, biomaterials, surfactants and cleaning products, cosmetics and personal care products, food, textiles and fibers, nanoparticles, polymer/plastics, composite materials.

Course Requirements

Minimum units required for minor:	45

This minor requires a total of five classes with a minimum of 45 units. The following four courses are mandatory:

06-609/09-509	Physical Chemistry of Macromolecules	9
06-607	Physical Chemistry of Colloids and Surfaces	9
06-426	Experimental Colloid Surface Science	9
06-466	Experimental Polymer Science	9

In addition, the student must take one CPS related elective course from the following list:

06-612	Formulation Engineering	12
06-610	Rheology and Structure of Complex Fluids	9
09-502	Organic Chemistry of Polymers	9
27-565	Nanostructured Materials	9
27-588	Polymer Physics and Morphology	9

Other CPS electives are possible but must be approved by the Director of the CPS minor, Dr. Hakem

Practical Internships for Senior Chemical Engineering Students (PISCES)

Chemical Engineering students may apply in the fall of their Junior year for a salaried, one-year PISCES internship with a partner company. Admitted students begin their internships after completion of the Junior year. Following the internship, students return to complete their Senior year. There are several advantages of a one full-year internship, including the opportunity to gain a breadth of professional experience that is not generally possible in a shorter program, more opportunity to make important contributions to the partner company, and the opportunity to complete Senior year courses in their normal sequence with no need for curriculum rearrangements. Interested students should consult with their faculty advisors.

International Chemical Engineering Exchange Programs

Chemical Engineering students may apply during their Sophomore year to spend their Junior year at RWTH Aachen in Germany, Yonsei University in Seoul, Korea, Universidad Nacional del Litoral in Argentina, or at Imperial College in London, Great Britain. A summer exchange program in Dortmund, Germany is also available. These exchange programs provide a great opportunity for students to obtain international experience while taking courses very similar to those offered at Carnegie Mellon. Students considering any of these programs should consult with their faculty advisors, and students considering the Aachen program in particular are advised to take at least one introductory German course before or during their Sophomore year.

Fifth Year Master of Chemical Engineering (MChE)

The CIT Integrated Masters/Bachelors (IMB) Degree program provides the opportunity for qualified undergraduate students to obtain a master's degree in Chemical Engineering with one or two extra semesters of study. The goal is to deepen our graduates' understanding of the fundamentals of chemical engineering, and to provide them with a broader set of professional skills or to expose them to other technical disciplines.

The MChE program is aimed at undergraduate students from Carnegie Mellon and candidates from other universities. Unfortunately, no financial support is available. For Carnegie Mellon students, the degree typically would be completed in their fifth year. Depending on advanced placement and semester overloads, however, CMU students can complete the degree at the time of the B.S. graduation or with one additional semester. All students must have graduate status once they have completed their B.S. degree; beyond eight semesters, degree program students must have full-time graduate student status in at least one (e.g., their final) semester whether or not they have already completed their BS degree. Upon graduating from this program, students seek industrial positions or placement in graduate programs at other universities. Students in the MChE program may apply for the PhD program at Carnegie Mellon University via the normal application process. Their applications are considered alongside all the other applications received that year. If accepted into the PhD program, they enter it after completing the MChE degree.

A minimum of five completed semesters in residence as an undergraduate student and an overall QPA of 3.0 is required for eligibility. Taking the GRE and recommendation letters are not required. The application fee is waived for currently-enrolled undergraduate Chemical Engineering students.

The MChE program differs from the MS program because the MChE program does not require a project report or thesis.

Research and Teaching Faculty

SHELLEY ANNA, Professor of Chemical Engineering – Ph.D., Harvard University; Carnegie Mellon, 2003–

LORENZ T. BIEGLER, University Professor and Bayer Professor of Chemical Engineering – Ph.D., University of Wisconsin; Carnegie Mellon, 1981–

KRIS N. DAHL, Professor of Chemical Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2006–

MICHAEL M. DOMACH, Professor of Chemical Engineering – Ph.D., Cornell University; Carnegie Mellon, 1983–

NEIL M. DONAHUE, Lord Professor of Chemistry and Chemical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000–

ANDREW J. GELLMAN, Lord Professor of Chemical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

CHRYSANTHOS GOUNARIS, Associate Professor of Chemical Engineering – Ph.D., Princeton University; Carnegie Mellon, 2013–

IGNACIO E. GROSSMANN, University Dean Professor of Chemical Engineering – Ph.D., Imperial College, University of London; Carnegie Mellon, 1979–

ILHEM-FAIZA HAKEM, Assistant Teaching Professor – Ph.D., Tlemcen Universitiy; Carnegie Mellon, 2018–

ANNETTE M. JACOBSON, Teaching Professor of Chemical Engineering and Director of Colloids, Polymers, and Surfaces Program – Ph.D., Carnegie Mellon; Carnegie Mellon, 1988–

COTY JEN, Assistant Professor of Chemical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2018–

MYUNG S. JHON, Emeritus, Professor of Chemical Engineering – Ph.D., University of Chicago; Carnegie Mellon, 1980–

ADITYA KHAIR, Professor of Chemical Engineering – PhD, California Institute of Technology; Carnegie Mellon, 2010–

JOHN KITCHIN, Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 2006–

SPYROS N. PANDIS, Research Professor of Chemical Engineering and Engineering and Public Policy – Ph.D., California Institute of Technology; Carnegie Mellon, 1993–

DENNIS C. PRIEVE, Emeritus, Gulf Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1974–

ANNE SKAJA ROBINSON, Professor of Chemical Engineering. Head of Department – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2019–

ALAN RUSSELL, Highmark Distinguished Career Professor of Chemical Engineering – Ph.D., Imperial College, London; Carnegie Mellon, 2012–

NIKOLAOS V. SAHINIDIS, John E. Swearingen Professor of Chemical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2007–

JAMES W. SCHNEIDER, Professor of Chemical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 1999–

PAUL J. SIDES, Emeritus, Professor of Chemical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1981–

JEFFREY J. SIIROLA, Distinguished Service Professor – PhD, University of Wisconsin; Carnegie Mellon, 2011–

SUSANA C. STEPPAN, Associate Teaching Professor – PhD, University of Massachusetts; Carnegie Mellon, 2004–

ROBERT D. TILTON, Chevron Professor of Chemical Engineering – Ph.D., Stanford University; Carnegie Mellon, 1992–

ZACHARY ULISSI, Assistant Professor of Chemical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–

LYNN M. WALKER, Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1997–

ELIZABETH WAYNE, Assistant Professor of Chemical Engineering – PhD, Cornell; Carnegie Mellon, 2019–

ARTHUR W. WESTERBERG, Emeritus, University Professor of Chemical Engineering – Ph.D., DIC, Imperial College, University of London; Carnegie Mellon, 1976–

KATHRYN WHITEHEAD, Associate Professor of Chemical Engineering – Ph.D., University of California; Carnegie Mellon, 2012–

B. ERIK YDSTIE, Professor of Chemical Engineering – Ph.D., Imperial College, University of London; Carnegie Mellon, 1992–

Department of Chemical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

06-100 Introduction to Chemical Engineering
Fall and Spring: 12 units
We equip students with creative engineering problem-solving techniques and fundamental chemical engineering material balance skills. Lectures, laboratory experiments, and recitation sessions are designed to provide coordinated training and experience in data analysis, material property estimation for single- and multi-phase systems, basic process flowsheet, reactive and non-reactive mass balances, problem solving strategies and tools, and team dynamics. The course is targeted for CIT First Year students.

06-200 Sophomore Research Project
Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-221 Thermodynamics
Fall: 9 units
This course introduces students to the process thermodynamics of single component systems. Topics include equilibrium and thermodynamic state variables; heat and work; conservation of energy and the first law of thermodynamics; entropy balances and the second law of thermodynamics; reversibility; free energies; interconversion of heat and work via engines, refrigeration and power cycles; absolute temperature and the third law of thermodynamics; equations of state; principle of corresponding states; thermodynamic property relationships; changes of state; phase equilibrium and stability in single component systems; vapor pressure and phase transition.
Prerequisites: (33-106 and 06-100) or (33-141 and 06-100) or (33-151 and 06-100) or (33-121 and 06-100)

06-222 Sophomore Chemical Engineering Seminar
Fall: 1 unit
This course provides an overview of the chemical engineering profession. It discusses the rationale for the curriculum, career paths, resume writing, written communication skills, and ethics, and also involves a project on the use and manufacture of chemicals.

06-261 Fluid Mechanics
Spring: 9 units
The principles of fluid mechanics as applied to engineering, including unit operations, are discussed; examples include flow in conduits, process equipment, and commercial pipes, flow around submerged objects, and flow measurement. Microscopic mass and momentum balances are described, including the continuity and Navier-Stokes equations, and modern solution techniques will be explored. Microscopic flow structures will be determined for flow visualization. Boundary layer theory, turbulence, and non-Newtonian fluids are also discussed. A case-study project based on new technological advancements is also required.
Prerequisites: 21-259 and 06-100

06-262 Mathematical Methods of Chemical Engineering
Spring: 12 units
Mathematical techniques are presented as tools for modeling and solving engineering problems. Modeling of steady-state mass and energy balance problems using linear and matrix algebra, including Gaussian elimination, decomposition, and iterative techniques. Modeling of unsteady-state engineering problems using linear and nonlinear differential equations. Analytical techniques, including Laplace transforms, and numerical techniques for the solution of first-and higher-order differential equations and systems of differential equations arising in engineering models. Finally, the modeling of processes affected by chance and subject to experimental error; statistical and regression techniques within the context of experimental design and analysis of experimental data.
Prerequisites: 06-221 and 06-100 and 21-122 Min. grade C

06-300 Junior Research Project
Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-321 Chemical Engineering Thermodynamics
Fall: 9 units
The objective of this course is to cover principles and solution techniques for phase and chemical equilibria in multicomponent systems. Topics include thermodynamic properties of ideal and non-ideal mixtures; criteria for equilibrium; chemical potential, fugacity and activity coefficients; flash calculations; Gibbs energy minimization; thermodynamics of chemical reactions including equilibrium conversions.
Prerequisite: 06-221

06-322 Junior Chemical Engineering Seminar
Fall: 2 units
This course discusses career choices for chemical engineers, professional practice, including alternate career paths, global industry, and graduate studies. It also emphasizes writing, interview skills, and oral presentations. Safety, environmental and ethical issues are illustrated in projects and via invited lectures.

06-323 Heat and Mass Transfer
Fall: 9 units
This course presents the fundamentals of heat and mass transfer, including steady-state and transient heat conduction and molecular diffusion, convection of heat and mass, and thermal radiation, with application to heat and mass transfer processes. Development of dimensionless quantities for engineering analysis is emphasized.
Prerequisites: 06-261 and (06-262 or 21-260)

06-361 Unit Operations of Chemical Engineering
Spring: 9 units
This course comprises many of the standard operations in chemical plants such as gas absorption, heat exchange, distillation and extraction. The design and operation of these devices is emphasized. A project dealing with a novel unit operation is also investigated.
Prerequisites: 06-321 and 06-323

06-363 Transport Process Laboratory
Spring: 9 units
Develop skills for proposing, designing, planning, implementing, interpreting, and communicating the results of experiments in fluid flow and heat and mass transfer. Oral and written reports are required.
Prerequisites: 06-261 and 06-323

06-364 Chemical Reaction Engineering
Spring: 9 units
Fundamental concepts in the kinetic modeling of chemical reactions, the treatment and analysis of rate data. Multiple reactions and reaction mechanisms. Analysis and design of ideal and non-ideal reactor systems. Energy effects and mass transfer in reactor systems. Introductory principles in heterogeneous catalysis.
Prerequisites: 06-321 and 06-323 and 09-347

06-365 Water Technology Innovation and Policy
Spring: 9 units
Innovation in water technologies is necessary to confront profound water resource challenges facing countries around the world. Students successfully completing this course will be able to discuss the factors and conditions that drive innovation in the water sector. Students will begin by describing and classifying the historical drivers for innovation in water treatment, including technical, economic, and regulatory drivers. After an introduction to the fundamental principles of water treatment technologies, students will identify present day technology shortcomings and distill these into discrete design objectives. Students will then formulate and answer quantitative and qualitative questions that respond to these design objectives by leveraging their knowledge of engineering fundamentals, regulatory tools, and pricing policies. Comparing their own solutions with those proposed in the peer-reviewed academic literature in engineering and the social sciences, students will evaluate the technical feasibility, usability, and social desirability of proposed water innovations in developed and developing countries and summarize their findings in policy briefs.
Prerequisites: 12-100 or 06-100 or 19-101 or 19-201

06-400 Senior Research Project
Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-421 Chemical Process Systems Design
Fall: 12 units
Screening of processing alternatives. Computational strategies for preliminary material and energy balances in large chemical processes. Preliminary sizing of process equipment. Cost estimation, economics, and evaluation for chemical plants. Strategies for synthesizing energy networks and separation sequences. Preliminary design of a large industrial project.
Prerequisites: 06-321 and 06-361 and 06-364

06-423 Unit Operations Laboratory
Fall: 9 units
Open-ended laboratory projects illustrate the principles of unit operations in Chemical Engineering. In this course students select, with course staff review, current societal problems to which chemical engineering subject knowledge can be applied. Students work in teams to design and implement an experimental plan to evaluate proposed solutions. Teams must work together to identify constraints and relationships between the unit operations they work on. Students must document implementation feasibility (cost, scheduling, analytic capability, etc.) and clearly identify the criteria and methods for assessing experimental results. Oral and written reports are required.
Prerequisites: 06-361 and 06-364

06-426 Experimental Colloid Surface Science
Fall: 9 units
Laboratory exercises will deal with preparation and stabilization of colloids, flocculation, micellar aggregates, surface tension, contact angle, spreading and adsorption. Basic concepts will be related to practical problems of wetting, lubrication, foaming, adhesion, coatings and corrosion.
Prerequisites: 06-607 and 09-221

06-462 Optimization Modeling and Algorithms
Spring: 6 units
Formulation and solution of mathematical optimization problems with and without constraints. Objective functions are based on economics or functional specifications. Both discrete and continuous variables are considered.
Prerequisite: 06-421

06-463 Chemical Product Design
Spring: 6 units
Computer-aided design of a chemical product. Course involves design of molecular structure, microstructure, or devices/processes that effect chemical change. This is a project-based course, for which an extensive report must be submitted.
Prerequisite: 06-421

06-464 Chemical Engineering Process Control
Spring: 9 units
This course presents basic concepts of process dynamics and feedback control. Included are selection of measurements and manipulated variables, definition of transfer functions, creation of block diagrams and closed loop configurations. The course also covers concepts of open loop and closed loop stability, and tuning of PID controllers.
Prerequisite: 06-262

06-466 Experimental Polymer Science
Spring: 9 units
Macromolecular behavior in bulk and in solution will be explored in experiments on tensile strength, elasticity, swelling of networks, solution viscosity, melt flow, and polymerization reactions. Particular reference will be made to aspects affecting production and fabrication of polymeric materials.
Prerequisites: 09-221 and (06-609 or 09-509)

06-606 Computational Methods for Large Scale Process Design & Analysis
Spring: 9 units
This course deals with the underlying computer-aided design techniques for steady-state and dynamic simulation, numerical solution and decomposition strategies for large systems of sparse nonlinear algebraic equations, stiff ordinary differential equations, strategies for mixed algebraic/differential systems and computer architectures for flowsheeting systems.
Prerequisites: 06-262 and 06-361

Course Website: http://numero.cheme.cmu.edu/course/06606.html

06-607 Physical Chemistry of Colloids and Surfaces
All Semesters: 9 units
Thermodynamics of surfaces; adsorption at gas, liquid, and solid interfaces; capillarity; wetting, spreading, lubrication and adhesion; properties of monolayers and thin films; preparation and characterization of colloids; colloidal stability, flocculation kinetics, micelles, electrokinetic phenomena and emulsions.
Prerequisites: 06-221 and 09-347

06-608 Safety Issues in Science and Engineering Practice
Fall: 3 units
Exposes the students to personal safety issues encountered in normal science and engineering practice. Topics covered include mechanical, electrical, chemical, radiation, and biological hazards, to provide an awareness of these hazards and appropriate action to be taken in the event of an accident.

06-609 Physical Chemistry of Macromolecules
Fall: 9 units
This course develops fundamental principles of polymer science. Emphasis is placed on physio-chemical concepts associated with the macromolecular nature of polymeric materials. Engineering aspects of the physical, mechanical and chemical properties of these materials are discussed in relation to molecular structure. Topics include an introduction to polymer science and a general discussion of commercially important polymers; molecular weight; condensation and addition synthesis mechanisms with emphasis on molecular weight distribution; solution thermodynamics and molecular conformation; rubber elasticity; and the rheological and mechanical properties of polymeric systems. Students not having the prerequisite listed may seek permission of the instructor.
Prerequisite: 09-347

06-610 Rheology and Structure of Complex Fluids
Fall: 9 units
This course will cover the basic concepts of rheology and mechanical behavior of fluid systems. Both the experimental and theoretical aspects of rehology will be discussed. The basic forces influencing complex fluid rheology and rheology will be outlined and discussed; including excluded volume, van der Waals, electrostatic and other interactions. Methods of characterizing structure will be covered including scattering techniques, optical polarimetry and microscopy. Examples will focus on several types of complex fluids including polymer solutions and melts, gelling systems, suspensions and self-assembling fluids.
Prerequisites: 06-609 or 09-509

06-612 Formulation Engineering
Fall and Spring: 12 units
Students will learn the scientific and design principles needed for careers in complex fluid formulation-based industries such as consumer products, pharmaceuticals, paints, agrochemicals or lubricants. The essential science and engineering principles of colloids, surfactants, interfaces and polymer solutions will be introduced. Students will learn to use these principles in combination with experimental measurements and statistical design of experiments tools to design effective liquid product formulations within specified economic, material and even aesthetic constraints. The lecture portion of the course is complemented by weekly lab sessions where student teams will design, prepare, test and improve their own formulations for a commercial complex fluid product, such as a detergent or an ink, that meets performance goals within specified constraints.

06-619 Semiconductor Processing Technology
Spring: 9 units
This is an introductory course to the physical and chemical concepts involved in integrated circuit processing. The material focuses on basic principles in chemical reaction engineering and how they can be applied to integrated circuit process engineering. Students not having the prerequisites listed may seek permission of the instructor.
Prerequisites: 06-364 and 09-347

06-622 Bioprocess Design
Fall and Spring: 9 units
This course is designed to link concepts of cell culture, bioseparations, formulation and delivery together for the commercial production and use of biologically-based pharmaceuticals; products considered include proteins, nucleic acids, and fermentation-derived fine chemicals. Associated regulatory issues and biotech industry case studies are also included. A fair knowledge of cell culture and fermentation operations is assumed.
Prerequisites: 06-621 or 42-621

06-640 Principles and Applications of Molecular Simulation
Fall and Spring: 9 units
This course will introduce modern concepts and methods for simulating physical and thermodynamics properties of materials from atomic-scales, with special emphasis on the gas and liquid states. Strengths and limitations of molecular simulation methods will be discussed. Topics will include basic statistical mechanics, interatomic potentials, Molecular Dynamics methods, Monte Carlo methods, computation of phase coexistence curves, and Brownian Dynamics.
Prerequisites: 06-262 and 06-321

06-679 Introduction to Meteorology
Fall and Spring: 12 units
Provide you with the basics of meteorology, with a focus on large-scale atmospheric motion. By the end of the class you will understand the basics of atmospheric dynamics, including horizontal and vertical motion, as well as the vertical structure of the atmosphere (atmospheric stability and boundary-layer dynamics). You will understand what makes weather happen and you will understand weather maps and charts. You will be able to critically watch the nightly weather forecast and you will be able to access available meteorological databases to make informed predictions of your own. Finally, you will understand atmospheric transport and boundary-layer dynamics, which will serve as a foundation for other coursework involving atmospheric transport and air-pollution if you are pursuing those topics more deeply.

06-708 Advanced Process Dynamics and Control
Spring: 12 units
Modeling and simulation of dynamic behavior of chemical processes. Theoretical and practical aspects of development of optimal and various regulatory control schemes for start-up and continuous process operation. Application of filtering techniques for noisy or estimated data. Process automation.

06-714 Surfaces and Adsorption
Fall and Spring: 12 units
A survey of solid surfaces and gas-solid interactions. Topics include the structure and electronic properties of metal surfaces, the kinetics and thermodynamics of adsorption and desorption processes, and concepts in heterogeneous catalysis. The course emphasizes the application of recent experimental techniques in studying these problems.

06-720 Advanced Process Systems Engineering
Spring: 12 units
A general background on problems, methods, and tools for solving analysis and synthesis problems in process engineering. Formulation and numerical solutions of steady-state and dynamic simulation and optimization problems will be discussed. Insights and solution methods are also covered, based on both heuristics and mixed-integer programming techniques for the synthesis of heat exchanger networks, separation processes, and total process systems.

Department of Civil and Environmental Engineering

David A. Dzombak, Head
Location: Porter Hall 119-D
www.cmu.edu/cee

The role of civil and environmental engineers, in the broadest sense, is to apply science and technology to develop sustainable solutions to meet society's needs. Civil engineers plan, design, construct, and operate infrastructure used daily by the public and industry, such as buildings, transportation networks, water systems, and energy distribution systems. Civil engineers also work to protect public health and the environment. They work at the intersection of the built, natural, and information environments. Today's civil and environmental engineers are also called upon by government and industry to provide leadership on complex technical and societal issues such as demands for infrastructure improvement, remediation of former industrial sites for reuse, renewable energy, climate change adaptation, provision of safe drinking water, smart transportation systems, and sustainable development .

Civil and environmental engineering requires broad technical training and strong communication skills because of the complexity of large projects and the interactions with engineers in other fields, lawyers, public officials, community members, and other stakeholders. Our curriculum provides this versatility for professional practice in civil and environmental engineering and as a strong foundation for other professional pursuits.

The Department of Civil and Environmental Engineering offers a wide spectrum of opportunities for entry into the engineering profession, for graduate education in engineering, or entry into various other graduate and professional fields, including business, law, and medicine. While maintaining its emphasis on the fundamental understanding of the behavior of constructed facilities through the application of the physical sciences, biology, mathematics, and computing, the curriculum has continually evolved in directions that exploit advances in technology. The curriculum introduces the methods of engineering design in the first year and continues to emphasize them throughout the curriculum in both traditional and project-oriented courses. **The basic undergraduate degree program leads to a B.S. in Civil Engineering.** A minor in Environmental and Sustainability Studies is also available.

Central to the evolution of technology and its impact on engineering practice is the modern emphasis on the use of computers in engineering. Several courses on computer methods are required in the curriculum, and most courses offered by the department require the use of computers in applications of either analysis or design.

Our curriculum emphasizes the development of scientific inquiry in the context of applications in civil and environmental engineering. For B.S. graduates who wish to enter the engineering profession directly in such specialties as structural engineering, construction engineering, or environmental engineering, this approach to teaching allows application of the most advanced technological developments. Others who wish to pursue graduate study are prepared to engage in research on the highest level, either in traditional specialties or in emerging fields such as smart infrastructure, climate change adaptation, and micromechanics.

The Civil Engineering curriculum is intended to allow ample opportunity for students to pursue areas of personal interest. A student may choose to concentrate in a specialty area in civil engineering, to pursue a minor in one of the designated minor programs offered in the College of Engineering, or to pursue an additional major. Information on these options follows the description of the curriculum in this section. Students are encouraged to participate in research with department faculty members, explore their chosen field through internships, and take advantage of opportunities to study abroad and be exposed to other cultures.

In addition to providing a solid technical foundation, the program emphasizes the development of professional skills. We incorporate design and team experiences throughout the curriculum, and provide hands-on experience in laboratory and project courses. Students also have multiple opportunities to practice and improve their communication skills through written and oral reports, and team activities.

Two common double major options chosen by students in Civil Engineering are in Biomedical Engineering and in Engineering and Public Policy. Both programs are described in their departments' sections of the catalog. Other double major programs selected by recent graduates include business, computer science, economics, history, mathematics, and foreign languages. Each student should have well-defined objectives in selecting courses leading to a specialty, a minor, or a double major. Faculty mentors and the Director of the Undergraduate Program are available to discuss students' educational goals and help define a path to reach them.

Program Educational Objectives

The Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. The objectives of the Bachelor of Science in Civil Engineering program are to develop graduates who embody the following definitions:

- Graduates distinguish themselves within their organizations as individuals able to provide solutions to a wide range of conventional, cutting-edge, and emerging professional challenges related to one or more of the areas of the built, natural and information environments, considering sustainability principles;
- Graduates are innovative, proactive, and adaptive professionals, highly engaged in their professional communities; graduates are prepared to take on leadership positions within their organizations and communities; and
- Graduates are able to contribute and collaborate on developing solutions to local and global problems; graduates are able to cross geographic, cultural, and traditional discipline boundaries in developing solutions.

The undergraduate Bachelor of Science in Civil Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

By the end of the B.S. program, students should have achieved the following student outcomes:

A. an ability to apply knowledge of mathematics, science and engineering
B. an ability to design and conduct experiments, as well as to analyze and interpret data
C. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
D. an ability to function on multidisciplinary teams
E. an ability to identify, formulate, and solve engineering problems
F. an understanding of professional and ethical responsibility
G. an ability to communicate effectively
H. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
I. a recognition of the need for, and an ability to engage in lifelong learning
J. a knowledge of contemporary issues relevant to engineering practice
K. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The curriculum has been designed, and is periodically evaluated and refined, to provide students instruction and experiences that lead to the development of these abilities and skills.

Curriculum

Minimum units required for B.S. in Civil Engineering 385

Students entering the College of Engineering declare a major near the end of the first year. First-year students take two introductory engineering courses as well as some restricted technical electives within the common foundation specified for first-year engineering students. By the end of the sophomore year, a Civil Engineering major is expected to have completed the Restricted Technical Electives in the following list and 12-100 Exploring CEE: Infrastructure and Environment in a Changing World.

Restricted Technical Electives		Units
09-101	Introduction to Experimental Chemistry	3
09-105	Introduction to Modern Chemistry I	10
15-110	Principles of Computing	10

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	9
21-260	Differential Equations	9
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12

Notes on Math Requirements

1. All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

Sample Curriculum

This section shows the recommended four-year program of study for the BS in Civil Engineering following a typical path. The curriculum for transfer students, students with advanced placement credit, and students planning to study abroad will not follow the same path. Students need to consult the department for appropriate advising and formulation of a plan to complete the degree within eight semesters.

First Year

Fall		Units
12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
21-120	Differential and Integral Calculus	10
33-141	Physics I for Engineering Students	12
99-10x	Computing @ Carnegie Mellon	3
xx-xxx	General Education Course	9
		46

Spring		Units
xx-xxx	Introduction to Engineering (other than CEE)	12
21-122	Integration and Approximation	10
33-142	Physics II for Engineering and Physics Students	12
09-101	Introduction to Experimental Chemistry	3
xx-xxx	General Education Course	9
		46

Sophomore Year

Fall		Units
12-200	CEE Challenges: Design in a Changing World	9
12-212	Statics	9
21-259	Calculus in Three Dimensions	9
15-110	Principles of Computing	10
xx-xxx	General Education Course	9
39-210	Experiential Learning I	0
		46

Spring		Units
12-231	Solid Mechanics	9
12-232	Solid Mechanics Lab	3
12-271	Introduction to Computer Application in Civil & Environmental Engineering	9
21-260	Differential Equations	9
09-105	Introduction to Modern Chemistry I	10
xx-xxx	General Education Course	9
39-220	Experiential Learning II	0
		49

Junior Year

Fall		Units
12-301	CEE Projects: Designing the Built, Natural and Information Environments	9
12-335	Soil Mechanics	9
12-336	Soil Mechanics Laboratory	3
12-355	Fluid Mechanics	9
12-356	Fluid Mechanics Lab	3
36-220	Engineering Statistics and Quality Control	9
xx-xxx	Elective 1	9
39-310	Experiential Learning III	0
		51

Spring		Units
12-351	Environmental Engineering	9
12-352	Environmental Engineering Lab	3
27-357	Introduction to Materials Selection	6
12-358	Materials Lab	3
xx-xxx	Elective 2	9
xx-xxx	Elective 3	9
xx-xxx	General Education Course	9
		48

Senior Year

Fall		Units
12-401	Civil & Environmental Engineering Design *	15
12-411	Project Management for Construction	9
12-421	Engineering Economics	6
xx-xxx	General Education Course	9
xx-xxx	Elective 4	9
		48

* 12-401 will change from 15 units to 12 units starting in Fall 2020.

Spring		Units
xx-xxx	General Education Course	9
xx-xxx	General Education Course	9
xx-xxx	Elective 6	9
xx-xxx	Elective 5	9
xx-xxx	Elective 7	9
xx-xxx	Elective 8	9
		54

Notes on Electives

1. One elective must be in the basic sciences, from the following list:

03-121	Modern Biology	9
12-201	Geology	9

   Substitutions may be made only with the approval of the Department Head.
2. One elective course is restricted to a 600-level Civil Engineering course of at least 9 units, except 12-648 and 12-690. This Civil Engineering elective is a co-requisite for 12-401.
3. **Students are encouraged to take multiple 12-6xx courses to provide them with specific civil and environmental engineering domain depth in their field(s) of interest.**

Specialty Areas in Civil Engineering

Students may select a set of civil engineering and technical electives in the junior and senior years that enable them to concentrate in a specialty area, if they so desire. Some examples for grouping electives into specialty areas, together with representative course selections, are indicated below. Other possible groupings may be discussed with a faculty mentor. These specialty areas are not noted on the official transcript.

Structural Engineering

		Units
12-600	AutoCAD	3
12-631	Structural Design	12
12-635	Structural Analysis	9
12-636	Geotechnical Engineering	9
12-638	Behavior of Structural Systems	9
21-241	Matrices and Linear Transformations	10
24-351	Dynamics	10
		62

Environmental Engineering - Air Quality

09-106	Modern Chemistry II	10
12-651	Air Quality Engineering	9
12-679	Special Topics: Intro to Meteorology	12
24-425	Combustion and Air Pollution Control	9
		40

Environmental Engineering - Water Quality

03-121	Modern Biology	9
09-106	Modern Chemistry II	10
12-629	Environmental Microbiology for Engineers	9
12-702	Fundamentals of Water Quality Engineering	12

Environmental Engineering - Water Resources

12-636	Geotechnical Engineering	9
12-657	Water Resource Systems Engineering	9

Environmental Engineering - Energy

06-221	Thermodynamics	9
09-106	Modern Chemistry II	10
24-424	Energy and the Environment	9

Computing in Civil Engineering

12-600	AutoCAD	3
12-631	Structural Design	12
12-635	Structural Analysis	9
12-657	Water Resource Systems Engineering	9
12-659	Special Topics: Matlab	6

Construction Management

12-600	AutoCAD	3
12-606	Traffic Engineering	6
12-631	Structural Design	12
12-635	Structural Analysis	9
12-636	Geotechnical Engineering	9

Double Majors and Minors

Civil Engineering students may pursue double majors and minors in a variety of subjects, taking advantage of the free elective courses to satisfy the requirements for the major or minor. The College of Engineering has designated minors to promote flexibility and diversity among engineering students. Many Civil Engineering undergraduates pursue designated minors in areas such as Architecture, Environmental and Sustainability Studies, or Global Engineering.

Internships and Co-Operative Education Program

Students in Civil Engineering are encouraged to undertake professional internships during summer breaks. In addition, a cooperative internship program is possible for either Jan-Aug or May-Dec in the junior year. Students undertaking these 8-month professional internships would ordinarily graduate after an additional semester of study.

Integrated B.S./M.S. Program

Interested undergraduates may plan a course of study that leads to both the BS in Civil Engineering and the MS in Civil and Environmental Engineering. This course of study will ordinarily require ten semesters of study, although advanced placement or other study may reduce this time. Students can apply appropriate units earned as undergraduates for their MS program as long as they are beyond the 379 units required for the BS in Civil Engineering degree. In the ninth semester of study, students must register in graduate status. Interested students should consult their academic advisor or the CEE Department office for information about admission to the MS program.

Faculty

AMIT ACHARYA, Professor of Civil and Environmental Engineering – Ph.D., University of Illinois at Urbana - Champaign; Carnegie Mellon, 2000–

PETER ADAMS, Professor of Civil and Environmental Engineering and Engineering and Public Policy – PhD., California Institute of Technology; Carnegie Mellon, 2001–

BURCU AKINCI, Paul P. Christiano Professor of Civil and Environmental Engineering – Ph.D., Stanford University; Carnegie Mellon, 2000–

MARIO BERGES, Associate Professor of Civil and Environmental Engineering – Ph.D., Carnegie Mellon Univesity; Carnegie Mellon, 2010–

JACOBO BIELAK, P.E., Hamerschlag University Professor Emeritus of Civil and Environmental Engineering – Ph.D., California Institute of Technology, , P.E.; Carnegie Mellon, 1978–

SARAH J. CHRISTIAN, P.E., Assistant Teaching Professor, Civil and Environmental Engineering – Ph.D., Stanford; Carnegie Mellon, 2015–

JARED L. COHON, President Emeritus, Carnegie Mellon University, University Professor of Civil and Environmental Engineering and Engineering and Public Policy – Ph.D., Massachusetts Institute of Technology, P.E.; Carnegie Mellon, 1997–

KAUSHIK DAYAL, Professor of Civil and Environmental Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2008–

DAVID A. DZOMBAK, Department Head and Hamerschlag University Professor of Civil and Environmental Engineering – Ph.D., Massachusetts Institute of Technology, P.E.; Carnegie Mellon, 1989–

SUSAN FINGER, Professor of Civil and Environmental Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–

JAMES H. GARRETT, P.E., JR., Dean, College of Engineering and Thomas Lord Professor, Civil and Environmental Engineering – Ph.D., Carnegie Mellon University, P.E.; Carnegie Mellon, 1990–

KELVIN GREGORY, Professor of Civil and Environmental Engineering – Ph.D., University of Iowa; Carnegie Mellon, 2006–

CHRIS T. HENDRICKSON, Hamerschlag University Professor Emeritus of Civil and Environmental Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1978–

XUESONG (PINE) LIU, Assistant Research Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2015–

GREGORY LOWRY, Walter J. Blenko, Sr. Professor of Civil and Environmental Engineering – Ph.D., University of Illinios; Carnegie Mellon, 2002–

H. SCOTT MATTHEWS, Professor of Civil and Environmental Engineering and Engineering and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2001–

HAE YOUNG NOH, Assistant Professor of Civil and Environmental Engineering – Ph.D., Stanford University; Carnegie Mellon, 2013–

IRVING J. OPPENHEIM, P.E., Professor of Civil and Environmental Engineering and Architecture – Ph.D., Cambridge University, P.E.; Carnegie Mellon, 1972–

MATTEO POZZI, Assistant Professor of Civil and Environmental Engineering – Ph.D., University of Trento, Italy; Carnegie Mellon, 2012–

ZHEN (SEAN) QIAN, Assistant Professor, Civil and Environmental Engineering – Ph.D., University of California, Davis; Carnegie Mellon, 2015–

CONSTANTINE SAMARAS, Assistant Professor, Civil and Environmental Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2014–

MITCHELL J. SMALL, H. John Heinz Professor, Civil and Environmental Engineering and Engineering and Public Policy – Ph.D., University of Michigan; Carnegie Mellon, 1982–

JAMES M. THOMPSON, P.E., Assistant Teaching Professor – Ph.D., Lehigh University; Carnegie Mellon, 2012–

JEANNE VANBRIESEN, P.E., Duquesne Light Company Professor of Civil and Environmental Engineering – Ph.D., Northwestern University; Carnegie Mellon, 1999–

GERALD J. WANG, Assistant Professor of Civil and Environmental Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2019–

Department of Civil and Environmental Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

12-100 Exploring CEE: Infrastructure and Environment in a Changing World
Fall and Spring: 12 units
Introduction to selected subfields in the discipline, such as structural engineering, construction project management, and environmental engineering. Problem-solving exercises apply fundamental concepts from these subfields to integrate the steps of analysis, synthesis, and evaluation through individual homework assignments and group projects that require attention to a broad range of issues. The course also exposes the students to issues related to engineering practice such as working in teams, scheduling, evaluating risk and making ethical decisions. In addition to regular lectures and project exercises, the course includes guest speakers and class demonstrations. 3 hrs., rec., 1 hr. lab.

12-200 CEE Challenges: Design in a Changing World
Fall: 9 units
Students will be challenged to solve problems related to conventional, cutting-edge, and emerging issues in Civil and Environmental Engineering and one or more of the areas of the built, natural and information environments, such as smart cities. Students will gain an understanding of the effects of uncertainty, such as changing climate conditions. Through several team projects, students will explore the impact and management of tradeoffs, like constructability, sustainability, cost, and maintenance on design. They will learn to apply mathematics and science, advanced technologies, and computing to solve open-ended problems. Students will learn communication and design skills and practice the design process, from problem definition to constructed work.
Prerequisite: 12-100

12-201 Geology
Fall and Spring: 9 units
Introduction to physical geology; common rocks and rock-forming minerals and their chemical compositions/structure, physical properties, origins, and uses; geologic processes: surface and ground-water flow, volcanism, mountain-building, tectonics, glaciation, sedimentation, seismicity, and atmospheric and oceanic circulation.

12-212 Statics
Fall: 9 units
Introduction to vector mechanics; equivalent systems of forces; equilibrium of rigid bodies; free body diagram; distributed forces, hydrostatic forces, effective forces, centroids; applications to simple statically determinate trusses, beams, frames, cables and other physical systems; friction.

12-215 Introduction to Professional Writing in CEE
Fall: 9 units
The objective of the course is to prepare students for writing technical reports and essays assigned in CEE courses and laboratories, writing professional letters and reports for internships and professional positions, preparing documents in a team setting, delivering individual and team oral presentations, and transforming information for several types of audiences (scientific accommodation). The course focuses on document purpose, organization and style; basic editing techniques; scientific accommodation; plagiarism and proper paraphrasing and summarizing; evaluating, citing and referencing sources; team communication strategies; oral presentations; and proper use of tables, graphics, and other visual aids in documents and presentations. Course activities include in-class exercises, peer workshops, and homework assignments to illustrate examples of good and poor communication and to practice technical communication skills. Concurrent with lectures and class activities, students draft and revise individual and team technical reports and will give individual and team oral presentations.

12-216 Research Skills and Topics in Civil and Environmental Engineering
Spring: 3 units
Civil Engineering undergraduates will learn and practice research skills relevant to both academic research and engineering practice. Exposure to a breadth of cutting-edge Civil Engineering research topics and projects will be achieved through expert presentations and practical exercises.
Prerequisites: 12-212 and 12-100

12-231 Solid Mechanics
Spring: 9 units
Analysis of deformable bodies incorporating concepts of stress, strain, mechanical properties of materials, and geometric compatibility. Response under axial loads, torsion, bending, transverse shear, and combined loadings. Stress and strain transformations and Mohr's circles, deflections of beams and shafts, buckling of columns.
Prerequisite: 12-212

12-232 Solid Mechanics Lab
Spring: 3 units
Analysis of stress-strain relationships, torsion of solid shafts, deformation due to bending, deformations in three dimensions, Mohr's circle representation of stress and strain, buckling of slender columns. Laboratory experiments and reports associated with theoretical concepts.
Prerequisite: 12-212

12-271 Introduction to Computer Application in Civil & Environmental Engineering
Spring: 9 units
Introduction to the use of computer-based applications in civil engineering, using generic tools such as spread-sheets, equation solvers and computer graphics. Discussion of the role of computer-based methods in civil engineering practice.
Prerequisites: 21-120 and (33-141 or 33-106)

12-301 CEE Projects: Designing the Built, Natural and Information Environments
Fall: 9 units
Students investigate the elements of civil and environmental engineering projects and advance their design, communication and teamwork skills through hands-on experiences. Students also advance their understanding of the professional and ethical aspects of engineering projects from conception through design, to implementation and operation. Students will design and build structures, use sensing to understand systems, and analyze sustainability as they work on open-ended projects.
Prerequisites: 12-212 and 12-271

12-335 Soil Mechanics
Fall: 9 units
Sampling, testing and identification of soils. Physical, chemical and hydraulic characteristics. Stress-strain-strength relationships for soils. Permeability, seepage, consolidation, and shear strength, with applications to deformation and stability problems, including earth dams, foundations, retaining walls, slopes and landfills.
Prerequisites: 12-231 and 33-142

12-336 Soil Mechanics Laboratory
Fall: 3 units
Examination of material properties and behavior of soils. Experiments include soil classification, permeability, compaction, consolidation and strength tests.
Prerequisite: 12-231

12-351 Environmental Engineering
Spring: 9 units
Provides a scientific and engineering basis for understanding environmental issues and problems. Introduces material and energy balances for tracking substances in the atmosphere, source and ground waters, and soil systems. Pertinent environmental laws are described, simple quantitative engineering models are developed, and qualitative descriptions of environmental engineering control technologies are presented.
Prerequisites: 12-355 and 21-260 and 09-105

12-352 Environmental Engineering Lab
Spring: 3 units
(Required for CEE students, not for others) Laboratory and field experiments that illustrate the basic principles of environmental engineering.

12-355 Fluid Mechanics
Fall: 9 units
Fluid characteristics; continuity, momentum and energy equations; dynamic similitude; laminar and turbulent boundary layers; flow in pipes; lift and drag on immersed bodies; open channel flow.
Prerequisites: 12-231 and 21-260 Min. grade C

12-356 Fluid Mechanics Lab
Fall: 3 units
Fluid properties: density, specific gravity, viscosity; fluid characteristics; continuity, conservation of energy; fluid behavior: center of pressure, pipe flow, open-channel flow. Laboratory experiments illustrating basic principles.

12-358 Materials Lab
Spring: 3 units
Examination of materials properties and behavior of concrete, masonry, and timber.
Prerequisite: 12-231

12-401 Civil & Environmental Engineering Design
Fall: 15 units
Methodology for formulating and solving design problems, characterized by incomplete specifications, open-ended solution space, and partial evaluations. The methodology is illustrated and applied in the context of realistic design problems drawn from civil and environmental engineering. Design projects performed by teams, emphasizing collaborative problem-solving and preparation of written and oral reports. The importance of ethics, life long learning, and professional licensure are also discussed. Senior Standing in Civil and Environmental Engineering or instructor approval for Design Minors. Corequisite: 12-301, 12-6xx 9 unit course
Prerequisite: 12-301

12-411 Project Management for Construction
Fall: 9 units
Introduction to construction project management from owner's perspective in organizing planning, design, construction and operation as an integrated process. Examination of labor productivity, material management and equipment utilization. Cost estimation and financing of constructed facilities. Contracting, construction planning and fundamental scheduling procedures. Cost control, monitoring and accounting for construction.
Prerequisite: 21-120 Min. grade C

12-421 Engineering Economics
Fall: 6 units
Basic concepts of economic analysis and evaluation of alternative engineering projects for capital investment. Consideration of time value of money and common merit measures such as net present value and internal rate of return. Selection of independent projects and mutually exclusive proposals, using various methods of analysis. Capital budgeting and project financing. Influence of price level changes, depreciation and taxation on choice of alternatives. Uncertainty and risk in operation and financing. Important factors affecting investment decisions for private and public projects.
Prerequisite: 21-120 Min. grade C

12-600 AutoCAD
Fall and Spring: 3 units
AutoCAD is a mostly online course. The course provides an introduction to the fundamentals of computer-aided design (CAD)software. Students learn how to set up CAD projects using Autodesk's AutoCAD software. Topics include coordinates, lines, circles, arcs, zooms, snaps and grids, text, views, layers, plines, blocks, reference files, dimensioning, isometrics, 3D commands, surfaces, solids, and more. CAD standards for layers, plotting, and symbol libraries are also covered. The course includes development of a CAD project by each student.

12-606 Traffic Engineering
Fall: 6 units
Introduction to traffic engineering providing practical experience that can be used directly in the workforce. Course material will provide a solid foundation in preparing for the Transportation portion of the Professional Engineer exam. The course incorporates the initial planning side of transportation engineering with tasks such as traffic analyses, traffic studies and transportation/traffic engineering report writing.

12-629 Environmental Microbiology for Engineers
Fall: 9 units
This class provides a general introduction to microorganisms in natural and engineered environments. Selected topics include: cellular architecture, energetics and energy conservation, growth and catabolism; evolution and genetics; population and community dynamics; water and soil microbiology; biogeochemical cycling; biofilms; and microorganisms in wastewater, pollution attenuation, and bioremediation.
Prerequisite: 03-121

12-631 Structural Design
Spring: 12 units
Design of structural members for bending moment, shear force, axial force, and combined axial force and bending. Reinforced concrete, structural steel, and composite beam construction are considered. Buckling effects in columns, beams and local plate segments are treated. Serviceability limits such as deflection and cracking are addressed. Design projects include the determination of loads and the selection of system geometry.
Prerequisite: 12-231

12-635 Structural Analysis
Fall: 9 units
Classical and matrix-based methods of structural analysis; energy principles in structural mechanics. Basic concepts of force and displacement methods for analyzing redundant structural systems. Matrix methods utilizing the flexibility (force) and stiffness (displacement) concepts.
Prerequisite: 12-231

12-636 Geotechnical Engineering
Spring: 9 units
Behavior of geotechnical structures; engineering design of geotechnical structures considering failure modes; uncertainties; economic issues, required design formats and relevant code provisions; performance requirements for foundations, subsurface investigations; allowable stress and LRFD design approaches; reliability-based design; shallow foundations; deep foundations; retaining structures; reinforced concrete foundations.
Prerequisite: 12-335

12-638 Behavior of Structural Systems
Spring: 9 units
Students will learn how structural systems work, the rationale behind building design codes, and how to design structures that can resist complicated loads like wind and earthquakes. Topics include fundamental principles of structural design, common structural systems, methods for determining and applying loads to buildings, approximate methods of analysis, distribution of gravity and lateral loads, frames, shear walls, and structural details for steel and reinforced concrete. The conceptual design for a building is developed through a semester-long project.
Prerequisites: 12-631 or 12-635

12-645 Smart Cities: Growth and Intelligent Transportation Systems
Fall: 6 units
Cities all around the world are being built and re-invented as smart cities utilizing information systems and innovative applications of data analytics. One major smart cities component is transportation. The Intelligent Transportation Systems (ITS) industry is expected to grow at a rate of 19% per year and reach $5.5 Billion in annual investment by 2020. This shifting dynamic provides great opportunity for improved transportation safety and efficiency but also poses challenging information systems and public policy challenges. Furthermore, there are new opportunities for professional-school graduates outside of engineering schools for employment in transportation planning and policy. This course is supported by CMU's Traffic21 Initiative and Technologies for Safe and Efficient Transportation (T-SET) University Transportation Center. Classes will feature guest lectures provided by T-SET faculty and industry and government ITS professionals.

12-648 CEE Senior Research Project
Fall and Spring
This course is designed to give students the opportunity to work on an open-ended project under the direction of a faculty member in the Civil & Environmental Engineering department. To register for this course, a student must have the approval of the faculty member for both the research topic and the number of units. A student in this course must write a proposal and submit progress reports to the advisor. The student must also make a formal presentation of the project results and submit a final report to the department. Senior standing in CEE and permission of the project advisor Units: 9-12

12-651 Air Quality Engineering
Fall: 9 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

12-657 Water Resource Systems Engineering
Spring: 9 units
Water Resource Systems Engineering combines hydrology, engineering, economics, and operations research to create tools and analyses that support decisions about large-scale water resource systems. The emphasis in this course will be on optimization methods, which are a core element of water systems analysis. Both water quantity and water quality problems will be covered.
Prerequisite: 12-355

12-659 Special Topics: Matlab
Fall: 6 units
This mini course is designed to be a practical introduction to engineering scientific computation. The topics of this class will include basic matrix computation, solving ordinary and partial differential equations, solving systems of linear equations, computing eigenvalues and eigenvectors, and basic signal processing and neural network techniques. Throughout the course, these scientific computation tools will be demonstrated using interactive scientific software called MATLAB.

12-676 Special Topics: Fundamental Concepts and Methods of Structural Mechanics
Fall: 12 units
This course will cover topics including an Introduction to Structural Dynamics, consisting of single degree-of-freedom systems, linear multi-degree-of-freedom systems, and relevant properties of symmetric matrices; Wave Propagation, consisting of Elements of Linear Elasticity, Formulation of Wave Propagation Problems, and Mathematical Aspects of Equations Relevant to Wave Propagation; and Elements of numerical methods applied to structural dynamics and wave propagation (if time permits).

12-679 Special Topics: Intro to Meteorology
Fall: 12 units
The course targets entering doctoral students in atmospheric research, as well as interested upper-level undergraduates (juniors and seniors) and masters students across engineering and sciences. It will provide students with the basics of meteorology, with a focus on large-scale atmospheric motion. By the end of the term students will understand the basics of atmospheric dynamics, including horizontal and vertical motion, as well as the vertical structure of the atmosphere (atmospheric stability and boundary-layer dynamics). They will understand what makes weather happen and they will understand weather maps and charts. They will be able to critically watch the nightly weather forecast and be able to access available meteorological databases to make informed predictions of their own. Finally, they will understand atmospheric transport and boundary-layer dynamics, which will serve as a foundation for other coursework involving atmospheric transport and air-pollution if they are pursuing those topics more deeply.

12-690 Independent Study
Fall and Spring
In-depth investigation of a special topic in Civil and Environmental Engineering under the direction of a faculty member. The topic usually involves open-ended problems whose solution requires some elements of syntheses, analysis, construction, testing and evaluation of an engineering device or system. Junior or Senior Standing or with instructor permission in Civil and Environmental Engineering. Faculty approval required. 3 to 12 units

12-702 Fundamentals of Water Quality Engineering
Fall: 12 units
This course is a systematic overview of water quality engineering designed for students with no prior civil and environmental engineering background. Topics examined include physical, chemical, and biological characteristics of water; common water pollutants; basic water chemistry and micriobiology; mass and energy balances and their use in reactor analysis; physical, chemical and biological processes affecting natural water quality and the use of these processes in water supply and wastewater management systems; and selected problems in surface water and groundwater quality management. A background in college-level general chemistry, physics, calculus, and differential equations is assumed.

12-704 Probability and Estimation Methods for Engineering Systems
Fall: 12 units
Overview of rules of probability, random variables, probability distribution functions, and random processes. Techniques for estimating the parameters of probability models and related statistical inference. Application to the analysis and design of engineered systems under conditions of variability and uncertainty.

12-712 Sustainable Engineering Principles
Fall: 12 units
This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems. Publicly available data sets and computational models will be explored to assess sustainability. A team-based project is required.

12-714 Environmental Life Cycle Assessment
Spring: 12 units
Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.
Prerequisites: (12-421 or 12-706) and 12-712

12-718 Environmental Engineering, Sustainability, and Science Project
Spring: 12 units
This course integrates and exercises students in a significant sustainable engineering and/or environmental project that is team-based and built upon the knowledge, skills, and technologies learned in the core and specialist courses in the EESS graduate curriculum.

12-720 Water Resources Chemistry
Fall: 12 units
This course provides a rigorous yet practical basis for applying the principles of physical chemistry to understanding the composition of natural waters and to the engineering of water and wastewater treatment processes. Topics covered include chemical equilibrium and kinetics; acid-base equilibria and buffering; solid precipitation and dissolution; oxidation and reduction reactions; adsorption on solids; and computer-aided problem solving. The primary objective of the course is to be able to formulate and solve chemical equilibrium models for complex aqueous systems. Knowledge of college-level general chemistry is assumed.

12-725 Fate, Transport & Physicochemical Processes of Orgnc Contaminants in Aqua Systms
Spring: 12 units
Examination of the major physical and chemical processes affecting the fate and treatment of organic compounds nanoparticles in aquatic systems. The emphasis is on anthropogenic organic compounds. The course will review some concepts from physical organic chemistry, and examine the relationships between chemical structure, properties, and environmental behavior of organic compounds. Chemical processes important to the fate, treatment, and biotransformation of specific organic compounds are addressed. Two laboratory sessions illustrate measurement techniques for organic compounds in water. 12-702 is a co- req for non environmental engineers or students who have not had and environmental engineering undergraduate course

12-726 Mathematical Modeling of Environmental Quality Systems
Spring: 12 units
Development and application of mathematical models for environmental systems. Material balance formulations and their solutions, computer implementation, model validation, uncertainty analysis, and use for projection and policy analysis. Applications to surface water, groundwater, atmospheric transport, indoor air pollution, and human exposure and risk. Prerequisite: 12-704 or equivalent.

12-740 Data Acquisition
Fall: 6 units
The intent of this course is to introduce students to the concepts, approaches and implementation issues associated with data acquisition for infrastructure systems. Students will be introduced to the types of data that is collected about infrastructure systems, excitation mechanisms, sensing technologies, data acquisition using sensors, signal pre-processing and post-processing techniques, and use of sensing in a variety of applications in construction and infrastructure management. Students will also gain experience with data acquisition hardware and software.

12-741 Data Management
Fall: 6 units
The intent of this course is to introduce students to database management systems and to knowledge discovery in database principles. Students will learn how to develop powerful tools for efficiently managing large amounts of civil engineering data so that it may persist safely over long periods of time. Students will be introduced to relational database systems and structured query languages. They will also be exposed to other existing data models. Students also will be introduced to data mining and analysis tools to discover patterns and knowledge from data.

12-746 Special Topics: Fundamental Python Prototyping for Infrastructure Systems
Fall: 6 units
This course uses the Python programming language to introduce fundamental programming approaches to students from civil and environmental engineering. No prerequisite required and students with no programming experience are recommended to take this course. This course will cover fundamental programming approaches, object-oriented programming concepts, graphical user interface design in Python, and file and database operation. Real-world examples from infrastructure management will be used in the class for demonstration and term project. Students will work individually and in teams to develop a series of applications that are potentially be used in real-world applications.

12-747 Sustainable Buildings
Fall: 6 units
This course will cover the basics of the design, retrofit and monitoring of buildings to achieve energy efficiency. We will introduce energy simulation tools, the fundamentals of the most important building systems (i.e., heating, cooling, ventilation, insulation, etc.) and the technologies that can be used to monitor their performance. Graduate Standing, or approval of instructor

12-748 Mechanical and Electrical System Design for Buildings
Fall: 6 units
Class will cover HVAC, Electrical, and Plumbing systems for buildings. We will calculate heat loss and heat gains manually and with computer programs and calculate operating costs with various fuels and system types. We will size building electrical systems and look at alternative generation, smart metering and new lighting systems. Plumbing will include sizing water, drain and vent lines along with system design. Focus of the class will be on energy conservation and use, and how future systems will meet this criteria. The final project will be the audit of a building on campus using what we learned. Graduate Standing, or approval of instructor.

12-749 Climate Change Adaptation
Fall: 6 units
While the specific timing and magnitude of climate change impacts are uncertain, long-lived civil engineering infrastructure will need to be resilient to these potential impacts. Engineers designing for climate change adaptation require the tools to maximize resiliency and minimize cost for existing and proposed energy, transportation, water, urban and other types of infrastructure. Students successfully completing this course will understand how climate change affects civil infrastructure and how to quantitatively incorporate resilient designs and co-benefits under uncertainty. Students will use open data to examine current adaptation engineering challenges, quantify solutions, and communicate their technical recommendations through policy briefs. Prerequisites: Graduate standing or consent of instructor.

12-750 Infrastructure Management
All Semesters: 12 units
This course takes a broad view of infrastructure systems to include physical infrastructure and information networks. The course will consider the need to protect these critical infrastructures from both degradation as well as malicious attacks. Infrastructure management generally depends on public-private partnerships to ensure long-term viability. We will look at relevant academic literature on the topics of infrastructure needs and requirements. We will explore the use of automated sensing and computer network systems to facilitate management.

12-755 Finite Elements in Mechanics I
Fall: 12 units
The basic theory and applications of the finite element method in mechanics are presented. Development of the FEM as a Galerkin method for numerical solution of boundary value problems. Applications to second-order steady problems, including heat conduction, elasticity, convective transport, viscous flow, and others. Introduction to advanced topics, including fourth-order equations, time dependence, and nonlinear problems.Prerequisite: Graduate standing or consent of instructor. Prerequisites: Graduate standing or consent of instructor.

12-798 Professional Communication for CEE Grad Students
Fall: 3 units
The course reviews skills and techniques for preparing technical documents, professional letters, resumes, and presentations typically encountered in advanced degree programs and in research and development positions in the public and private sector. Class topics focus on document purpose and organization; researching technical sources; summarizing, paraphrasing, and citing sources; simplifying and revising techniques; and the proper use of tables, graphics, and other visual aids in documents and oral presentations. Course content emphasizes North American writing norms.

Department of Electrical and Computer Engineering

Lawrence Pileggi, Head

James Bain, Associate Head, Academic Affairs

Jose Moura, Associate Head, Research & Strategic Initiatives
www.ece.cmu.edu

The field of electrical and computer engineering encompasses a remarkably diverse and fertile set of technological areas, including analog and digital electronics, computer architecture, computer-aided design and manufacturing of VLSI/ULSI circuits, intelligent robotic systems, computer-based control systems, telecommunications and computer networking, wireless communication systems, signal and information processing and multimedia systems, solid state physics and devices, microelectromechanical systems (MEMS), electromagnetic and electromechanical systems, data storage systems, embedded systems, distributed computing, mobile computing, real-time software, digital signal processing, and optical data processing. The extraordinary advances in the field during the last fifty years have impacted nearly every aspect of human activity. These advances have resulted not only in advanced computer systems but also in consumer products such as “smart” cars, programmable dishwashers and other home appliances, cell phones and mobile computing systems, video games, home security systems, advanced medical systems for imaging, diagnosis, testing and monitoring. Systems and products such as these serve to enhance our quality of life and have also served as the basis for significant economic activity. In short, the field of electrical and computer engineering has become central to society as we know it.

The Department of Electrical and Computer Engineering at Carnegie Mellon is actively engaged in education and research at the forefront of these new technologies. Because of the diverse and broad nature of the field and the significant growth in knowledge in each of its sub areas, it is no longer possible for any single individual to know all aspects of electrical and computer engineering. Nevertheless, it is important that all electrical and computer engineers have a solid knowledge of the fundamentals with sufficient depth and breadth. Society is placing increasing demands on our graduates to try their skills in new contexts. It is also placing increasing value on engineers who can cross traditional boundaries between disciplines, and who can intelligently evaluate the broader consequences of their actions. Our curriculum is designed to produce world-class engineers who can meet these challenges.

Educational Outcomes and Objectives

The B.S. in Electrical and Computer Engineering is a broad and highly flexible degree program structured to provide students with the smallest set of constraints consistent with a rich and comprehensive view of the profession. It is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. Students are encouraged and stimulated to explore multiple areas of theory and application. The Faculty of Electrical and Computer Engineering have adopted the following outcomes from ABET and have established the following objectives for the B.S. in Electrical and Computer Engineering curriculum:

Educational Outcomes

1. An ability to apply knowledge of mathematics, science and engineering.
2. An ability to design and conduct experiments, as well as to analyze and interpret data.
3. An ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.
4. An ability to function in multi-disciplinary teams.
5. An ability to identify, formulate and solve engineering problems.
6. An understanding of professional and ethical responsibilities.
7. An ability to communicate effectively.
8. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context.
9. A recognition of the need for, and an ability to engage in life-long learning.
10. A knowledge of contemporary issues.
11. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

ECE Education Objectives

The ECE program objectives are shown below. They represent our vision for what our students will be doing in their engineering careers five years after they have graduated. The principal behaviors we seek to foster in our students are *expertise*, *innovation* and *leadership*.
Our graduates will be:

Experts

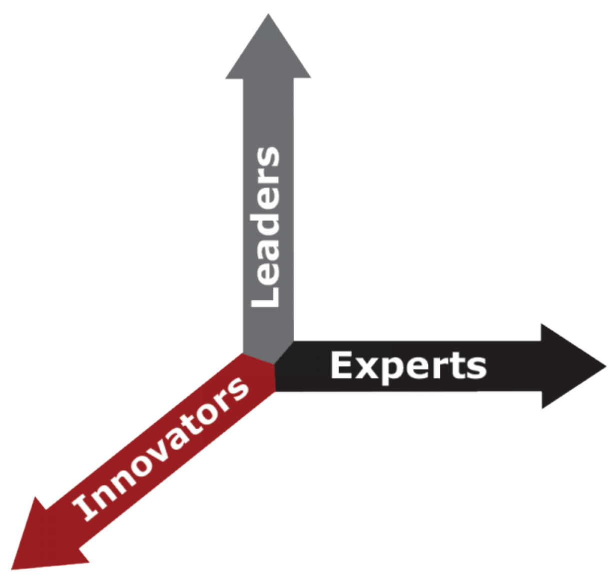
- They will solve problems by applying ECE fundamentals
- Their solutions will reflect depth of understanding in their sophistication.
- Their solutions will reflect breadth of understanding by drawing on multiple disciplines.

Innovators

- They will demonstrate creativity in their engineering practice.
- They will consider holistic systems-oriented approaches in their designs.
- They will think strategically in their planning and execution.

Leaders

- They will take initiative, and demonstrate resourcefulness.
- They will collaborate in multidisciplinary teams.
- They will be leaders in their organizations, their profession and in society.



Three dimensions of objectives for our graduates.

Curriculum Overview

In addition to the Carnegie Institute of Technology general education (http://coursecatalog.web.cmu.edu/carnegieinstituteoftechnology/#generaleducationtext) and First Year requirements (http://coursecatalog.web.cmu.edu/carnegieinstituteoftechnology/#firstyearforengineeringstudentstext) (143 units), the B.S. in Electrical and Computer Engineering requires: 15-122 Principles of Imperative Computation (10 units), Physics II (12 units), two math or science electives (18 units), a Probability and Statistics course (9 units), 109 units of Electrical and Computer Engineering coursework, and 2 math co-requisites (22 units). The remaining units needed to reach the 379 required to graduate are Free Electives (56 units).

The Electrical and Computer Engineering coursework is divided into the categories of Core, Area Courses, Coverage, and Capstone Design. The Core consists of five courses (18-100 Introduction to Electrical and Computer Engineering, 18-220 Electronic Devices and Analog Circuits, 18-240 Structure and Design of Digital Systems, 18-213 Introduction to Computer Systems, and 18-290 Signals and Systems). There are additional co-requisites: 18-202 Mathematical Foundations of Electrical Engineering, 21-127 Concepts of Mathematics and 33-142 Physics II for Engineering and Physics Students, that are required to be taken with the core. These courses provide the fundamental knowledge-base upon which all other electrical and computer engineering courses are built.

Students generally take 18-100 Introduction to Electrical and Computer Engineering during their first year, while they start the remaining courses in the Core in their sophomore year, ideally completing them by the end of the junior year. It is recommended that students do not take more than two core courses in the same semester. Although the core courses (and their co-requisites) may be taken in any order, students generally first take the course in their primary area of interest, which gives added flexibility to later course selection in related areas.

Students are required to complete a seminar course during the fall semester of the sophomore year. This course, 18-200 ECE Sophomore Seminar, introduces students to the many areas within ECE and helps them decide which areas are of primary interest to them.

To satisfy the ECE Area Courses Requirement (http://www.ece.cmu.edu/programs-admissions/bachelors/academic-guide/#collapse-4), at least two Area courses must be completed from one of the following five principal areas in ECE (24 units):

- *Device Sciences and Nanofabrication*: Solid State Physics, Electromagnetic Fields and Waves, Magnetics, Optics, etc.;
- *Signals and Systems*: Digital Signal Processing, Communication Systems, Control Systems, etc.;
- *Circuits*: Analog and Digital Circuits, Integrated Circuit Design, etc.;
- *Computer Hardware*: Logic Design, Computer Architecture, Networks, etc.; and
- *Computer Software*: Programming, Data Structures, Compilers, Operating Systems, etc.

One additional course from a second area must be taken (12 units)

The Coverage requirement is satisfied by taking any additional ECE course(s) or an approved Computer Science course (see the ECE website (http://www.ece.cmu.edu/programs-admissions/bachelors/academic-guide/#collapse-5) for the list of approved coverage courses) totaling at least 12 units.

All students are required to take a Capstone Design course. The Capstone Design course is a senior-level project course (numbered 18-5XX) in which students participate in a semester-long design experience on a team with other students. Students learn project management skills, create oral presentations, write reports, and discuss the broader social and ethical dimensions of ECE. At the completion of the course students will conclude with a demonstration of their product and will be able to explain the design process. Current Capstone Design courses are listed on the ECE Department website (http://www.ece.cmu.edu/programs-admissions/bachelors/academic-guide/#collapse-6).

B.S. Curriculum

Minimum units required for B.S. in Electrical and Computer Engineering 379

For detailed information and regulations of the curriculum along with the degree requirements and the most recent version of the ECE curriculum and course descriptions, please refer to the ECE Academic Guide (http://www.ece.cmu.edu/programs-admissions/bachelors/academic-guide).

University Requirement

		Units
99-101	Computing @ Carnegie Mellon	3
		3

CIT Requirements (see CIT section of the catalog for specifics (http://coursecatalog.web.cmu.edu/carnegieinstituteoftechnology)):

CIT General Education		Units
Two semesters of calculus		20
One other introductory engineering course (generally taken during the freshman year)		12
33-141	Physics I for Engineering Students **	12
or 33-131	Matter and Interaction I	
		44

** 33-141/33-142 is the recommended course sequence, although 33-131/33-132 will also satisfy this requirement.

Specific ECE requirements:

		Units
One Introduction to Electrical and Computer Engineering course (generally taken during the freshman year)		
18-100	Introduction to Electrical and Computer Engineering	12
One ECE Seminar, taken during the fall of the sophomore year		
18-200	ECE Sophomore Seminar	1
Four ECE core courses, three with math co-requisites		
18-220	Electronic Devices and Analog Circuits	12
33-142	Physics II for Engineering and Physics Students (co-requisite for 18-220)	
18-202	Mathematical Foundations of Electrical Engineering (co-requisite for 18-220)	
18-290	Signals and Systems	12
18-202	Mathematical Foundations of Electrical Engineering (co-requisite for 18-290)	
18-240	Structure and Design of Digital Systems	12
21-127	Concepts of Mathematics (co-requisite for 18-240)	
18-213	Introduction to Computer Systems	12
Two Area Courses from 1 of the 5 Areas within ECE		24
One additional Area Course from a second Area		12
One Coverage Course (any additional ECE course or Approved CS course as listed on the ECE web site)		12
One Capstone Design Course (any 18-5xx course)		12
		121

Other ECE Requirements:

		Units
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	10
Two Math/Science electives		18
36-217	Probability Theory and Random Processes	9
or 36-225	Introduction to Probability Theory	
Free Electives		56
		105

Math/Science Electives

The math/science electives are satisfied with any course from The Mellon College of Science or The Department of Statistics and Data Science except for: 100-level courses in Mathematics or Statistics, and courses designed for non-science or engineering majors, such as (but not limited to) 03-132, 09-103, 09-108, 21-240, 21-257, 33-115, 33-124, 36-201, 36-202, 36-207 or 36-208. Although shown in the Junior and year, these courses may be taken at any time. Mathematics courses of particular interest to students in ECE are:

21-228	Discrete Mathematics	9
21-241	Matrices and Linear Transformations	10
21-259	Calculus in Three Dimensions	9
21-260	Differential Equations	9

Free Electives 56 units

A Free Elective is defined as any graded course offered by any academic unit of the university (including research institutes such as the Robotics Institute (http://www.ri.cmu.edu) and the Software Engineering Institute (http://www.sei.cmu.edu)). A total of at least 56 units of Free Electives must be taken.

Up to 9 units of Student Taught Courses (StuCO) and Physical Education courses, or other courses taken as Pass/Fail, may also be used toward Free Electives.

Transfer of courses from other high-quality universities may be accepted through submission of the Transfer Credit Request form on the CIT web page (https://engineering.cmu.edu/education/academic-policies/undergraduate-policies/transfer_credit). Please see the CIT website (https://engineering.cmu.edu/education/academic-policies/undergraduate-policies/transfer-credit.html) for further information regarding the process.

The large number of units without categorical constraints provides the student, in consultation with their Advisor or Mentor, with the flexibility to design a rich educational program.

Sample Curriculum

The following table shows a possible roadmap through our broad and flexible curriculum:

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
18-100 Introduction to Electrical and Computer Engineering	Introductory Engineering course	18-200 ECE Sophomore Seminar	18-2xx ECE Core course
15-112 Fundamentals of Programming and Computer Science	33-106 Physics I for Engineering Students	18-2xx ECE Core Course	21-127 Concepts of Mathematics or 18-202 Mathematicl Foundations of Electrical Engineering
21-120 Differential and Integral Calculus	21-122 Integration and Approximation	18-202 Mathematical Foundations of Electrical Engineering or 21-127 Concepts of Mathematics	15-122 Principles of Imperative Computation
76-101 Interpretation and Argument	General Education course	General Education course	36-217 Probability Theory and Random Processes
99-101 Computing @ Carnegie Mellon		33-142 Physics II for Engineering and Physics Students	General Education course
		39-210 Experiential Learning I	39-220 Experiential Learning II

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
18-2xx ECE Core course	18-2xx ECE Core course	18-xxx ECE Coverage course	18-5xx ECE Capstone Design course
18-3xx/4xx ECE Area 1 course (first course in Area)	18-3xx/4xx ECE Area course (either 2nd course from Area 1 or the Area 2 course)	18-3xx/4xx ECE Area course (either 2nd course from Area 1 or the Area 2 course)	General Education course
General Education course	Math/Science Elective 2	General Education course	Free Elective
Math/Science elective 1	General Education course	Free Elective	Free Elective
Free Elective	Free Elective	Free Elective	Free Elective
39-310 Experiential Learning III			

Academic Policies

Policy on ECE Coverage Courses with Fewer than 12 Units

The basic curriculum requirements for Area courses, Coverage and Capstone Design are stated in terms of courses rather than units. The nominal total of 60 units for these categories is determined by assuming that each course is 12 units. In the event that courses with fewer than 12 units are used to satisfy some or all of these requirements, additional courses from the ECE coverage lists must be taken until the total units in ECE courses beyond the core meets or exceeds 60 units. Any ECE coverage course is acceptable, and any excess units beyond the required 60 may be counted as free elective credit.

QPA Requirement and Overload Policy

An overload is defined as any schedule with more than 54 units in one semester. A student will only be permitted to overload by 12 units if she or he achieved an overall QPA of at least 3.5 out of 4.0. If the student's overall QPA is below a 3.5, then the QPA of the previous semester for which he or she is registering will instead be utilized. If that QPA is at least a 3.5 then the student will be permitted to Overload.

Grade Policy for Math Courses

1. CIT states that all mathematics (21-xxx) courses required* for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.

2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a prerequisite for the next higher level required mathematics (21-xxx) course.

3. In addition, ECE requires that 18-202 Mathematical Foundations of Electrical Engineering must be completed with a grade of C or better.

*Elective mathematics courses (like the math/science electives required for ECE) are not included in this policy

Pass/Fail policy

Up to 9 units of StuCo and/or Physical Education courses or other courses taken as Pass/Fail may be used toward Free Electives. ECE core courses may not be taken as pass/fail. ECE project-based courses (including capstone design courses) may not be taken pass/fail. No ECE requirements may be fulfilled using a pass/fail course (except for 99-10x and 18-200)

Other Graduation Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Students are encouraged to confirm all graduation requirements with their academic advisor.

CIT has the following requirement for graduation. “Students must complete the requirements for their specified degrees with a cumulative quality point average of 2.00 or higher for all courses taken after the freshman year [this is the CIT QPA on the Academic Audit]. In addition, a student is expected to achieve a cumulative quality point average of 2.00 in a series of core departmental courses.”

In ECE, this means that the student must complete 18-100 Introduction to Electrical and Computer Engineering, ECE Core, Area Courses, Coverage, and Capstone Design courses with a minimum QPA of 2.0 to graduate. When more than one possibility exists for meeting a specific requirement (e.g., Area Course), the courses used for calculating the ECE QPA will be chosen so as to maximize the QPA. Similarly, when an ECE course is retaken, the better grade will be used in the computation of the minimum QPA for the ECE QPA requirement to graduate.

Other Opportunities in ECE

ECE Cooperative Education Program

Our Cooperative Education Program invites students to gain valuable experience in employment that relates directly to their major and career goals. At the same time, it provides employers with opportunities to evaluate students as potential full-time employees, while having them complete meaningful projects. Participation in this program is voluntary, and obtaining a cooperative education assignment is competitive.

Due to federal restrictions on student work experiences, international students are not eligible for co-ops. Please visit the ECE CPT page (http://www.ece.cmu.edu/programs-admissions/bachelors/cpt.html) for information regarding international student internships.

The co-op experience

We require a minimum of eight months of co-op experience to identify the work experience as a co-op. Students must have minimally completed their sophomore year to qualify for application to a co-op and should connect with their Academic Advisor for information on how to apply. While on co-op assignment, students are participating in a recognized CIT educational program, retaining their full-time student status, akin to our students who study abroad in established exchange programs (such as EPFL) for one or two semesters. The Cooperative Education Program agreement may be discontinued if the employers do not provide the students with career-related work experience or if the students do not meet the accepted level of performance as defined by the employers.

Upon returning to Carnegie Mellon, the students are required to submit for approval the following two documents to the ECE Undergraduate Office: a three to five page technical report of the Co-Op work, and a one page assessment and evaluation of the Co-Op experience.

Students may obtain more detailed information through the ECE department (http://www.ece.cmu.edu/programs-admissions/bachelors/cooperative-education-program.html) or the Career and Professional Development Center (http://www.cmu.edu/career).

Integrated M.S./B.S. Degrees Program

The Integrated Master's/Bachelor's program (http://www.ece.cmu.edu/programs-admissions/integrated) (otherwise known as the IMB program) is an exciting opportunity for students who excel academically to achieve not just a Bachelor's degree in ECE, but also a Master's degree- through our Professional MS degree program-without needing to apply separately. This means no application fee, and no need to take the GRE (Graduate Record Exam). In order to be awarded the MS degree in the IMB program, the student must also earn their BS degree, either simultaneously with the MS degree or at least one semester prior to the awarding of the MS degree. If a course is eligible for the MS degree but must be used to complete the BS degree, the BS degree takes priority over the MS degree.

If a student is at least a 2nd semester junior, has completed at least 270 units and has at least an overall 3.00 QPA, he or she is guaranteed admission into the Professional MS degree in ECE through the IMB program. To be officially admitted, the student must complete the IMB Program form.

If a student does not meet the exact overall 3.00 QPA requirement, he or she is eligible to petition for his or her admission into the IMB program during his or her senior year. Students may obtain the petition forms through a meeting with their assigned academic advisor.

Professional MS Degree Requirements:

Please see the ECE web site for the requirements for the Professional MS degree (http://www.ece.cmu.edu/programs-admissions/masters/ms-requirements.html). For students in the ECE IMB program, all requirements for the Professional MS degree are in addition to the requirements for the BS in ECE. No requirements for the MS degree may be used in any way toward the BS degree, including minors, additional majors or dual degrees.

Residency requirements and financial impacts:

Once a student in the IMB program has completed all of the requirements for the BS degree, he or she may become a graduate (Masters) student. To do this, the student's undergraduate degree is certified, and that student officially graduates with the BS degree. Once a student's undergraduate degree has been certified, no more courses may then be applied toward the BS degree. This includes courses toward minors and additional majors, although students pursuing an undergraduate dual degree with another department may still continue to apply additional coursework toward that second degree.

If a student takes more than 8 semesters to complete both the BS and MS degrees, then he or she must be a graduate student for at least one semester before graduating with the MS degree.

To determine the most appropriate time for an undergraduate student to become a graduate student, he or she should consult with Enrollment Services to understand how becoming a graduate student will affect financial aid, and with his or her academic advisor to determine a course schedule. When a student is a graduate student through the IMB program, the department is able to provide some financial assistance through Teaching Assistantships. Please see the ECE web site (http://www.ece.cmu.edu/programs-admissions/integrated) for further information regarding this financial assistance.

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JANA KAINERSTORFER, Assistant Professor, Biomedical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Vienna/NIH; Carnegie Mellon, 2015–

TAKEO KANADE, U.A. and Helen Whitaker Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Kyoto University; Carnegie Mellon, 1980–

SHAWN KELLY, Senior Systems Scientist, Engineering Research Accelerator; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2012–

KRIS KITANI, Assistant Research Professor, Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Tokyo; Carnegie Mellon, 2011–

ZICO KOLTER, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D.,Carnegie Mellon, 2015–

DAVE LAUGHLIN, ALCOA Professor of Materials Science Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1974–

CHANGLIE LIU, Assistant Professor, Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley;

SARA MAJETICH, Professor of Physics; Courtesy Faculty of Electrical and Computer Engineering; Affiliated Faculty - DSSC – Ph.D., University of Georgia; Carnegie Mellon, 2010–

CARMEL MAJIDI, Clarence H. Adamson Associate Professor, Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2011–

ROY MAXION, Research Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Colorado; Carnegie Mellon, 1984–

FLORIAN METZE, Associate Research Professor, Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Dr.-Ing., Fakultät für Informatik der Universität Karlsruhe; Carnegie Mellon, 2009–

HOSEIN MOHIMANI, Assistant Professor, Computational Biology; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 2017–

JAMES MORRIS, Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering; – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1982–

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HAE YOUNG NOH, Assistant Professor of Civil and Environmental Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University ; Carnegie Mellon, 2014–

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ANDY PAVLO, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Brown University; Carnegie Mellon, 2014–

JON M. PEHA, Professor of Engineering and Public Policy; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 1991–

ANDRE PLATZER, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Oldenburg, Germany; Carnegie Mellon, 2010–

BHIKSHA RAJ RAMAKRISHNAN, Associate Professor of Language Technologies Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2009–

RAJ REDDY, Mozah Bint Nasser University Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2000–

MAJD SAKR, Teaching Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Pittsburgh; Carnegie Mellon, 20015–

MAHADEV SATYANARAYANAN, Carnegie Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1983–

JEFF SCHNEIDER, Research Professor, Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Rochester; Carnegie Mellon, 2013–

SRINIVASAN SESHAN, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2000–

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METIN SITTI, Professor, Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Tokyo; Carnegie Mellon, 2002–

ASIM SMAILAGIC, Research Professor of ICES; Director of LINCS; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Sarajevo and University of Edinburgh; Carnegie Mellon, 1992–

STEPHEN SMITH, Research Professor, Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Pittsburgh; Carnegie Mellon, 1982–

KOUSHIL SREENATH, Assistant Professor, Robotics Institute; Courtesy Faculty of Electrical and Computer Science – Ph.D., University of Michigan; Carnegie Mellon, 2014–

REBECCA TAYLOR, Assistant Professor, Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2016–

SRIDHAR TAYUR, Professor, Tepper School of Business; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Cornell University; Carnegie Mellon, 2017–

MANUELA VELOSO, Herbert A. Simon University Professor; Head Machine Learning; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2011–

RASHMI VINAYAK, Assistant Professor, Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2017–

TONY WASSERMAN, Professor, Software Management Practice; Executive Director of the Center for Open Source Investigation, Carnegie Mellon University Silicon Valley; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Wisconsin–Madison; Carnegie Mellon, 2005–

LEE WEISS, Research Professor, Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2009–

WILLIAM (RED) WHITTAKER, University Professor, Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1979–

ERIK YDSTIE, Professor of Chemical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Imperial College, London; Carnegie Mellon, 1992–

HUI ZHANG, Professor of Computer Science; Courtesy Professor of Electrical and Computer Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1995–

Department of Electrical and Computer Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

18-090 Twisted Signals: Multimedia Processing for the Arts
Fall: 10 units
[IDeATe portal course] - This course presents an overview on manipulating and synthesizing sound, video, and control signals. Signals are the raw materials used in many forms of electronic art and design - electronic music, interactive art, video art, kinetic sculpture, and more. In these fields, signals are used to represent information about sound, images, sensors, and movement. By transforming and manipulating these types of signals, we are able to create powerful new tools for digital art, multimedia applications, music, responsive environments, video and sound installation, smart products, and beyond. In this course we will study Signal Processing from a practical point-of-view, developing tools that can be easily integrated into art-making using the graphical programming environment Max (a.k.a. Max/MSP/Jitter). We will present a survey of Signal Processing techniques used in the sonic and visual arts, and will discuss the mathematical theories underlying these techniques. Students will be encouraged to combine, modify, and extend working examples of software to create original digital artworks.

18-099 Special Topics: Mobile App Design & Development
Fall: 12 units
[IDeATe collaborative course] IDeATe is partnering with YinzCam to develop and offer a studio course on mobile app design and development. The course will leverage the extensive expertise of YinzCam on mobile-app development in the sports and entertainment space, both for real-time and asynchronous enrichment of the fan experience and the stadium experience. However, the lessons learned will apply to mobile-app development broadly. Issues covered will include cross-platform development, mobile video, streaming media, real-time content delivery, along with best practices in server-side cloud management for large-scale mobile-app deployment. Please note that this course is for students to take as one of their IDeATe concentration/minor options and will NOT fulfill a CIT/ECE requirement. Open to juniors and seniors. DC and MCS students should take the course after completing another IDeATe collaborative course.
Prerequisites: 18-090 or 62-150 or 15-104

18-100 Introduction to Electrical and Computer Engineering
Fall and Spring: 12 units
The goals of this freshman engineering course are: * To introduce basic concepts in electrical and computer engineering in an integrated manner; * To motivate basic concepts in the context of real applications; * To illustrate a logical way of thinking about problems and their solutions, and; * To convey the excitement of the profession. These goals are attained through analysis, construction and testing of an electromechanical system (e.g., a robot) that incorporates concepts from a broad range of areas within Electrical and Computer Engineering. Some of the specific topics that will be covered include system decomposition, ideal and real sources, Kirchhoff's Current and Voltage Laws, Ohm's Law, piecewise linear modeling of nonlinear circuit elements, Ideal Op-Amp characteristics, combinational logic circuits, Karnaugh Maps, Flip-Flops, sequential logic circuits, and finite state machines. 3 hrs. lec., 1 hr. rec., 3 hr. lab.

18-200 ECE Sophomore Seminar
Fall: 1 unit
"The class comprises of a series of lectures from our own faculty and alumni, Department and University staff, and student groups. Students are required to attend each lecture. The lectures are designed to serve the following purposes: 1. Introduce to students to the faculty member's research field and the most current world advancements in engineering and technology in that area; 2. Provide students a good understanding of our curriculum structure and the courses in various areas; 3. Present correlations between the present technological developments and our courses for each course area; 4. Introduce new undergraduate courses; 5. Advertise on-campus/off-campus research opportunities for undergraduate students and explain the corresponding research projects; 6. Motivate students with positive presentations on the importance of obtaining education and gaining self-learning ability; 7. Provide basic education on learning and working ethics."
Prerequisite: 18-100

18-202 Mathematical Foundations of Electrical Engineering
Fall and Spring: 12 units
This course covers topics from engineering mathematics that serve as foundations for descriptions of electrical engineering devices and systems. It is the corequisite mathematics course for 18-220, Fundamentals of Electrical Engineering. The topics include: 1.MATLAB as a robust computational tool, used to reinforce, enrich and integrate ideas throughout the course, including software exercises and projects in combination with homework assignments; 2.Complex Analysis, including rectangular and polar representations in the complex plane with associated forms of complex arithmetic, powers, roots and complex logarithms, complex differentiation, analytic functions and Cauchy-Riemann equations, complex Taylor series, complex exponential, sinusoidal and hyperbolic functions, and Euler's formula; 3.Fourier Analysis, including orthogonality of sinusoids, trigonometric and exponential forms of Fourier series, Fourier integrals and Fourier transforms; 4.Linear, Constant-Coefficient Differential Equations, including complex exponential solutions to homogeneous equations and particular solutions with polynomial and sinusoidal driving functions described by phasors; 5.Difference Equations, with emphasis upon their relationship to differential equations, and; 6.Linear Algebra and Matrices, including matrix arithmetic, linear systems of equations and Gaussian elimination, vector spaces and rank of matrices, matrix inverses and determinants, eigenvalue problems and their relationship to systems of homogeneous differential equations.
Prerequisite: 21-122 Min. grade C

18-213 Introduction to Computer Systems
Spring and Summer: 12 units
This course provides a programmer's view of how computer systems execute programs, store information, and communicate. It enables students to become more effective programmers, especially in dealing with issues of performance, portability and robustness. It also serves as a foundation for courses on compilers, networks, operating systems, and computer architecture, where a deeper understanding of systems-level issues is required. Topics covered include: machine-level code and its generation by optimizing compilers, performance evaluation and optimization, computer arithmetic, memory organization and management, networking technology and protocols, and supporting concurrent computation. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course. Prerequisites: 15-123 (Grade of C or higher is required in the prerequisite)
Prerequisite: 15-122 Min. grade C

Course Website: http://www.cs.cmu.edu/~213/

18-220 Electronic Devices and Analog Circuits
Fall and Spring: 12 units
This course covers fundamental topics that are common to a wide variety of electrical engineering devices and systems. The topics include an introduction to semiconductor devices and technology, DC circuit analysis techniques, operational amplifiers, energy storage elements, sinusoidal steady-state response, frequency domain analysis, filters, and transient response of first- and second-order systems. The laboratories allow students to use modern electronic instrumentation and to build and operate circuits that address specific concepts covered in the lectures, including semiconductor devices and sensors, layout, operational amplifiers, filters, signal detection and processing, power converters and circuit transients. 3 hrs. lec., 1 hr. rec., 3 hrs. lab.
Prerequisite: 18-100

Course Website: https://www.ece.cmu.edu/courses/items/18220.html

18-231 Sophomore Projects
Fall
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is conducting undergraduate research with a faculty member. Students do not need to officially register for undergraduate research unless they want it listed on their official transcripts. An ECE student who is involved in a research project and is interested in registering this undergraduate research for course credit on the official transcript may request to be enrolled in this course. To do this, the student should first complete the on-line undergraduate research form available on the ECE undergraduate student page. Once the form has been submitted and approved by the faculty member the student is conducting the research with, the ECE Undergraduate Office will add the course to the student's schedule. Typical credit is granted as one hour of research per week is equal to one unit of credit.

18-232 Sophomore Projects
Spring
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is conducting undergraduate research with a faculty member. Students do not need to officially register for undergraduate research unless they want it listed on their official transcripts. An ECE student who is involved in a research project and is interested in registering this undergraduate research for course credit on the official transcript may request to be enrolled in this course. To do this, the student should first complete the on-line undergraduate research form available on the ECE undergraduate student page. Once the form has been submitted and approved by the faculty member the student is conducting the research with, the ECE Undergraduate Office will add the course to the student's schedule. Typical credit is granted as one hour of research per week is equal to one unit of credit.

18-240 Structure and Design of Digital Systems
Fall and Spring: 12 units
This course introduces basic issues in design and verification of modern digital systems. Topics include: Boolean algebra, digital number systems and computer arithmetic, combinational logic design and simplification, sequential logic design and optimization, register-transfer design of digital systems, basic processor organization and instruction set issues, assembly language programming and debugging, and a hardware description language. Emphasis is on the fundamentals: the levels of abstraction and hardware description language methods that allow designers to cope with hugely complex systems, and connections to practical hardware implementation problems. Students will use computer-aided digital design software and actual hardware implementation laboratories to learn about real digital systems. 3 hr. lec., 1 hr. rec., 3 hr. lab.
Prerequisite: 18-100

18-290 Signals and Systems
Fall and Spring: 12 units
This course develops the mathematical foundation and computational tools for processing continuous-time and discrete-time signals in both time and frequency domain. Key concepts and tools introduced and discussed in this class include linear time-invariant systems, impulse response, frequency response, convolution, filtering, sampling, and Fourier transform. Efficient algorithms like the fast Fourier transform (FFT) will be covered. The course provides background to a wide range of applications including speech, image, and multimedia processing, bio and medical imaging, sensor networks, communication systems, and control systems. This course serves as entry and prerequisite for any higher level course in the fields of signal processing, communications, and control. Prerequisite(s): 18-100
Corequisite(s): 18-202
Prerequisite: 18-100

Course Website: http://www.ece.cmu.edu/~ece290

18-300 Fundamentals of Electromagnetics
Fall: 12 units
This course introduces electromagnetic principles and describes ways in which those principles are applied in engineering devices and systems. Topics include: vector calculus as a mathematical foundation for field descriptions, Maxwell's equations in integral and differential forms with associated boundary conditions as descriptions of all electromagnetic principles, quasistatic electric fields in free space and in materials, superposition for known charge sources, conduction and polarization, resistance and capacitance, charge relaxation, analytic and numerical methods for electric field boundary value problems, quasistatic magnetic fields in free space and in materials, superposition for known current sources, magnetization, inductance, magnetic diffusion, and analytic and numerical methods for magnetic field boundary value problems. 4 hrs. lec.
Prerequisite: 18-220

18-310 Fundamentals of Semiconductor Devices
Spring: 12 units
This course replaced 18311 in Spring 2005. In this course you will receive an introduction to the operation and fabrication of the most important semiconductor devices used in integrated circuit technology together with device design and layout. At the end of the course you will have a basic understanding of pn diodes, bipolar transistors, and MOSFETs as well as some light emitting and light detecting devices such as photodiodes, LEDs and solar cells. You will also receive an introduction to the fundamental concepts of semiconductor physics such as doping, electron and hole transport, and band diagrams. In the laboratory you will learn how to lay out both bipolar and MOS devices and you will design small (2-3 transistor) circuits. The laboratory portion of the course emphasizes the relation between device design and layout and circuit performance. You will also experimentally evaluate the operation of amplifier and gate circuits fabricated with discrete devices. This course will give you an excellent understanding of the operation and fabrication of the devices which is necessary for high-performance analog and digital circuit design. 3 hrs. lec. (Note: the prerequisite is typically waived for MSE students who intend to pursue the Electronic Materials Minor.)
Prerequisite: 18-220

18-320 Microelectronic Circuits
Spring: 12 units
18-320 introduces students to the fundamentals of microelectronic circuits. The course will emphasize the analysis and design of basic analog and digital integrated circuits in preparation for further study in analog, digital, mixed-signal, and radio-frequency integrated circuit design. Additionally, students will learn to design and analyze microelectronic circuits using industry standard computer aided design (CAD) software. Topics to be covered include: MOSFET fabrication and layout MOSFET models for analog and digital design Analysis and design of digital CMOS logic gates Analysis and design of clocked storage elements (e.g., flip-flops, latches, memory cells) Delay optimization of digital circuits Circuit topologies for arithmetic and logical functional units Analysis and design of single-stage MOS amplifiers Frequency response characteristics of single-stage amplifiers Differential amplifiers and simple operational amplifiers Analog filters using operational amplifiers The course includes a lab component which will give students hands-on experience in the design and implementation of analog and digital circuits. Labs will employ both design using discrete, SSI, and MSI parts, as well as using CAD design tools.
Prerequisite: 18-220

18-330 Introduction to Computer Security
Fall: 12 units
Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.
Prerequisite: 18-213

18-331 Junior Projects
Fall
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is conducting undergraduate research with a faculty member. Students do not need to officially register for undergraduate research unless they want it listed on their official transcripts. An ECE student who is involved in a research project and is interested in registering this undergraduate research for course credit on the official transcript may request to be enrolled in this course. To do this, the student should first complete the on-line undergraduate research form available on the ECE undergraduate student page. Once the form has been submitted and approved by the faculty member the student is conducting the research with, the ECE Undergraduate Office will add the course to the student's schedule. Typical credit is granted as one hour of research per week is equal to one unit of credit.

18-332 Junior Projects
Spring
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is conducting undergraduate research with a faculty member. Students do not need to officially register for undergraduate research unless they want it listed on their official transcripts. An ECE student who is involved in a research project and is interested in registering this undergraduate research for course credit on the official transcript may request to be enrolled in this course. To do this, the student should first complete the on-line undergraduate research form available on the ECE undergraduate student page. Once the form has been submitted and approved by the faculty member the student is conducting the research with, the ECE Undergraduate Office will add the course to the student's schedule. Typical credit is granted as one hour of research per week is equal to one unit of credit.

18-334 Network Security
Spring: 12 units
Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to advance attacks on end systems. This course provides an in-depth study of network attack techniques and methods to defend against them. The course will cover topics spanning five broad themes: (1) infrastructure topics such as firewalls, network intrusion detection, secure routing protocols, and recent advances such as software-defined networking; (2)network attacks such as denial of service (DoS) and distributed denial-of-service (DDoS) attacks, worm and virus propagation; (3)analysis and inference topics such as network forensics and attack economics; (4) user related topics such as authentication, anonymity and censorship resilience; and (5) new technologies related to next-generation networks, and cellular and wireless networks. Students in 18-334 will share lectures and homeworks with students in 18-731. However, 18-731 will have additional requirements not shared by 18-334, including the requirement to produce scribe notes and to practice and demonstrate the ability to read and summarize scientific papers on the topics covered by the course.
Prerequisites: 15-330 or 18-330

18-335 Secure Software Systems
Spring: 12 units
Poor software design and engineering are the root causes of most security vulnerabilities in deployed systems today. Moreover, with code mobility now commonplace—particularly in the context of web technologies and digital rights management—system designers are increasingly faced with protecting hosts from foreign software and protecting software from foreign hosts running it. This class takes a close look at software as a mechanism for attack, as a tool for protecting resources, and as a resource to be defended. Topics covered include the software design process; choices of programming languages, operating systems, databases and distributed object platforms for building secure systems; common software vulnerabilities, such as buffer overflows and race conditions; auditing software; proving properties of software; software and data watermarking; code obfuscation; tamper resistant software; and the benefits of open and closed source development. Students in 18-335 will share lectures and homeworks with students in 18-732. However, 18-732 has additional requirements not shared by 18-335, including the requirement to produce scribe notes and to practice and demonstrate the ability to read and summarize scientific papers on the topics covered by the course.
Prerequisites: 15-330 or 18-330

18-340 Hardware Arithmetic for Machine Learning
Fall: 12 units
In this course, students explore the techniques for designing high-performance digital circuits for computation along with methods for evaluating their characteristics. We begin by reviewing number systems and digital arithmetic along with basic arithmetic circuits such as ripple-carry adders. From there, we move to more complex adders (carry-look-ahead, carry-skip, carry-bypass, etc.), multipliers, dividers, and floating-point units. For each circuit introduced, we will develop techniques and present theory for evaluating their functionality and speed. Other methods will be described for analyzing a circuit's power consumption, testability, silicon area requirements, correctness, and cost. In addition, we will utilize various CAD tools to evaluate the circuits described. Finally, advanced timing and clocking concepts will be investigated. For example, the notion of clock skew will be introduced and its impact on clock period for sequential circuits will be analyzed. We will also learn how to analyze and design asynchronous circuits, a class of sequential circuits that do not utilize a clock signal. Course projects focus on key arithmetic aspects of various machine learning algorithms including: K-nearest neighbors, neural networks, decision trees, and support vector machines. *Note: Although students in 18-340 and 18-640 will share lectures, labs, and recitations, students in 18-340 and 18-640 will receive different homework assignments, design projects, and exams. In some cases 18-640 students will also have different or additional lab sessions. The homework assignments, design projects, and exams that are given to the students registered for 18-640 will be more challenging than those given to the students registered for 18-340 in that they will have more complex designs, involve additional theoretical analysis, and have more stringent specifications (e.g., in area, power, performance, and robustness).
Prerequisite: 18-240

18-341 Logic Design and Verification
Fall: 12 units
This course is a second level logic design course, studying the techniques of designing at the register-transfer and logic levels of complex digital systems using modern modeling, simulation, synthesis, and verification tools. Topics include register-transfer level systems (i.e., finite state machines and data paths), bus and communication system interfacing (such as a simplified USB interface), discrete-event simulation, testbench organization, assertion-based verification and functional coverage. Design examples will be drawn from bus and communication interfaces, and computation systems, emphasizing how these systems are designed and how their functionality can be verified. A modern hardware description language, such as SystemVerilog, will serve as the basis for uniting these topics. Quizzes, homeworks and design projects will serve to exercise these topics.
Prerequisite: 18-240

18-342 Fundamentals of Embedded Systems
Fall: 12 units
This practical, hands-on course introduces students to the basic building-blocks and the underlying scientific principles of embedded systems. The course covers both the hardware and software aspects of embedded procesor architectures, along with operating system fundamentals, such as virtual memory, concurrency, task scheduling and synchronization. Through a series of laboratory projects involving state-of-the-art processors, students will learn to understand implementation details and to write assembly-language and C programs that implement core embedded OS functionality, and that control/debug features such as timers, interrupts, serial communications, flash memory, device drivers and other components used in typical embedded applications. Relevant topics, such as optimization, profiling, digital signal processing, feedback control, real-time operating systems and embedded middleware, will also be discussed. This course is intended for INI students. Anti-requisites: 18348 or 18349
Prerequisite: 18-240

18-345 Introduction to Telecommunication Networks
Spring: 12 units
This course introduces the fundamental concepts of telecommunication networks. Underlying engineering principles of telephone networks, computer networks and integrated digital networks are discussed. Topics in the course include: telephone and data networks overview; OSI layers; data link protocol; flow control, congestion control, routing; local area networks; transport layer; introduction to high-speed networks; performance evaluation techniques. The course also reviews important aspects of network security and widely used classes of Internet application and services, such as peer-to-peer, content delivery networks, and video streaming.
Prerequisites: (36-217 or 36-226 or 36-212) and 18-213

18-349 Introduction to Embedded Systems
Fall and Spring: 12 units
This practical, hands-on course introduces the various building blocks and underlying scientific and engineering principles behind embedded real-time systems. The course covers the integrated hardware and software aspects of embedded processor architectures, along with advanced topics such as real-time, resource/device and memory management. Students can expect to learn how to program with the embedded architecture that is ubiquitous in smartphones, portable gaming devices, robots, etc. Students will then go on to learn and apply real-time principles that are used to drive critical embedded systems like automobiles, avionics, medical equipment, etc. Topics covered include embedded architectures (building up to modern 16/32/64-bit embedded processors); interaction with devices (buses, memory architectures, memory management, device drivers); concurrency (software and hardware interrupts, timers); real-time principles (multi-tasking, scheduling, synchronization); implementation trade-offs, profiling and code optimization (for performance and memory); embedded software (exception handling, loading, mode-switching, programming embedded systems). Through a series of laboratory exercises with state-of-the-art embedded processors, sensors, actuators and industry-strength development tools, students will acquire skills in the design/implementation/debugging of core embedded real-time functionality.
Prerequisites: 18-213 and 18-240

Course Website: http://www.ece.cmu.edu/~ee349

18-370 Fundamentals of Control
Fall: 12 units
An introduction to the fundamental principles and methodologies of classical feedback control and its applications. Emphasis is on problem formulation and the analysis and synthesis of servomechanisms using frequency and time domain techniques. Topics include analytical, graphical, and computer-aided (MATLAB) techniques for analyzing and designing automatic control systems; analysis of performance, stability criteria, realizability, and speed of response; compensation methods in the frequency domain, root-locus and frequency response design, and pole-zero synthesis techniques; robust controller design; systems with delay and computer control systems; transfer function and state space modeling of linear dynamic physical systems; nonlinearities in control systems; and control engineering software (MATLAB). 4 hrs. lec., 1 hr. rec.
Prerequisites: 18-290 or 18-396

18-372 Fundamental Electrical Power Systems
Fall: 12 units
This course introduces the fundamentals in electric energy systems which will enable you to understand current issues and challenges in electric power systems ("smart grid") and what it takes for you to have a reliable electric power supply at your house. First, the general structure of an electric power system (current and future trends) will be introduced. This includes electric power plants (renewable and non-renewable); transmission and distribution; and consumers. Then, electric power is addressed from a mathematical point of view. The mathematical formulae for AC power and models for the above mentioned elements are derived which will enable you to calculate how much power is flowing over which lines on its way from the power plant to the consumer. Maintaining the balance between generation and consumption is important to avoid catastrophic blackout events. Hence, the notion of stability and available control concepts will be introduced.
Prerequisites: 18-220 and 18-202

18-390 ECE CO-OP
Fall and Spring
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is cooperative education, which provides a student with an extended period of exposure with a company. To participate, students must complete an ECE Co-op Approval form (located in HH 1116) and submit for approval. Students must possess at least junior status and have an overall grade point average of 3.0 or above. All co-ops must be approximately 8 months in uninterrupted length. If the co-op is approved, the ECE Undergraduate Studies Office will add the course to the student's schedule. Upon completion of the co-op experience, students must submit a 1-2 page report of their work experience, and a 1-2 page evaluation from the company supervisor to the ECE Undergraduate Studies Office. Due to federal restrictions on student work experiences, international students are not eligible for co-ops. Please visit the CPT page for information regarding international student internships.

18-401 Electromechanics
12 units
This course provides a broadly based introduction to interactions between mechanical media and electromagnetic fields. Attention is focused on the electromechanical dynamics of lumped-parameter systems, wherein electrical and mechanical subsystems may be modeled in terms of discrete elements. Interactions of quasistatic electric and magnetic fields with moving media are described and exemplified. Unifying examples are drawn from a wide range of technological applications, including energy conversion in synchronous, induction, and commutator rotating machines, electromechanical relays, a capacitor microphone and speaker, and a feedback-controlled magnetic levitation system. 4.5 hrs. rec.
Prerequisite: 18-300

18-402 Applied Electrodynamics
Spring: 12 units
This course builds upon the electric and magnetic field foundations established in 18-300 to describe phenomena and devices where electromagnetic waves are a central issue. Topics include: review of Maxwell's equations, propagation of uniform plane waves in lossless and lossy media, energy conservation as described by the Poynting Theorem, reflection and transmission with normal and oblique incidence upon boundaries, sinusoidal steady state and transients on 2-conductor transmission lines, modal descriptions of waveguides, radiation and antennas. 4 hrs. lec.
Prerequisite: 18-300

18-403 Microfabrication Methods and Technology
Fall: 12 units
This course is a laboratory-based introduction to the theory and practice of microfabrication. Lectures and laboratory sessions cover fundamental processing techniques such as photo-mask creation, lithographic patterning, thin film vacuum deposition processes, wet-chemical and dry-etching processes. This is primarily a hands-on laboratory course which brings students into the microfabrication facility and device testing laboratories. Students will fabricate electronic and opto-electronic devices such the metal-oxide-semiconductor (MOS) capacitor, the Schottky diode, the MOS transistor, the solar cell, and the light-emitting diode. An understanding of the operation of these building block devices will be gained by performing measurements of their electrical and opto-electronic characteristics. Emphasis is placed on understanding the interrelationships between the materials properties, processing, device structure, and the electrical and optical behavior of the devices. The course is intended to provide a background for a deeper appreciation of solid state electronic devices and integrated circuits. 2 lecture periods per week and a minimum of 4 laboratory hours.
Prerequisite: 18-310

18-411 Computational Techniques in Engineering
Spring: 12 units
This course develops the methods to formulate basic engineering problems in a way that makes them amenable to computational/numerical analysis. The course will consist of three main modules: basic programming skills, discretization of ordinary and partial differential equations, and numerical methods. These modules are followed by two modules taken from a larger list: Monte Carlo-based methods, molecular dynamics methods, image analysis methods, and so on. Students will learn how to work with numerical libraries and how to compile and execute scientific code written in Fortran-90 and C++. Students will be required to work on a course project in which aspects from at least two course modules must be integrated.
Prerequisites: 21-260 and 15-100 and 21-120 and 21-122 and 21-259

18-415 From Design to the Market for Deep Submicron IC's
Spring: 12 units
The general objective of the 18-415 class is to introduce and analyze all major design-dependent trade-offs which decide about the IC product commercial success. This objective will be achieved via playing in the class an "imaginary fabless IC design house startup game"- a main class activity. In this game students will be asked to construct "business plans" for a startup fabless IC design house. Each team in the class will have to envision, as an IC design objective, a new product with a functionality, which is already provided by another existing IC product (i.e. by microprocessor). The envisioned product should provide a subset of functionality of the existing product but it should be "better" in some other respect (e.g. it could be less expensive to fabricate, faster etc.). To handle the above assignment, students in the class will be using skills learned in 18-322 as well as all legal sources of "industrial intelligence" typically available for the IC industry. They can also use the class teacher as a source of free consulting, as well as, they can ask for any sequence of lectures or literature sources which they will need to meet the class objectives.
Prerequisite: 18-320

18-416 Nano-Bio-Photonics
Spring: 12 units
Light can penetrate biological tissues non-invasively. Most of the available bio-optic tools are bulky. With the advent of novel nanotechnologies, building on-chip integrated photonic devices for applications such as sensing, imaging, neural stimulation, and monitoring is now a possibility. These devices can be embedded in portable electronic devices such as cell phones for point of care diagnostics. This course is designed to convey the concepts of nano-bio-photonics in a practical way to prepare students to engage in emerging photonic technologies. The course starts with a review of electrodynamics of lightwaves. The appropriate choice of wavelength and material platform is the next topic. Then optical waveguides and resonators are discussed. Resonance-based sensing is introduced followed by a discussion of the Figure of Merits (FOMs) used to design on-chip sensors. Silicon photonics is introduced as an example of a CMOS-compatible platform. On-chip spectroscopy is the next topic. The second part covers nano-plasmonics for bio-detection and therapy. The design methods are discussed, followed by an overview of nanofabrication and chemical synthesis, and then a discussion of applications. The last part of this course will be dedicated to a review of recent applications such as Optogenetic neural stimulation, Calcium imaging, Cancer Imaging and Therapy. Senior or graduate standing required. This course is cross-listed with 18616. Although students in 18-616 and 18-416 will share the same lectures and recitations, students in 18-616 will receive distinct course projects. Students in 18-416 and 18-616 will be graded on separate curves.
Prerequisite: 18-300

18-418 Electric Energy Processing: Fundamentals and Applications
Spring: 12 units
This course provides an introduction to the fundamentals of electrical energy conversion and its use in several real-life systems. The course starts with a brief review of general mathematical and physical principles necessary for subsequent study of electrical energy conversion applications. This includes modeling, analysis, and control of general physical systems in time and frequency domain. Since the focus of energy conversion methods studied in this course is from electrical to mechanical systems, special attention is paid to electromagnetic theory. Rotating machines theory is developed and intuitively explained starting with Maxwell equations and analyzing general static and dynamic electromagnetic circuits. Power electronics methods are also introduced because most of modern electrical systems employ such methods. At this point, the necessary background is gained to analyze real life electrical energy conversion systems. We will focus on automotive, airplane, space station, and sea power systems. The main focus will be on operational principles and when appropriate stability issues of particular implementations. Time allowing, dynamic problems with interconnecting such systems will be briefly introduced and possibly studied by curious students in their course projects.
Prerequisite: 18-220

18-421 Analog Integrated Circuits
Spring: 12 units
Some form of analog circuit design is a critical step in the creation of every modern IC. First and foremost, analog circuits act as the interface between digital systems and the real world. They act to amplify and filter analog signals, and to convert signals from analog to digital and back again. In addition, high performance digital cell design (either high speed or low power) also invokes significant analog circuit design issues. The goal of this course is to teach students some of the methods used in the design and analysis of analog integrated circuits, to illustrate how one approaches design problems in general, and to expose students to a broad cross-section of important analog circuit topologies. The course will focus on learning design through carrying out design projects. Design and implementation details of wide-band amplifiers, operational amplifiers, filters and basic data converters will be covered. Example topics to be covered include transistor large- and small-signal device models, small-signal characteristics of transistor-based amplifiers, large-signal amplifier characteristics and nonidealities, operational amplifier design, basic feedback amplifier stability analysis and compensation, and comparator design. The course will focus primarily on analog CMOS, but some aspects of BJT design will be discussed. 18-290 and 18-320 or equivalent background material with permission of the instructor. Although students in 18-623 will share Lectures and Recitations with students in 18-421, students in 18-623 will receive distinct homework assignments, distinct design problems, and distinct exams from the ones given to students in 18-421 and will be graded on a separate curve from students taking 18-421.
Prerequisites: 18-320 Min. grade C and 18-290 Min. grade C

18-422 Digital Integrated Circuit Design
Fall: 12 units
This course covers the design and implementation of digital circuits in a modern VLSI process technology. Topics will include logic gate design, functional unit design, latch/flip-flop design, system clocking, memory design, clock distribution, power supply distribution, design for test, and design for manufacturing. The lab component of the course will focus on using modern computer aided design (CAD) software to design, simulate, and lay out digital circuits. The final project for the course involves the design and implementation to the layout level of a small microprocessor. 18-240 and 18-320 or equivalent background material with permission of the instructor. Although students in 18-422 and 18-622 will share lectures, labs, and recitations, students in 18-422 and 18-622 will receive different homework assignments, design projects, and exams, and in some cases 18-622 students will also have different or additional lab sessions.
Prerequisites: 18-320 and 18-240

18-431 Undergraduate Projects - Senior
Fall
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is conducting undergraduate research with a faculty member. Students do not need to officially register for undergraduate research unless they want it listed on their official transcripts. An ECE student who is involved in a research project and is interested in registering this undergraduate research for course credit on the official transcript may request to be enrolled in this course. To do this, the student should first complete the on-line undergraduate research form available on the ECE undergraduate student page. Once the form has been submitted and approved by the faculty member the student is conducting the research with, the ECE Undergraduate Office will add the course to the student's schedule. Typical credit is granted as one hour of research per week is equal to one unit of credit.

18-432 Senior Projects
Spring
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is conducting undergraduate research with a faculty member. Students do not need to officially register for undergraduate research unless they want it listed on their official transcripts. An ECE student who is involved in a research project and is interested in registering this undergraduate research for course credit on the official transcript may request to be enrolled in this course. To do this, the student should first complete the on-line undergraduate research form available on the ECE undergraduate student page. Once the form has been submitted and approved by the faculty member the student is conducting the research with, the ECE Undergraduate Office will add the course to the student's schedule. Typical credit is granted as one hour of research per week is equal to one unit of credit.

18-441 Computer Networks
Spring: 12 units
The Internet has transformed our everyday lives, bringing people closer together and powering multi-billion dollar industries. The mobile revolution has brought Internet connectivity to the last-mile, connecting billions of users worldwide. But how does the Internet work? What do oft repeated acronyms like "LTE", "TCP", "WWW" or a "HTTP" actually mean and how do they work? This course introduces fundamental concepts of computer networks that form the building blocks of the Internet. We trace the journey of messages sent over the Internet from bits in a computer or phone to packets and eventually signals over the air or wires. We describe concepts that are common to and differentiate traditional wired computer networks from wireless and mobile networks. Finally, we build up to exciting new trends in computer networks such as the Internet of Things, 5-G and software defined networking. Topics include: physical layer and coding (CDMA, OFDM, etc.); data link protocol; flow control, congestion control, routing; local area networks (Ethernet, Wi-Fi, etc.); transport layer; and introduction to cellular (LTE) and 5-G networks. A final project asks you to a build a HTTP video server of your own. This course is cross-listed with 18-741 - both editions will share Lectures and Recitations. However, students in the two courses will receive different exams and will have a different project. The students in the two versions of the course will be graded on a separate curve.
Prerequisites: (36-212 or 36-217 or 36-226) and 18-213

18-447 Introduction to Computer Architecture
Spring: 12 units
Computer architecture is the science and art of selecting and interconnecting hardware components to create a computer that meets functional, performance and cost goals. This course introduces the basic hardware structure of a modern programmable computer, including the basic laws underlying performance evaluation. We will learn, for example, how to design the control and data path hardware for a MIPS-like processor, how to make machine instructions execute simultaneously through pipelining and simple superscalar execution, and how to design fast memory and storage systems. The principles presented in the lecture are reinforced in the laboratory through the design and simulation of a register transfer (RT) implementation of a MIPS-like pipelined superscalar in Verilog. Learning to design programmable systems requires that you already have the knowledge of building RT systems, the knowledge of the behavior storage hierarchies (e.g., cache memories) and virtual memory, and the knowledge of assembly language programming.
Prerequisites: 18-240 and (18-213 or 15-213) and (18-349 or 18-340 or 18-348 or 18-320 or 18-341)

18-451 Networked Cyberphysical Systems
Spring: 12 units
Cyber-physical systems (CPS) represent a new class of systems that bring together sensing, computation, communication, control and actuation to enable continuous interactions with physical processes. This integration of networked devices, people, and physical systems provides huge opportunities and countless applications in biology and healthcare, automotive and transportation, power grids and smart buildings, social and financial markets, etc. Hence, CPS need to provide real-time efficiency, adaptability, optimality, security and robustness to natural disasters or targeted attacks. While the focus on embedded systems relies on building computational models for specific applications, CPS need a multidisciplinary approach and a more general computational paradigm such that more-direct interactions between the system and physical world become possible. This course is primarily an in-depth introduction to networked CPS with an emphasis on methods for modeling, design, and optimization. Focus is on the dominant design paradigms like low-power and communication-centric design. Topics to be covered include: physical processes, models of concurrency, sensing and workload modeling, human behavior modeling, data-driven modeling, networking at micro- and macro-scale, system-wide resources management, programming, validation and integration. From a practical standpoint, students will directly experiment with hardware prototypes and software tools to explore concrete CPS examples. By structure and contents, this class is primarily targeted to ECE students; it can also provide a valuable basis for interdisciplinary research to students in CS and related disciplines.
Prerequisites: 18-349 or (18-240 and 18-213)

18-452 Wireless Networking and Applications
Spring: 12 units
This course introduces fundamental concepts of wireless networks. The design of wireless networks is influenced heavily by how signals travel through space, so the course starts with an introduction to the wireless physical layer, presented in a way that is accessible to a broad range of students. The focus of the course is on wireless MAC concepts including CSMA, TDMA/FDMA, and CDMA. It also covers a broad range of wireless networking standards, and reviews important wireless network application areas (e.g., sensor networks, vehicular) and other applications of wireless technologies (e.g., GPS, RFID, sensing, etc.). Finally, we will touch on public policy issues, e.g., as related to spectrum use. The course will specifically cover: Wireless networking challenges Wireless communication overview Wireless MAC concepts Overview of cellular standards and LTE Overview of wireless MAC protocols WiFi, bluetooth and personal area networks, etc. Wireless in today's Internet: TCP over wireless, mobility, security, etc. Advanced topics, e.g., mesh and vehicular networks, sensor networks, DTNs, localization, sensing, etc. Although students in 18-750 will share Lectures and Recitations with students in 18-452, they will receive distinct homework assignments and exams from students in 18-452. The main project will also be different. The students in the two version of the course will also be graded on a separate curve.
Prerequisites: 15-213 or 18-600 or 18-213

18-460 Optimization
Spring: 12 units
Many design problems in engineering (e.g., machine learning, finance, circuit design, etc.) involve minimizing (or maximizing) a cost (or reward) function. However, solving these problems analytically is often challenging. Optimization is the study of algorithms and theory for numerically solving such problems, and it underpins many of the technologies we use today. This course is an introduction to optimization. Students will: (1)learn about common classes of optimization problems, (2) study (and implement) algorithms for solving them, and (3) gain hands-on experience with standard optimization tools. We will focus on convex optimization problems, but will also discuss the growing role of non-convex optimization, as well as some more general numerical methods. The course will emphasize connections to real-world applications including machine learning, networking, and finance. The course will involve lectures, homework, exams, and a project. This course is crosslisted with 18660. Although students in 18460 will share lectures with students in 18660, students in 18460 will receive distinct homework assignments, distinct design problems, and distinct exams from the ones given to students in 18660. Specifically, the homework assignments, design problems and exams that are given to the 18660 students will be more challenging than those given to the 18460 students.
Prerequisites: 18-202 and 21-241 and 36-217

18-461 Introduction to Machine Learning for Engineers
Fall: 12 units
This course provides an introduction to machine learning with a special focus on engineering applications. The course starts with a mathematical background required for machine learning and covers approaches for supervised learning (linear models, kernel methods, decision trees, neural networks) and unsupervised learning (clustering, dimensionality reduction), as well as theoretical foundations of machine learning (learning theory, optimization). Evaluation will consist of mathematical problem sets and programming projects targeting real-world engineering applications. This course is crosslisted with 18661. Although students in 18461 will share lectures with students in 18661, students in 18461 will receive distinct homework assignments, distinct programming projects, and distinct exams from the ones given to students in 18661. Specifically, the homework assignments, programming projects, and exams that are given to the 18661 students will be more challenging than those given to the 18461 students.
Prerequisites: 18-202 and 36-217 and 21-127 and 15-122

18-464 ULSI Technology Status and Roadmap for System on Chips and System in Package
Fall and Spring: 12 units
This course will provide the necessary background for the state-of-the art technologies utilized by the leading edge products covering full spectrum of market drivers from mobile platforms, microprocessors, game chips to the highest performance systems for enterprise solutions computing. We will present all key components of such systems, i.e., logic, analog/RF and embedded memories. Then we present the technology roadmap for the upcoming generations in terms of device architecture options for logic devices (FinFET, Nanowire and Tunnel FET) and memories (Phase Change Memory , Resistive RAM and Magnetic RAM/Spin-Transfer Torque RAM) from the device level all the way to the system level specifications. The last part of the class will be devoted to the system integration issues, namely 3-dimensional integration approaches. This course is designed for MS and PhD students from diverse areas: System/Hardware Design, Circuits and Devices/Nanofabrication and is aimed at bridging the gap among these areas.
Prerequisites: 18-422 or 18-320

18-474 Embedded Control Systems
Spring: 12 units
This course introduces principles for design of embedded controllers. In applications ranging from airplanes, to automobiles, to manufacturing systems, embedded computers now close feedback loops that were previously closed by mechanical devices or by humans in the loop. This course emphasizes practical insight into the tools for modeling and simulating these dynamic physical systems, and methods for designing the real-time software for embedded computers to control them. Lectures cover relevant theory and background from real-time systems and control engineering, including event-based and clock-based sampling, switching control, PWM (pulse-width modulation), PID (proportional-integral-derivative) design, state-variable feedback, state estimation, and methods for setpoint control and trajectory tracking. Basic embedded computing, sensor, and actuator technologies are reviewed, including microcontrollers, DC motors and optical encoders. In the laboratory, students use commercial tools for simulation and automatic code generation to design and implement embedded control system experiments. 3 hrs. lecture, 3 hrs. lab.
Prerequisites: (15-213 or 18-213) and (18-396 or 18-370)

18-482 Telecommunications Technology and Policy for the Internet Age
Spring: 12 units
Modern telecommunications is the nervous system of society. The Internet and wireless communications have transformed every aspect of our modern life. This course provides a comprehensive introduction to basic principles of telecommunications technology and the legal, economic, and regulatory environment of today's networks. Topics covered include the fundamentals of communication network technologies, including video, voice, and data networks; the rising dominance of wireless networks; principles behind telecommunications regulation from common carrier law and natural monopoly to information diversity, privacy and national security; traffic differentiation on the Internet and the debate over network neutrality; universal service and the digital divide; mergers, antitrust, and the changing industrial structure of the communications sector. We will explore current topical questions such as the future of competition; the shift of entertainment video from cable and satellite to Internet delivery; how cloud computing concepts are transforming networks; and communications support for the Internet of Things. Comparison with European approaches to communications regulation. Special emphasis on how new technologies have altered, and are altered by, regulation. Junior, Senior or graduate standing required.
Prerequisite: 73-102

18-487 Introduction to Computer Security
Fall: 12 units
Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems. Anti-requisites: 18-631 and 18-730
Prerequisite: 18-213

18-491 Fundamentals of Signal Processing
Fall: 12 units
This course addresses the mathematics, implementation, design and application of the digital signal processing algorithms widely used in areas such as multimedia telecommunications and speech and image processing. Topics include discrete-time signals and systems, discrete-time Fourier transforms and Z-transforms, discrete Fourier transforms and fast Fourier transforms, digital filter design and implementation, and multi-rate signal processing. The course will include introductory discussions of 2-dimensional signal processing, linear prediction, adaptive filtering, and selected application areas. Classroom lectures are supplemented with implementation exercises using MATLAB.
Prerequisite: 18-290

18-493 Electroacoustics
Fall: 12 units
This course provides an introduction to physical, engineering, and architectural acoustics. The course begins with a review of the wave equation and some of its solutions that are relevant to the propagation of sound from planar and spherical sources, and from arrays of simple sources. Lumped-parameter electrical circuit analogies are developed to describe mechanical and acoustical systems, leading to a discussion of the constraints and tradeoffs involved in the design of loudspeakers, microphones, and other transducers. The characteristics of sound in regular and irregular enclosures will be developed and discussed in the context of the acoustical design for rooms and auditoriums. The interaction of sound and man is also discussed, with introductory lectures on auditory perception and the acoustics of speech production, with applications in the areas of efficient perceptually-based coding of music and speech, and virtual acoustical environments.
Prerequisites: 18-290 and 18-220

18-496 Introduction to Biomedical Imaging and Image Analysis
Fall: 12 units
Bioimage Informatics (formerly Bioimaging) This course gives an overview of tools and tasks in various biological and biomedical imaging modalities, such as fluorescence microscopy, electron microscopy, magnetic resonance imaging, ultrasound and others. The major focus will be on automating and solving the fundamental tasks required for interpreting these images, including (but not restricted to) deconvolution, registration, segmentation, pattern recognition, and modeling, as well as tools needed to solve those tasks (such as Fourier and wavelet methods). The discussion of these topics will draw on approaches from many fields, including statistics, signal processing, and machine learning. As part of the course, students will be expected to complete an independent project.
Prerequisite: 18-290

18-499 Internship
All Semesters
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. ECE students interested in registering their internship for course credit on their transcript may request to be enrolled in this course. The ECE Undergraduate Office will add the course to the student's schedule, and the student will be assessed tuition for 3 units. This process should be used by international students interested in Curricular Practical Training (CPT) or by any other engineering undergraduate wishing to have their internship experience reflected on their official University transcript. International students should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website.

18-500 ECE Design Experience
Fall and Spring: 12 units
The ECE Design Experience is a capstone design course that serves to introduce students to broad- based, practical engineering design and applications through an open-ended design problem. Students will work with a team on a project of their choosing (subject to instructor approval) throughout the semester culminating with a final project presentation, report, and public demonstration. The projects will need to encompass a minimum of two ECE areas. Throughout the semester, teams will need to give both written and oral project proposals and periodic performance updates. Team-building experiences designed to educate students on group dynamics, resource management, deadline planning, Big-picture implications of engineering applications: societal, human, ethical, and long-term impact will be explored. PREREQUISITES: Any TWO 18-xxx ECE Area courses AND all four ECE Sophomore Core courses, 18-213, 18-220, 18-240 and 18-290.
Prerequisites: 18-213 and 18-240 and 18-220 and 18-290

18-540 Rapid Prototyping of Computer Systems
Spring: 12 units
This is a project-oriented course which will deal with all four aspects of project development; the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class, in conjunction with the instructors, will develop specifications for a mobile computer to assist in inspection and maintenance. The application will be partitioned between human computer interaction, electronics, industrial design, mechanical, and software components. The class will be divided into groups to specify, design, and implement the various subsystems. The goal is to produce a working hardware/software prototype of the system and to evaluate the user acceptability of the system. We will also monitor our progress in the design process by capturing our design escapes (errors) with the Orthogonal Defect Classification (ODC). Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided design tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. Senior standing is required. This course is crosslisted as 18745
Prerequisites: (18-320 or 18-491 or 18-370) and (18-349 or 18-341 or 18-340)

18-578 Mechatronic Design
Spring: 12 units
Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. Because of the emphasis upon integration, this course will center around system integration in which small teams of students will configure, design, and implement a succession of mechatronic subsystems, leading to a main project. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, electronics, and control components. Class lectures will cover topics intended to complement the laboratory work, including mechanisms, actuators, motor drives, sensors and electronic interfaces, microcontroller hardware and programming and basic controls. During the first week of class, each student will be asked to complete a questionnaire about their technical background. The class will then be divided into multi-disciplinary teams of three students. During the first half of the class, lab assignments will be made every 1-2 weeks to construct useful subsystems based on material learned in lecture. The lab assignments are geared to build to the main project. This course is cross-listed as 16-778 and 24-778. Students in other departments may take the course upon availability of slots with permission of instructor. Non ECE students may take the course upon availability of slots with permission of the instructor.
Prerequisites: (18-320 and 18-348) or (15-313 and 18-348) or (18-348 and 18-370) or (18-370 and 18-349) or (18-349 and 15-313) or (18-320 and 18-349) or (18-320 and 18-370)

18-661 Introduction to Machine Learning for Engineers
Fall: 12 units
This course provides an introduction to machine learning with a special focus on engineering applications. The course starts with a mathematical background required for machine learning and covers approaches for supervised learning (linear models, kernel methods, decision trees, neural networks) and unsupervised learning (clustering, dimensionality reduction), as well as theoretical foundations of machine learning (learning theory, optimization). Evaluation will consist of mathematical problem sets and programming projects targeting real-world engineering applications. This course is crosslisted with 18461. Although students in 18461 will share lectures with students in 18661, students in 18461 will receive distinct homework assignments, distinct programming projects, and distinct exams from the ones given to students in 18661. Specifically, the homework assignments, programming projects, and exams that are given to the 18661 students will be more challenging than those given to the 18461 students.
Prerequisites: 21-127 and 15-122 and 18-202 and 36-217

18-663 Hardware Architectures for Machine Learning
Fall and Spring: 12 units
Machine learning is poised to change the landscape of computing in more ways than its broad societal applications. Indeed, hardware architectures that can efficiently run machine learning face increasing challenges due to power consumption or run time constraints that technology, platforms, or users impose. This course provides an overview of current advances in hardware architectures that can enable fast and energy efficient machine learning applications from the edge to the cloud. Topics include hardware accelerators, hardware-software co-design, and general or application specific system design and resource management for machine learning applications.
Prerequisites: (18-661 or 10-601 or 10-401 or 18-461 or 10-701) and (18-447 or 18-340)

18-883 Special Topics in Energy Systems
Spring: 6 units
Please see the ECE website for a full course description describing the sections of this course.

18-989 Introduction to Graduate Studies
Fall and Spring: 1 unit
The Introduction to Graduate Studies course is designed to increase awareness and understanding of academic integrity issues, Carnegie Mellon community standards and the ethical job search. This is done via various sessions/modules that are already offered via several entities throughout campus (such as the CPDC, ICC, and GCC). Topics covered include: paraphrasing and citation, participating in the US classroom, avoiding plagiarism, unconscious bias, combating sexual violence on campus, finding jobs and internships, negotiation, communication, relationship building and other topics of interest. The course culminates in students writing a reflection paper. For international students, the paper should compare western academic and cultural standards to those of their home country. For domestic students, the paper should be a reflection on CMU's community standards. Active participation in 5 sessions/modules in the above mentioned areas and the submission of the reflection paper will determine a pass/fail grade.

Department of Engineering and Public Policy

Peter Adams, Interim Department Head

Deanna H. Matthews, Associate Department Head for Undergraduate Affairs

Location: Baker Hall 129
www.cmu.edu/epp

The Department of Engineering and Public Policy (EPP) is a unique department that works on problems at the interface between technology and society. Society is largely responsible for setting the goals and framing the problems that engineers and scientists work on. However, technologies designed by engineers and scientists profoundly change the societies in which they operate. Technology has enabled a healthier, richer, and more productive society. At the same time, technology has contributed to the creation of many of the more serious problems our society faces.

Technology can help us build a happier, freer, and more fulfilling life, while maintaining risks and undesirable impacts at acceptable levels. But that does not happen automatically. It takes careful hard work by people who understand both technology and the society in which they live. In order to do their jobs responsibly and well in today's world, engineers and scientists must develop an understanding of the interface between technology and society and a command of the skills necessary to work at that interface. The undergraduate degree programs of the Department of Engineering and Public Policy (EPP) have been designed to allow undergraduate students at Carnegie Mellon University to add this important dimension to their traditional engineering or science education. EPP additional major graduates, for the most part, will enter traditional engineering or science careers, but will carry with them a set of insights and skills that will help them to better deal with issues in technology and policy, and better exercise their ethical and social obligations as practicing professionals.

Overview of the Undergraduate Programs in EPP

The undergraduate additional major programs in EPP combine the strong foundation in mathematics and physical sciences, and the development of engineering or science skills with a rigorous preparation in the analysis of social and political problems. The curriculum includes subject matter which is not part of traditional technical or social science curricula, but which contains elements of each. Students complete courses in four core areas: economics, statistics, decision-making, and communication. Breadth is achieved through EPP Technology-Policy elective courses. Finally, students apply their skills in a project preparatory course and two interdisciplinary problem-solving projects. Problem areas for these projects are chosen from local, state, and national situations, and include such topics as climate change, energy systems, technological innovation, telecommunication issues, computer security and privacy, risk analysis and communication, among others. Students from several CMU colleges enroll in these projects courses exposing EPP additional majors to working in truly interdisciplinary situations. Examples of past project course topics (http://www.cmu.edu/epp/prospective/undergraduate/epp-project-courses) and final reports are available.

Additional Major in Engineering and Public Policy

The EPP department offers an additional major in Engineering and Public Policy (EPP) with each of the five traditional engineering departments in the engineering college. The engineering additional major leads to a fully accredited engineering degree that prepares students for traditional technical careers. EPP additional major engineers are not educated to be a different kind of engineer. Rather, their education is intended to enable them to be better, more socially responsible engineers in the traditional technical fields.

Additional Major in Science, Technology, and Public Policy

The EPP department offers an additional major in Science, Technology and Public Policy (STPP) for students outside of the engineering college who are earning a B.S. degree. This includes students in the Mellon College of Science, the School of Computer Science, Tepper School of Business, and select majors in the Dietrich College and College of Fine Arts. Similar to the additional major in Engineering and Public Policy, the additional major in Science, Technology and Public Policy is meant to broaden the perspectives on a student’s primary major and provide additional skills for future careers.

Minor in Technology and Policy

The department also offers a minor in Technology and Policy for non-engineering majors. The Technology and Policy minor exposes students to issues at the interface of science, technology, and society, and how interdisciplinary approaches are needed to solve complex problems.

Career Options with EPP Additional Majors

Students who select one of the EPP additional majors graduate with an accredited engineering degree or complete science degree, and thus have all of the options for traditional technical careers as their single major classmates. A large portion of our additional major students pursue traditional technical careers after graduation in areas such as product development, consulting, project management, etc.

The advantage of the additional major is the added set of skills and perspectives, which allow a graduate of the program to improve the quality, sensitivity, and social responsiveness of their work, and the work of their colleagues. Employers recognize these skills and often view our graduates as more attractive for a traditional engineering or technical position. Firms contact the EPP department every year to recruit EPP graduates because of their satisfaction with the knowledge and skills acquired by EPP students.

The additional major also opens up a collection of other options that are not available to most technical graduates. These include jobs in policy analysis in federal, state, and local government or in public policy consulting firms. Alumni also pursue careers in companies to deal with issues like government regulation, environmental control, worker health and safety, product liability and safety, telecommunications policy, energy systems, and the social impact of large technological systems.

Students also choose to continue their formal education, doing graduate work in engineering, the social sciences, law, or interdisciplinary programs.

Faculty Advisors

Faculty in several departments serve as advisors and information resources to students selecting the EPP undergraduate programs. Given the interdisciplinary perspective of EPP, students may find that a faculty member outside their traditional major can provide support and guidance with EPP-related courses and career paths. The EPP Associate Department Head for Undergraduate Affairs is Deanna Matthews. Dr. Matthews can provide general academic advice and guidance for all EPP undergraduates. Other faculty affiliated with the undergraduate programs in EPP are:

- Civil Engineering: Peter Adams, Jared Cohon, Scott Matthews, Mitch Small
- Chemical Engineering: Neil Donahue
- Computer Science: Lorrie Cranor, Doug Sicker
- Economics: Nicholas Muller
- Electrical and Computer Engineering: Jon Peha, Marvin Sirbu
- Engineering and Public Policy: Daniel Armanios, Alex Davis, Erica Fuchs, Paulina Jaramillo, Deanna Matthews, Granger Morgan
- Institute for Politics and Strategy: Baruch Fischhoff
- Mechanical Engineering: Jeremy Michalek, Edward Rubin, Kate Whitefoot
- Material Science and Engineering: Jay Whitacre
- Social and Decision Sciences: Paul Fischbeck

EPP Program Educational Objectives

Students who earn an additional major in Engineering and Public Policy at the undergraduate level do so in conjunction with a traditional engineering major. The elements of the EPP undergraduate program broaden the traditional scope of technical analysis to encompass an engineering solution’s potential impact on society. Thus, our graduates have all of the skills as their peers in traditional engineering majors, but with a broader societal perspective and additional analysis skills. This enables our graduates to understand the interface between technology and society and to help solve the complex, interdisciplinary systems problems facing our world in their careers. Students will be able to work in a variety of career fields, including technical and non-technical, in industry, government or elsewhere where these broad skills are needed.

EPP Student Outcomes

By the end of the combined B.S. programs in a traditional engineering program and the EPP program, students should have attained the following:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The additional major in Engineering and Public Policy is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

Course Requirements for the Additional Major in EPP

Minimum units for the additional major 106

Students pursuing an additional major in EPP must complete three sets of requirements: courses for the EPP additional major, courses for their traditional disciplinary major, and general education courses. The student should refer to the relevant sections of this catalog for the required courses in the traditional disciplinary major. The EPP additional major is designed to be completed with a traditional disciplinary major in the standard four-year time frame. However, additional units or course work may be required. Some courses for the EPP additional major may also satisfy requirements for traditional disciplinary majors or for general education courses.

Overview

Course		Units
19-101	Introduction to Engineering and Public Policy	12
19-201	EPP Sophomore Seminar	1
73-102	Principles of Microeconomics	9
36-220	Engineering Statistics and Quality Control (or other approved statistics course)	9
19-301	Decision Making Methods for Engineers and Scientists	9
or 88-223	Decision Analysis	
or 88-302	Behavioral Decision Making	
or 84-369	Decision Science for International Relations	
(or other approved decision science course)		
19-325	Technology and Policy Writing for Lay Audiences	9
or 76-270	Writing for the Professions	
(or other approved writing course)		
19-351	Applied Methods for Technology-Policy Analysis	9
19-451	EPP Projects	12
19-452	EPP Projects	12
Three EPP Technology-Policy Electives		min. 24

Introductory Courses

		Units
19-101	Introduction to Engineering and Public Policy	12
19-201	EPP Sophomore Seminar	1

The two introductory courses prepare students for the additional major experience through discussion and assessment of technology-policy interactions. 19-101 Introduction to Engineering and Public Policy may be taken as the second introductory engineering course during the first year for engineering students. 19-201 EPP Sophomore Seminar is required in addition to any corresponding seminar course in a student's traditional degree program.

Core Area Courses

73-102	Principles of Microeconomics	9
36-220	Engineering Statistics and Quality Control	9
EPP Decision Science elective - one of the following, or other approved course:		
19-301	Decision Making Methods for Engineers and Scientists	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9
84-369	Decision Science for International Relations	9
EPP Writing and Communications elective - one of the following, or other approved course		
19-325	Technology and Policy Writing for Lay Audiences	9
76-270	Writing for the Professions	9

The four core area courses provide the foundational skills in the social sciences that are needed for robust analysis of policy problems. 73-102 Principles of Microeconomics should be taken as a CIT General Education course.

36-220 Engineering Statistics and Quality Control is required for all CE, ME, and MSE students in their traditional engineering majors. ChE students will substitute 36-220 for 03-232 Biochemistry I. ECE students, who take 36-217 Probability Theory and Random Processes for their traditional engineering major, may take 36-220 or 36-226 Introduction to Statistical Inference. Students should complete the statistics requirement by the end of sophomore year. A statistics course is a prerequisite for the EPP Decision Science elective.

The EPP Decision Science elective fulfills either the CIT General Education Social Analysis and Decision Making requirement or a CIT General Education free elective. The EPP Writing and Communications course fulfills the CIT General Education Writing and Expressions requirement.

Technology-Policy Electives

- At least 3 courses of EPP Technology-Policy electives (24 units minimum)

EPP Technology-Policy Electives include courses that belong to three categories. First, EPP Technology-Policy Electives include courses that synthesize engineering analysis and social analysis perspectives and apply them to problems with substantial societal and technological components. Specific areas of interest for these courses are (1) energy, resources, and the environment, (2) risk assessment, (3) technology innovation, (4) urban engineering, (5) information and communication technology, and (6) product engineering and design, among others. Second, EPP Technology-Policy Electives include courses that teach methods or analysis skills necessary for solving complex problems. Examples include mathematical or statistical courses related to optimization or estimation, or economics courses related to economic analysis. Finally, EPP Technology-Policy Electives include courses that provide technical background for policy relevant issues. These courses are fundamental for understanding our current engineering systems and how proposed changes can be implemented. Examples include courses on electricity systems, engine design, or atmospheric systems. A sample of courses for EPP Technology-Policy Electives is below, a full list of approved courses is available from the department.

19-211	Ethics and Policy Issues in Computing	9
19-355	Special Topic: Cryptocurrencies, Blockchains, and Applications	Var.
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-425	Sustainable Energy for the Developing World	9
19-443	Climate Change Science and Adaptation	9
19-458	Special Topics: Organizational Theory for Engineers	9

Qualifying courses for EPP Technology-Policy Electives are determined each semester. The majority of 19-xxx EPP departmental courses are considered EPP Technology-Policy Electives. Exceptions will be identified when the courses are offered. 19-301 and 19-351 are required courses for the EPP additional major and may not be used as EPP Technology-Policy electives. Courses from other departments also are acceptable as electives. Students should work with their advisors to define areas of concentration or a selection of breadth courses for the EPP Technology-Policy Electives.

Students are required to take at least three EPP Technology-Policy electives for a minimum of 24 units. Units may be added in any combination, but a maximum of one 3-unit course is permitted. Up to 9 units of research may be used with approval. Students may not use a required course from their traditional disciplinary major for these elective units. However, students may use an elective course from their traditional major requirements to meet the requirements of both their traditional engineering major and an EPP Technology-Policy elective, but the units for the course will not be double-counted toward units required for their degree. Some EPP Technology-Policy elective courses may fulfill requirements for CIT General Education categories (e.g., 19-411 Global Competitiveness: Firms, Nations and Technological Change is an I&I course), otherwise students use Free Elective units to complete this requirement.

Capstone Courses

		Units
19-351	Applied Methods for Technology-Policy Analysis	9
19-451	EPP Projects	12
19-452	EPP Projects	12

The capstone courses synthesize the technical skills and knowledge from a student's traditional major with the social science skills and broad perspective of the EPP major.

19-351 Applied Methods for Technology-Policy Analysis is a preparatory course for the EPP Projects. 19-351 may be completed as a co-requisite of 19-451 EPP Projects. The course fulfills CIT General Education free elective units.

19-451 and 19-452 EPP Projects are technology/policy projects which deal with research and development of recommendations for solving actual and critical problems currently affecting society. The students, faculty, and graduate student managers for the project are drawn from EPP, Social and Decision Sciences, and the Heinz College, and other CMU departments, and hence bring different areas of expertise to the structuring and solution of the problem. The topics for EPP Projects are drawn from diverse areas such as environmental systems and resources, public transportation, urban engineering problems, energy and fuel utilization, the interaction of law and technology, strategic materials and vulnerability of supply, technical issues in national security, and problems in automation, robotics, and communication technology. Students use Free Elective units to complete this requirement.

Notes on EPP additional major requirements

Students should follow the suggested curriculum timelines for completing the math, science, and engineering course requirements of the traditional major with the exception of 36-220 which should be taken as early as possible and no later then the end of sophomore year.

All students must complete 76-101 Interpretation and Argument. Some courses as noted above may be used to fulfill requirements of general education courses. Acceptable courses for the CIT General Education requirements are maintained by the CIT Dean's Office. Students must submit a plan during their first-semester as an EPP student (usually Fall sophomore year) for these general education courses demonstrating their relevance to EPP.

Students must complete the minimum number of units as required by their traditional major for graduation. In some cases, students completing the EPP additional major may need to complete additional units to meet all requirements for the traditional major and EPP additional major.

In addition to any other graduation requirements (e.g., regarding course work, minimum QPA, pass/fail course work, etc.) of the student's traditional disciplinary major, students must earn a minimum QPA of 2.0 in all courses required for the EPP major.

Side-by-side curriculum charts (http://www.cmu.edu/epp/prospective/undergraduate/epp-additional-major/curriculum-charts) of the curricula for the traditional engineering majors alone versus the traditional engineering majors with the EPP additional major can assist students in determining the course requirements and scheduling needed to complete the degree requirements.

A proposed semester plan is below. Students work with their faculty advisors to determine the best sequence of courses given the varied requirements in the traditional majors.

Course	Semester
19-101 Introduction to Engineering and Public Policy	**First-year Spring**
73-102 Principles of Mircoeconomics	**First-year Fall or Spring**
19-201 EPP Sophomore Seminar	**Sophomore Fall**
36-220 Engineering Statistics and Quality Control	**Sophomore Fall or Spring**
EPP Writing and Communications Elective	**Sophomore Fall or Spring**
EPP Decision Science Elective	**Junior Fall**
19-351 Applied Methods for Technology-Policy Analysis	**Junior Spring**
3 EPP Technology-Policy Electives	**Junior and/or Senior year**
19-451/19-452 EPP Projects	**Senior Fall and Spring**

Course Requirements for the Additional Major in STPP

Minimum units required for additional major 106

The requirements for the Science, Technology and Public Policy additional major are similar to those for the Engineering and Public Policy additional major. Some courses may fulfill some major requirements or "general education" requirements in other colleges. Other courses will use student's elective spaces or free elective units. Core courses required for a student's major will not be allowed to double-count for Technology Policy electives, but elective courses can be selected that fulfill both major elective requirements and Technology Policy electives. Students pursuing the STPP additional major should work with their advisors to determine how best to fit the additional major requirements into their course load.

Introductory Courses

		Units
19-101	Introduction to Engineering and Public Policy	12
19-201	EPP Sophomore Seminar	1

Core Area Courses

73-102	Principles of Microeconomics	9

Statistics course — one of the following:

36-220	Engineering Statistics and Quality Control	9
36-226	Introduction to Statistical Inference	9
or other approved statistics course		

EPP Decision Science course — one of the following:

19-301	Decision Making Methods for Engineers and Scientists	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9
84-369	Decision Science for International Relations	9
or other approved decision science course		

EPP Writing and Communications course — one of the following:

19-325	Technology and Policy Writing for Lay Audiences	9
76-270	Writing for the Professions	9
76-271	Introduction to Professional and Technical Writing	9
or other approved writing and communications course		

Technology-Policy Electives

3 courses, at least 24 units	**24 minimum units**

Capstone Courses

19-351	Applied Methods for Technology-Policy Analysis	9
19-451/452	EPP Projects *	12
19-451/452	EPP Projects *	12

* Must be taken twice.

Fifth Year M.S. program in Engineering and Public Policy

Students, regardless of whether they complete an undergraduate additional major or not, may apply for the fifth year masters program that will lead to the additional degree of Master of Science in Engineering and Public Policy. This course of study will ordinarily require two additional semesters of study beyond that required for the undergraduate degrees in the primary major and EPP/STPP additional major. Some coursework towards the MS may be able to be completed during the student's senior year, however no courses taken may count for both a BS program and the MS in EPP. Students interested in the program must have a minimum 3.0 QPA and should contact their advisor for details on the application process and course requirements.

Bachelor of Science in Engineering and Public Policy and Master of Science in Public Policy and Management

Highly motivated and talented students can earn the EPP additional major bachelor's degree, and a master's degree in the H. John Heinz College of Public Policy and Management in a five-year course of study. Students interested in the combined degree program should enroll in a standard additional major program in an engineering specialty and EPP. During the third year of study, the student applies to the Heinz College for admission to the master's program; an academic record of B average or better is normally a prerequisite for admittance.

The five-year course of study is possible because of specific course load overlaps between the EPP and Heinz College programs: (1) some social analysis requirements in EPP, usually four semester courses, can be satisfied with Heinz College common core courses in economics and social science; (2) at least one project course is common and applicable to both curricula; (3) at least one additional EPP technical elective, engineering option, or project course will be accepted for Heinz College credit following the usual request to the master's committee.

Students desiring this option should seek faculty advice and counsel in their sophomore year so that a curriculum satisfying all the degree requirements can be ensured. Contact the Associate Department Head for Undergraduate Affairs in EPP for more information. For general information on Heinz 3-1-1 programs please contact the Heinz College or refer to their website.

Minor in Technology and Policy

The department also offers a minor in Technology and Policy to non-CIT majors. This minor allows students outside of engineering to sample the EPP requirements and develop exposure and awareness to issues at the interface of science, technology, and society.

Pre-requisites: Students should have prerequisite knowledge in economics (73-102 Principles of Microeconomics or higher level economics course) and statistics (36-202 Statistics & Data Science Methods or higher level statistics course) in order to pursue the Technology and Policy Minor.

Course Requirements		Units
19-101	Introduction to Engineering and Public Policy	12
19-301	Decision Making Methods for Engineers and Scientists (or other approved Decision Science course)	9
or 19-351	Applied Methods for Technology-Policy Analysis	
19-451	EPP Projects	12
or 19-452	EPP Projects	
xx-xxx	Two EPP Technology-Policy Electives	18

EPP Technical Electives include courses in CIT, MCS, or SCS that address problems at the society-technology interface and the means of analyzing these issues. A list of qualifying Technology-Policy electives is assembled each semester and is available from the EPP Department. Example Technology-Policy electives include:

19-211	Ethics and Policy Issues in Computing	9
19-365	Water Technology Innovation and Policy	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-424	Energy and the Environment	9

Students must earn a cumulative QPA of 2.0 in all courses taken for the minor. Required courses taken for a student's primary major may not be counted toward the Technology and Policy Minor. Elective courses for a student's primary major or courses fulfilling general education requirements may be counted, however.

Details of this program are provided in the discussion of CIT minors; see Technology and Policy Minor Description (http://coursecatalog.web.cmu.edu/carnegieinstituteoftechnology/minorsfornonengineeringstudents/#technologyandpolicyminor).

Notes on EPP Undergraduate/ Graduate Level Courses

Many courses taught by the department (19-XXX courses) are offered to undergraduate and graduate students. These "dual level" courses are offered in two formats:

- Some courses are taught under both an undergraduate and graduate number. An example is Telecommunications Technology and Policy for the Internet Age (19-402) and (19-722). In these types of courses, students who sign up under the 700-level (graduate) course number may be expected to perform the same coursework at a higher level, and/or complete additional coursework, compared to 400-level students. Undergraduates who choose to take the course under the graduate number will be also be expected to work at the higher expectation/coursework level.
- Other courses are taught under a 600 level number. An example is 19-626 Climate Science and Policy. These courses may be taken by undergraduates as a senior level course, or by graduate students as a graduate level course. As with dual number courses, graduate level students or undergraduates taking the course for graduate credit may be required to perform coursework at a higher level and/or complete additional coursework. Undergraduates who are taking a 600 level course for graduate credit should identify this fact to both the course instructor and to their EPP department advisor.

Students who have questions about the requirements of a specific EPP 400/700, or 600 level course, should contact the course instructor. Some courses have pre-requisites which may be waived for students given prior background.

Other departments may have different policies regarding courses offered under both an undergraduate and graduate number, and courses offered under numbers other than the 100, 200, 300, 400, or 700 levels. Students who wish to take these courses should check with those departments for their specific policies.

Faculty

AHMED ABDULLA, Assistant Research Professor of Engineering and Public Policy – PhD, Carnegie Mellon University; Carnegie Mellon, 2019–

PETER ADAMS, Interim Department Head, Engineering and Public Policy; Professor of Civil and Environmental Engineering / Engineering and Public Policy; Director, Center for Atmospheric Particle Studies – Ph.D., Caltech; Carnegie Mellon, 2001–

JAY APT, Professor of Technology of The Tepper School of Business / Engineering and Public Policy – Ph.D., MIT; Carnegie Mellon, 2000–

DANIEL ARMANIOS, Assistant Professor of Engineering and Public Policy – PhD, Stanford University; Carnegie Mellon, 2015–

MICHEL BEZY, Distinguished Service Professor of Engineering and Public Policy – Ph.D., Université Catholique de Louvain; Carnegie Mellon, 2011–

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NICOLAS CHRISTIN, Associate Professor of Electrical and Computer Engineering / Engineering and Public Policy – Ph.D., University of Virginia; Carnegie Mellon, 2005–

JARED L. COHON, University Professor of Civil and Environmental Engineering / Engineering and Public Policy; President Emeritus – Ph.D., MIT; Carnegie Mellon, 1997–

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ALEX DAVIS, Assistant Professor of Engineering and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2012–

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M. GRANGER MORGAN, Hammerschlag University Professor of Engineering; Professor of Engineering and Public Policy / Electrical and Computer Engineering / The H. John Heinz III College – Ph.D., University of California, San Diego; Carnegie Mellon, 1974–

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SPYROS N. PANDIS, Research Professor of Chemical Engineering / Engineering and Public Policy – Ph.D., California Institute of Technology; Carnegie Mellon, 1993–

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DOUGLAS SICKER, Lord Chair Professor of Engineering and Public Policy / Computer Science – Ph.D., University of Pittsburgh; Carnegie Mellon, 2014–

MARVIN A. SIRBU, Professor of Engineering and Public Policy / Industrial Administration / Electrical and Computer Engineering – Sc.D., MIT; Carnegie Mellon, 1985–

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ESWARAN SUBRAHMANIAN, Research Professor of Institute for Complex Systems / Engineering and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1984–

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HAIBO ZHAI, Associate Research Professor of Engineering and Public Policy – Ph.D., North Carolina State University; Carnegie Mellon, 2008–

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TUNG AU, University Professor of Civil and Environmental Engineering / Engineering and Public Policy, Emeritus – Ph.D., University of Illinois; Carnegie Mellon, 1957–

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ELIZABETH CASMAN, Associate Research Professor of Engineering and Public Policy, Emeritus – PhD, Johns Hopkins University; Carnegie Mellon, 1997–

JAMES GOODBY, Distinguished Service Professor, Emeritus – A.B., Harvard ; Carnegie Mellon, 1989–

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MARIJA ILIC, Professor of Electrical and Computer Engineering / Engineering and Public Policy, Emeritus – D.Sc., University of Washington, St. Louis; Carnegie Mellon, 2002–

INDIRA NAIR, Vice Provost for Education, Carnegie Mellon University; Professor of Engineering and Public Policy, Emeritus – PhD, Northwestern University; Carnegie Mellon, 1978–

SAROSH TALUKDAR, Professor of Electrical and Computer Engineering / Engineering and Public Policy, Emeritus – Ph.D., Purdue University; Carnegie Mellon, 1974–

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Department of Engineering and Public Policy Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

19-101 Introduction to Engineering and Public Policy
Fall and Spring: 12 units
This course examines the processes of public and private decision making and of policy formation, which shape the evolution of a technology and its impact on our society. Technology plays an important role in shaping our worlds. At the same time, social forces often play a central role in the evolution of a technology. A particular technology such as an automobile or computer is chosen to study technology and policy in context. Specific topics covered in the case of the automobile includes automotive design and manufacture, safety, pollution, fuel economy and their interactions. In each area, we discuss the technological and institutional issues, their interaction, the possible need for public policy and the factors that govern the policy. The course will involve several group problem-solving sessions.

19-201 EPP Sophomore Seminar
Fall: 1 unit
EPP Sophomore Seminar is for students enrolling in the Engineering and Public Policy (EPP) Additional Major and the Science, Technology and Public Policy (STPP) Additional Major. The course presents the interdisciplinary nature of EPP/STPP problems at the interface of technology and society. Students are introduced to the technical and policy dimensions of these problems as well as to skills such as data collection and analysis, group work, and oral and written presentations. Sessions include discussion of case studies dealing with aspects of decision-making and ethics in policy issues with a technological basis. Seminars by EPP faculty and students are included to give the student an idea of careers and problems in this area.

19-211 Ethics and Policy Issues in Computing
Spring: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

19-213 The American Railroad: Decline and Renaissance in the Age of Deregulation
Intermittent: 6 units
Railroads in the USA are often considered as a subject for nostalgia or public sector failure, an image largely based on passenger service. However, the USA's private sector freight rail industry is considered a model for the world as the result of its renaissance following deregulation in 1980. This is a "stealth" industry whose history and economics are both intertwined and complex. Starting with the development of the first U. S. railroads, students will gain a basic understanding of the industry's history and economics, with special attention to the past half-century. In addition, students will participate in small group research projects in particular areas of special interest — for example, economic history, industry culture, network economics, utility regulation or transportation policy.

19-301 Decision Making Methods for Engineers and Scientists
Fall: 9 units
This course covers various economic, statistical, and decision analysis techniques used for examining complex decisions where technology, society, and policy interconnect. Topics covered include: estimation techniques, benefit-cost analysis, decision trees, dealing with uncertainty, risk perception and analysis, survey design and implementation, utility theory, heuristics and biases in inference and prediction, methods for combining information from different sources and dealing with conflicting objectives.
Prerequisites: 36-220 Min. grade C or 19-250 Min. grade C or 36-217 Min. grade C

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-303 Cryptocurrencies, Blockchains and Applications
Spring
Note: Previously offered as 19-355. Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies. Prerequisites: Introduction to Computer Systems or equivalent strongly recommended

19-325 Technology and Policy Writing for Lay Audiences
Fall and Spring: 9 units
This course is designed to teach the fundamentals of persuasive, accurate writing about technical, highly specialized information for a general audience, based on an axiom attributed to Albert Einstein: If you can't explain it simply, you don't understand it well enough. Readings will be selected from writing style guides, and from nonfiction and science fiction literature. Course work will include the translation of data and journal articles into prose for a sophisticated general audience, as well as original writing.

19-351 Applied Methods for Technology-Policy Analysis
Spring: 9 units
This course synthesizes concepts from economics, statistics, decision analysis, and other humanities and social science areas as they relate to analysis of technology and public policy issues. Students will focus on applying skills, tools, and techniques of social science to critically examine issues of current importance to society that have engineering systems at the core, and how public policy can be informed by the results of these analyses. Students will discover the relationship between formulating research questions considering a wide range of perspectives (e.g., political, ethical, social, economic, and legal aspects) and implementing the appropriate research methods for answering them. The course will emphasize interpretation and communication of analysis results in written and oral presentation, especially to non-technical audiences. As a precursor to the EPP Project courses, the course also prepares EPP juniors for structuring real-world problems into a feasible work plan, and to deal with revising work plans as work proceeds.

19-355 Special Topic: Cryptocurrencies, Blockchains, and Applications
Spring
Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies. Units: 9 (without semester-long project) or 12 (with semester-long project) Prerequisites: 15-213 or equivalent strongly recommended

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-356 Special Topics:Information Technology Policy: Evidence, Communication, Advocacy
Spring: 9 units
In recent decades, developments in Information and Communication Technologies (ICTs) have rapidly moved from research environments to products and services used by billions of people. This rapid rate of change has often resulted in a public which does not understand the technologies shaping their lives and lawmakers who are poorly equipped to make sound policy. It is therefore incumbent upon specialists to communicate how ICTs work to the public and lawmakers so policy making is shaped by evidence and reflects public desires. This course will train students to be effective communicators and advocates in the ICT space. Students taking this course will learn about the broader scope of technology policymaking including formal lawmaking, agency rule-making, strategic litigation, and corporate social responsibility. Current ICT policy topics in privacy, free expression, net neutrality, and competition will be covered. Public communication strategies such as writing op-eds, interviewing with journalists, producing explanatory videos and interactive games will be explored. Finally, students will learn how to perform an expert role in areas such as writing policy briefs and providing testimony. The course is open to advanced undergraduate and graduate students. Graduate students whose research has public policy implications are encouraged to develop projects related to their research. There is no requirement for programming knowledge, but students with experience in developing interactive media and games will be encouraged to utilize such skills. The class will focus heavily on readings, critical evaluation of real ICT advocacy campaigns, and homework will provide hands-on experience with numerous strategies for public engagement. At the end of the semester students will have a portfolio of projects which they may release publicly.

19-365 Water Technology Innovation and Policy
Spring: 9 units
Innovation in water technologies is necessary to confront profound water resource challenges facing countries around the world. Students successfully completing this course will be able to discuss the factors and conditions that drive innovation in the water sector. Students will begin by describing and classifying the historical drivers for innovation in water treatment, including technical, economic, and regulatory drivers. After an introduction to the fundamental principles of water treatment technologies, students will identify present day technology shortcomings and distill these into discrete design objectives. Students will then formulate and answer quantitative and qualitative questions that respond to these design objectives by leveraging their knowledge of engineering fundamentals, regulatory tools, and pricing policies. Comparing their own solutions with those proposed in the peer-reviewed academic literature in engineering and the social sciences, students will evaluate the technical feasibility, usability, and social desirability of proposed water innovations in developed and developing countries and summarize their findings in policy briefs.
Prerequisites: 06-100 or 19-201 or 19-101 or 12-100

19-402 Telecommunications Technology and Policy for the Internet Age
Intermittent: 12 units
Modern telecommunications is the nervous system of society. The Internet and wireless communications have transformed every aspect of our modern life. This course provides a comprehensive introduction to basic principles of telecommunications technology and the legal, economic, and regulatory environment of today's networks. Topics covered include the fundamentals of communication network technologies, including video, voice, and data networks; the rising dominance of wireless networks; principles behind telecommunications regulation from common carrier law and natural monopoly to information diversity, privacy and national security; traffic differentiation on the Internet and the debate over network neutrality; universal service and the digital divide; mergers, antitrust, and the changing industrial structure of the communications sector. We will explore current topical questions such as the future of competition; the shift of entertainment video from cable and satellite to Internet delivery; how cloud computing concepts are transforming networks; and communications support for the Internet of Things. Comparison with European approaches to communications regulation. Special emphasis on how new technologies have altered, and are altered by, regulation. Junior, Senior or graduate standing required.
Prerequisites: 73-102 and 73-100

19-403 Policies of Wireless Systems
Intermittent: 12 units
This course will address public policy issues related to wireless systems. It investigates policies related to a wide variety of emerging wireless systems and technologies, including current and next-generation cellular systems, wifi and white space devices, emerging methods of accessing spectrum, communications systems for emergency responders (firefighters, police, emergency medical services), current and next-generation television, and satellite communications. This can include the government role in facilitating the creation of infrastructure, in advancing competition among broadcasters and communications service providers, in using scarce spectrum efficiently, in promoting public safety and homeland security, and in protecting privacy and security. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. This course is cross-listed as 18-650, 19-403, 19-713, and 95-824. Senior or graduate standing required.

19-411 Global Competitiveness: Firms, Nations and Technological Change
Fall: 9 units
Global Competitiveness introduces students to the fundamental principles surrounding global competitiveness and technological change in the 21st century. The course is broken into three sections. The first section introduces students to competing economic, sociological, and political science theories on the structures supporting technological change. The second section presents the contemporary literature on technological change. The concluding section leverages lessons from the preceding two sections to evaluate national innovation systems, and the factors that lead to national comparative advantage. Students should leave the class able to reflect competently on what the existing literature tells us about the factors influencing global technology competitiveness, and on how modern changes in the structures supporting innovation as well as technology itself may be changing the rules of the game for firms and for nations. The course is open to undergraduate juniors, seniors & graduate students.

19-421 Emerging Energy Policies
Intermittent: 9 units
Interested in what's happening in energy policy and how to analyze potential policy options in response? Focusing on current hot topics in energy policy, students will learn the basic principles of public policy analysis and underlying techniques such as program evaluation, cost benefit analysis, life cycle analysis, prince analysis, and risk analysis as well as the variety of policy mechanisms available. Class time will include a combination of faculty and guest speaker lectures, discussion of issues, videos, and problem solving. Students will review and edit Wikipedia entries on an energy policy topic of their choice, and then analyze policy options resulting in an executive summary or paper on that topic. While the course has no prerequisites, students should feel comfortable with scientific and technical topics. Upon completion of this course, students should have a deeper and more strategic understanding of the opportunities and challenges associated with emerging energy policies. Open to seniors. Open to juniors with permission only.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-424 Energy and the Environment
Intermittent: 9 units
This course will explore the relationships between environmental impacts and the utilization of energy through a series of case studies on topics of current interest. Such topics might include the use of renewable and non-renewable fuels for electric power generation; energy use for automobiles and other transportation systems; energy use for buildings and industrial processes; and environmental issues such as urban air pollution, ozone formation, acid rain, and global warming. The emphasis will be on analysis of energy-environmental interactions and tradeoffs, and their dependency upon engineering design choices, economic variables, and public policy parameters. Junior or Senior standing in CIT or permission of instructor.

19-425 Sustainable Energy for the Developing World
Fall and Spring: 9 units
This course examines the current state of the energy system in developing countries and the challenges these countries will face in sustainably meeting their energy needs in the 21st century. The following are examples of questions and issues we will cover throughout the semester. What is the current status of the energy system in the developing world? What is the role of energy in supporting economic growth and alleviating poverty? What are the future energy needs of developing countries? What are the challenges developing countries will face as they build/improve their energy systems? What technologies are available to meet the energy challenges in the developing world?

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-427 Special Topics: Energy Innovation and Entrepreneurship
Fall: 9 units
Want to be an energy innovator, business entrepreneur, social entrepreneur, or intrapreneur? Students in this class will learn the fundamentals of energy innovation and entrepreneurship, and how innovation and entrepreneurship in energy differs from that in other fields. Students will then develop a business and non-market strategy for an idea of their own, or in response to a real-world challenge proposed by a business, industry, or a non-governmental organization. The resulting strategy can, if students wish, be submitted for student competitions that typically take place each spring throughout the United States.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-432 Special Topics: Bitcoin and Cryptocurrencies
Spring: 6 units
Provides an understanding of the technology, usability, business, and regulatory issues of digital currencies in the context of the cryptocurrency, Bitcoin. How does it work? How do people use it? Can I make money with it? Is it safe? Is it legal? To address these questions, we investigate Bitcoin's underlying technology; digital wallets; Bitcoin mining; cybersecurity; and regulatory issues.

19-440 Combustion and Air Pollution Control
Intermittent: 9 units
Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and postcombustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-443 Climate Change Science and Adaptation
Fall and Spring: 9 units
This course consists of four parts. The first part will provide a primer for those who are curious about the physical mechanisms by which climate is determined, and by which climate change occurs. The treatment of these mechanisms will not be overly quantitative, and no knowledge of meteorology or atmospheric science is needed. College-level physics, as well as basic calculus and basic chemistry is, however, needed. The second part will describe the projected consequences of climate change, as well as those that are already occurring. This part will also familiarize students with how societies might adapt to these changes. The third part will explore (and critique) some of the tools that decision-makers use to quantify and compare the damages caused by these consequences. The final part of the course will discuss some of the technologies that could be used to prevent dangerous climate change.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-451 EPP Projects
Spring: 12 units
Interdisciplinary problem-solving projects in which students work as leaders or members of project teams. Problem areas are abstracted from local, state and national situations and involve the interaction of technology and public policy, with different projects being chosen each semester. Oral and written presentations concerning the results of project studies are required. NOTE: All students will enroll in section A at first. During the 1st class, students will choose either project A or B. Those choosing B, will be moved into that section.

19-452 EPP Projects
Fall: 12 units
Interdisciplinary problem-solving projects in which students work as leaders or members of project teams. Problem areas are abstracted from local, state and national situations and involve the interaction of technology and public policy, with different projects being chosen each semester. Oral and written presentations concerning the results of project studies are required.

19-458 Special Topics: Organizational Theory for Engineers
Spring: 9 units
Why do so many technical problems of global importance persist even when there exists engineering solutions? This course will explore the organizational challenges that can hinder the deployment of engineering solutions towards solving some of our most critical global technical challenges. We will explore a variety of organizational theories such as institutional theory, network theory, social movement theory, and actor-network theory and then see how they are applied to a variety of engineering systems such as those around energy, mechanical design, water, information and communication technology, and other such civil infrastructure. By the end of the course, students will be able to a) learn how to read and synthesize organizational research from a variety of theoretical lenses, b) understand how such research can apply to a variety of engineering systems, and c) learn how to advance and conduct engineering research that incorporates an organizational perspective. Intended for graduate students; seniors and juniors with permission.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-461 Invention & Innovation for Materials Intensive Technologies Part 1
Fall: 4.5 units
Two 4.5 unit classes that can be taken in sequence or as stand-alone mini's. Courses will be cross-listed between EPP and MSE. This course is intended to instill a sense of how technologies are conceived and brought to market. The students will be exposed to a variety of formalized invention and innovation processes/concepts and will be asked to complete projects that will pull from the full range of their engineering training. It is intended for seniors who are eager to creatively apply their learned knowledge skills, and who are interested in invention, innovation, and entrepreneurship. The first half (part 1 (19461), mini 1) will focus on the process of invention for devices and technologies that are enabled by materials functionality. This will start by providing historical context and addressing the questions "What is invention?" This will be followed by an assessment of various systematic methods by which the process of invention is practiced, with a specific focus on materials intensive devices and products. The second half of the course (part 2 (19462), mini 2) will examine innovation theory in the context of materials intensive technologies. Specifically, the concepts of incumbency, disruption, value chain, supply chain, funding models and paths to market will be addressed. In this class, significant time will be dedicated to covering the impact of international market and technology development.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-462 Invention Innovation for Materials Intensive Technologies Part 2
Fall: 4.5 units
Note: students must take and pass 27-501/19-461 to take 27-502/19-462.Two 4.5 unit classes that can be taken in sequence or as stand-alone mini's. Courses will be cross-listed between EPP and MSE. This course is intended to instill a sense of how technologies are conceived and brought to market. The students will be exposed to a variety of formalized invention and innovation processes/concepts and will be asked to complete projects that will pull from the full range of their engineering training. It is intended for seniors who are eager to creatively apply their learned knowledge skills, and who are interested in invention, innovation, and entrepreneurship. The first half (part 1 (19461), mini 1) will focus on the process of invention for devices and technologies that are enabled by materials functionality. This will start by providing historical context and addressing the questions "What is invention?" This will be followed by an assessment of various systematic methods by which the process of invention is practiced, with a specific focus on materials intensive devices and products. The second half of the course (part 2 (19462), mini 2) will examine innovation theory in the context of materials intensive technologies. Specifically, the concepts of incumbency, disruption, value chain, supply chain, funding models and paths to market will be addressed. In this class, significant time will be dedicated to covering the impact of international market and technology development.

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19-466 Spec Topic: Stochastic Discrete Choice Models: Estimation and Behavioral Theory
Fall: 9 units
This course will cover the rational and behavioral foundations of discrete choice models, current behavioral theories, and estimation methods. Content will include an overview of the history of thinking about discrete choice models, rational foundations, behavioral theories, signal detection theory, multinomial logit, mixed logit using restricted MLE and monte-carlo simulation, and experimental design. If time permits we will cover item-response models and Bayesian methods.

19-486 Special Topics: New Technology Commercialization: Public Policy Strategies
Spring: 9 units
During this project-based class, students will develop non-market strategies for real-world clients. As defined, by David Baron, "The nonmarket environment consists of the social, political, and legal arrangements that structure interactions among companies and their public." This class will focus on non-market strategies at the intersection of new technologies, public policies, and business. Entrepreneurs and innovators interested in commercializing technology in the biomedical, energy, transportation, information technology, robotics, aerospace, food, healthcare, and other industries require more than knowing whether a technology works and the potential market. Non-market factors such as regulations, standards, and grants influence product, price, location, research, development, and testing, and other decisions. As a result, public policies provide both opportunities and challenges for the commercialization of an invention. Only by recognizing these opportunities or overcoming these challenges can an invention become a commercialized innovation.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-500 Directed Study in EPP: Undergraduate
All Semesters
Students may do undergraduate research as one course for EPP technical elective credit, with an EPP faculty member, or on an approved project with a faculty member from another department. The research credits must be pre-approved by your advisor, and should result in a written product, one copy of which should be sent to EPP.

19-534 Usable Privacy and Security
Spring: 9 units
There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an essential role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user-interface problems related to privacy and security and to give them experience in understanding and designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Students will also work on a group project throughout the semester. The course is open to all students who have technical backgrounds. The 12-unit course numbers (17-734, 5-836, 19-734) are for PhD students and masters students. Students enrolled in these course numbers will have extended homework assignments and will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit course numbers (17-334, 5-436, 19-534) are for undergraduates and masters students (if permitted by their program).

19-624 Emerging Energy Policies
Intermittent: 12 units
Interested in what's happening in energy policy and how to analyze potential policy options in response? Focusing on current hot topics in energy policy, students will learn the basic principles of public policy analysis and underlying techniques such as program evaluation, cost benefit analysis, life cycle analysis, prince analysis, and risk analysis as well as the variety of policy mechanisms available. Class time will include a combination of faculty and guest speaker lectures, discussion of issues, videos, and problem solving. Students will review and edit Wikipedia entries on an energy policy topic of their choice, and then analyze policy options resulting in an executive summary or paper on that topic. While the course has no prerequisites, students should feel comfortable with scientific and technical topics. Upon completion of this course, students should have a deeper and more strategic understanding of the opportunities and challenges associated with emerging energy policies. Open to seniors. Open to juniors with permission only.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-625 Sustainable Energy for the Developing World
Fall and Summer: 12 units
This course examines the current state of the energy system in developing countries and the challenges these countries will face in sustainably meeting their energy needs in the 21st century. The following are examples of questions and issues we will cover throughout the semester. What is the current status of the energy system in the developing world? What is the role of energy in supporting economic growth and alleviating poverty? What are the future energy needs of developing countries? What are the challenges developing countries will face as they build/improve their energy systems? What technologies are available to meet the energy challenges in the developing world?

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-626 Climate Science and Policy
Intermittent: 12 units
This course will survey both scientific and policy issues associated with climate change. We will begin by surveying important factors governing the Earth's climate including solar and terrestrial radiative equilibrium and ocean heat storage and transport. Next, we will discuss the several perturbations or "forcings" that industrial society has imposed on Earth's climate: changes in greenhouse gas concentrations, ozone, and aerosols. The course will examine how complex climate feedbacks lead to significant uncertainty regarding the response of the Earth to these forcings. Decision-making strategies that policy makers can use to deal with these uncertainties will be discussed. We will outline major impacts of climate change on society as well as natural systems and strategies for mitigating climate change.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-627 Special Topics: Energy Innovation and Entrepreneurship
Fall: 12 units
Want to be an energy innovator, business entrepreneur, social entrepreneur, or intrapreneur? Students in this class will learn the fundamentals of energy innovation and entrepreneurship, and how innovation and entrepreneurship in energy differs from that in other fields. Students will then develop a business and non-market strategy for an idea of their own, or in response to a real-world challenge proposed by a business, industry, or a non-governmental organization. The resulting strategy can, if students wish, be submitted for student competitions that typically take place each spring throughout the United States.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-639 Policies of the Internet
Fall: 12 units
This course will address public policy issues related to the Internet. This may include policy issues such as network neutrality and the open Internet, Internet governance and the domain name system (and the role of the United Nations), copyright protection of online content, regulation of indecency and pornography, universal access to Internet and Internet as a "human right", government surveillance of the Internet, Internet privacy and security, and taxation of electronic commerce. It will also teach some fundamentals of Internet technology. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. Senior or graduate standing required.

19-648 Special Topics: International Climate Adaptation & Infrastructure Innovation
Spring: 6 units
Although an international problem, climate change will affect each country's critical infrastructure in diverse ways. This course will focus on understanding how international communities are adapting and innovating to reduce critical infrastructure risk. Students will be able to list and describe natural hazards affected by climate change, focusing on their impacts on natural and built critical infrastructure systems in physically, socially, and economically diverse countries. Students will then use cost-benefit analysis, the triple bottom line approach (physical, social, economic), and robust decision making to analyze, compare, and contrast different countries' responses. The class will culminate in a final paper and presentation on one country's approach to decision-making under uncertainty for adaptation. Learning Objectives: By the end of the semester, you should be able to: · Understand risk. o Define risk, hazard, vulnerability, exposure, adaptation, hazard mitigation, greenhouse gas mitigation. o Explain the link between some natural hazards and climate change o List 10 natural hazards and their impacts on the international community. · Analyze outcomes/impacts. o Predict how physically, socially, and economically detrimental a given natural hazard will actually be in different critical infrastructure systems. o Compare and contrast different adaptations to reduce risk. · Create recommendations for improving adaptation in an international community

19-653 Climate Change Mitigation
Intermittent: 12 units
Have you ever thought about how we could address the climate change problem? In this course we will study the technological and policy options for responding to the threat of climate change. We will review climate-change science, understand the current systems for energy supply and use, and have a deep dive onto technological solution for low-carbon energy supply and use, as well as the policy frameworks that can help us reduce greenhouse gas emissions. 2hrs 40min of lectures per week.

19-665 Environmental Politics and Policy
Fall: 6 units
Engineers, scientists, policymakers, industry, environmental groups, and the public all influence environmental policy making, and should have an understanding of past and current environmental issues, technologies, policies, programs, and politics. Using a case study approach, students will learn how to how to use program evaluation to analyze the effectiveness of past policies (e.g., CFCs, DDT) and apply the lessons learned to conduct policy analysis of current environmental challenges (e.g., nanotechnology, climate change). Students will gain an understanding of the variety of policy mechanisms available to attain environmental goals including the use of voluntary standards. Student interest will guide topic selection for both issues discussed in class and for project work. Class time will include a combination of faculty and guest speaker lectures, discussion of issues, videos, and problem solving time. While the course has no prerequisites, students should feel comfortable with scientific and technical topics.

19-666 Energy Policy and Economics
Intermittent: 6 units
This course will begin with a review of microeconomic concepts and tools necessary for analysis of the topics covered in the class. The course will explore how past energy technology policies and choices are intertwined with pathways of economic development, social impacts, macroeconomic measurement and performance. This course will explore how a wide variety of policy mechanisms- technology policy, utility regulation and restructuring, emissions policies, multilateral interventions and agreements, and corporate strategies-can shape energy use and the environmental impacts of energy systems. Study examples will draw from both developed and developing countries.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-670 Quantitative Entrepreneurship: Analysis for New Technology Commercialization
Intermittent: 12 units
This course provides engineers with a multidisciplinary mathematical foundation for integrated modeling of engineering design, manufacturing, and enterprise planning decisions for commercializing new technologies and products. Topics include economics in product design, manufacturing and operations modeling and accounting, consumer choice modeling, survey design, conjoint analysis, optimization, model integration and interpretation, and professional communication skills. Students will apply theory and methods to a team project for a new product or emerging technology, developing a business plan to defend technical and economic competitiveness. This course assumes fluency with multivariable calculus, linear algebra, and probability theory.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-671 Tech Start-up: Market Discovery
Spring: 6 units
The first three years of a technology start-up are the most critical; when the company's DNA or trajectory is set. Too few entrepreneurs appreciate this fact and, as a result, many start without the essential skills talents and capabilities needed to set the company on a successful path. Some of these entrepreneurial skills can only be learned through starting and growing a business while others can be learned. This course attempts to bridge the challenging gap between learning and doing entrepreneurship. We introduce you to an essential skill of market discovery or learning to create, develop and evaluate your concept of your business. Is my idea a real innovation? Is it also a business or a product or neither? How do I know how big the market is for my product? What are the technology market and competitive risks in my idea and how do I assess them? Can I compete? Can I sell it? How? When? Where? Students will have the opportunity to apply their newfound practical skills gathered in part from lectures from experienced entrepreneurs and investors to case studies role-playing and solving actual problems of local tech businesses. The best way to learn entrepreneurship is by doing, which is why this course will use 'true-to-life' scenarios as the anchor for the course. The class will be divided into 4 teams will focus on a company that is either (1) a student idea for new start-up, (2) an existing start-up (ideally local) or (3) a hypothetical start-up proposed/conceived by the students, the professor or both

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-672 Special Topics: Tech Start-up: Building Your Own Company
Fall: 6 units
(Session 2) - The first year or two of a tech start-up set the trajectory and character of that company for years to come. Too few entrepreneurs appreciate this reality and, as a result, many carry forward misperceptions and misconceptions about creating and building a successful tech company that set it on the path for failure. This class attempts to remedy that challenge by exposing the student the practical reality of building a team and funding a start-up team. This class should help the student answer (or know how to find the answer) to the following questions: How do I find manage and evaluate a start-up team Do I have the skill motivation and ability to be a tech entrepreneur? Can I build a company from scratch (really?)? Should I be the CEO Sales Account Manager VP of Engineering or something else altogether? How much money do I raise and where and when do I raise it? Students will have the opportunity to apply their newfound practical skills gathered in part from lectures from experienced entrepreneurs and investors to case studies.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-680 E&TIM Seminar on Innovation Management in Practice
Intermittent: 6 units
Innovation has been described as "the intersection of invention and insight, leading to the creation of social and economic value." Companies increasingly rely on innovation to establish and drive their success. Public policy makers see innovation as a critical driver for economic development. This course is an opportunity to learn about innovation management from those in the front lines. How are innovation opportunities identified? What are the challenges to realizing these opportunities, and how can the challenges be addressed? What roles are played by processes, technologies and the business environment, as well as by individuals in organizations? This course will feature speakers who drive innovation in a variety of settings, paired with readings from the innovation literature that will help frame the presentations and discussion.

19-681 Managerial and Engineering Economics
Intermittent: 12 units
This course will introduce students to the fundamentals of engineering and managerial economics. The course emphasizes the application of economic frameworks to understand how technology markets evolve and what strategies allow firms to capture value from innovation. The aim of the course is to develop a rigorous foundation in the relevant economic models that students can use to manage innovation in high-technology organizations. The course is oriented around developing answers to three key questions: (1) How should managers of technology firms evaluate potential strategies or projects when the outcome of innovation is uncertain? To address this question, the course introduces cost-benefit models for determining project value and how to use these models to make managerial decisions. (2) How do market characteristics shape the optimal pricing decisions of the firm? This part of the course provides economic models that translate the competitive dynamics of markets into the return-based measures required for optimal decision-making. (3) How do market characteristics shape a firm's ability to capture value from innovation? The final part of the course extends the frameworks in the second module to model value capture when firms invest in the development of breakthrough innovations. We will cover a number of different game theoretical models of innovation competition, bargaining, and pricing of platform and information products.

19-682 The Strategy and Management of Technological Innovation
Intermittent: 12 units
Strategy is distinctive approaches executives use to realize firm performance goals. In this course, we will prepare you for analyzing how technology and innovation affects how executives formulate and execute strategies. This course teaches how incorporating technology and innovation into the corporate strategy of the firm can achieve profitable and sustainable competitive advantage. It addresses the role of technology management in both emerging and established firms, and examines how all of the firm's activities, assets, and relationships must complement one another in order to capture value from innovation. The course will progress in two parts. We will first cover how strategy is formulate through frameworks, models, and tools essential for those actively engaged in the innovation process within a firm and apply these to case studies illustrating their importance in technology industries. We will then cover the obstacles that prevent firms form executing the ideal strategy. In each framework we analyze during the class, we will have the following objectives: 1) Recognizing the performance metric targeted by each framework 2) Identifying the assumptions each framework makes about firm structure, the speed of market and technological change 3) Analyze the strengths and weakness of each framework 4) Apply tools suited for each framework to determine the appropriate strategy that the firm should undertake 5) Using organizational theory to recognize obstacles that prevent the firm from implementing the desired strategies and how to overcome such barriers to implementation

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-684 Engineering and Technology Innovation Management in Practice
Intermittent: 6 units
Innovation takes place inside organizations, whether it's a small company, a large corporation, a university or a government laboratory or agency. In this course, we will focus on the people who lead innovative organizations, what they do to promote and sustain innovation, and the skills and attributes they need to be successful. The instructor's experience as President of Carnegie Mellon, guest lecturers from industry and the literature will be the sources from which the course will draw. Students will gain insight into the roles they may play in contributing to and leading innovative organizations, and the skills and attributes they will need for success. 19684 is part of the Engineering and Technology Innovation Management (E&TIM) Masters Program. E&TIM students should register for the 6 unit course, reflecting the supplemental course requirements for E&TIM. Other students are welcome to enroll for the 3 unit course.

19-687 Managing Research, Development and Innovation
Intermittent: 6 units
This course considers key issues and trade-off in R&D strategy and organization, paying attention to dynamic competitive contexts where technology plays a key role. These topics are treated assuming the perspective of the decision maker. It addresses typical problems of large, medium and small firms having a structured R&D and operating businesses where R&D is the source of competitive advantages. Although we will heavily focus on R&D, emphasis is placed on viewing R&D as a part (although, a key part) of the process of technological innovation; therefore, as an activity to be strongly and appropriately integrated with other functions to make innovation successful.

19-691 Special Topics: Decision-Making Methods for Innovation Management
Fall: 6 units
In this course, there will be several main elements all focused around the decision-making process that corporations typically use in making decisions regarding innovation / R&D investments. This course will build upon the financial concepts that were initially discussed in Finance of Innovation Management (19-689). Specifically this course will build on the following: Basic concepts around an appropriate decision-making process that should be used for making investment decisions related to innovation management and other strategic decisions. Discussion around the framework of decision quality and how this framework is used to improve the decision-making process around innovation decisions and other strategic decisions. Discussion of decision-making under uncertainty and the use of decision analysis methods that are commonly used to make Innovation / R&D investment decisions to assess the value of potential innovation decisions. Introduction to real options theory to include discussion of various calculation methods including the Black Scholes model and the binomial model and to consider the practical issues of implementing such an evaluation methodology. Should have taken 19-689 or elementary accounting / financial management course or by permission of instructor.
Prerequisite: 19-689 Min. grade C

19-692 Special Topics: Customer-Centric Product Management for Tech Innovations
Intermittent: 12 units
The purpose of this master's level course is to develop the knowledge and skills needed to formulate marketing and product strategies for new technological product/service innovations in their market introductory phase. The course introduces the principles, concepts, frameworks and proven practices for analysis and strategic decision-making in an uncertain and constrained environment (i.e. when ample historical data and large budgets don't exist.) The course uses lectures, readings, group exercises, an individual project with instructor feedback, and an optional recitation sessions to achieve the learning objectives. The primary work in this course is hands-on application of the material by the student to create a strategic marketing plan for their own, approved product innovation idea with evaluation and feedback from the instructor. A customer-centric orientation is emphasized throughout the course. The course addresses strategic marketing decisions and activities including identifying value creation opportunities; generating and selecting innovation ideas; understanding the market, competition, customer needs and customer experience; segmenting, targeting markets; developing a positioning strategy and compelling customer value proposition; making marketing-mix decisions for product, pricing, route-to-market/distribution, and customer base development. This course is ideal for students who are interested in becoming a product manager, entrepreneur, innovation manager, strategic marketer or related role. A syllabus and project description are available from the instructor. NOTE: Starting in Week 4 of this course, an optional recitation session with the instructor will be scheduled every 2 weeks on Friday. Students can sign up for one of two sections: Group A meets from 1:00 - 2:00 and Group B meets from 2:00 - 3:00.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-693 Managing and Leading Research and Development
Intermittent: 12 units
This course will provide an insider's look at issues in industrial research and development laboratories that future industrial R&D personnel are likely to face.

Course Website: http://www.ece.cmu.edu/courses/items/18703.html

19-694 Leadership and Innovation Management
Fall: 6 units
The attributes and skills of the contributors to innovation are important elements in the effectiveness of the innovation process and the success of the outcome. In this course, we will focus on these skills and attributes, with an emphasis on the leaders of innovation and innovative organizations. Selected literature, case studies, and guest lectures by leaders, as well as the instructor's own experience as Carnegie Mellon's eighth president, will be the sources from which the course will draw. Students will gain insight into the roles they may play in contributing to and leading innovation and organizations and the skills and attributes they will need for success.

19-696 Sustainable Development and Innovation
Fall: 9 units
This course will explore how technology and business contribute to sustainable development. Course segments will include examining global megatrends in ten major sectors (e.g., food, water, energy, health, etc.), opportunities and risks in these key sectors, and developing key metrics for success in sustainable development. Solution pathways that use existing, transferable, and new models in both policy and innovation will be discussed and proposed by the class. Issues for both large multi-nationals and start-ups will be covered. Class time will include a combination of lectures, guest speakers from industry, and problem solving activities. Students will experience how to create a business in this climate of sustainable development. Instructor is former CTO of Alcoa, and Co-Chair of the Vision 2050 project of the World Business Council for Sustainable Development. He is also currently an Advisor & Board Member at a number of Venture Capital firms and a Adjunct Prof. at CMU. The course is intended for MS students. Upper-level undergraduates may enroll with permission.

19-697 Lean Product Development
Spring: 12 units
Students in Lean Product Development will explore a wide variety of tools and techniques for evaluating the feasibility of proposed new products, services, and solutions to business problems. They will work with an iterative process of: proposing solutions structuring tests to evaluate those solutions with prototypes creating the prototype efficiently and cost-effectively evaluating the effectiveness of the prototype learning from the experiment and iterating until an acceptable solution is found. There will be a strong focus on soliciting customer feedback as a basis for improvement and validation throughout the process. Students will learn prototyping techniques for addressing design, business, and technical problems. This will be a very hands-on course. Students will learn to use, and practice using, a diverse set of prototyping tools to complete their projects including computational, physical, visual design, and ethnographic tools.

19-698 Special Topics: "Principles and Practices of Corporate Entrepreneurship
Fall: 6 units
This course defines the key concepts of corporate entrepreneurship as part of the process for building new business within an established organization. Emphasis will be placed on viewing corporate entrepreneurship as a part of the overall growth strategy, paying specific attention to how to integrate corporate entrepreneurships key practices with other kinds of strategic growth initiatives. The topics will include corporate entrepreneurship strategies, structures and processes, and decision making (at both the team and organizational levels) to achieve commercial impact. Key challenges that companies face when pursuing corporate entrepreneurship will be addressed the lack of tools and systematic frameworks for designing new businesses, the fit of entrepreneurial efforts at the organizational level, and the transition of successfully validated new business concepts to business units in order to achieve meaningful growth. Specific attention will be given to the context of technology-driven enterprise and technological innovation, as well as to the role that Technology and R&D organizations should play in uncovering new substantial paths to growth.

19-699 Special Topics: Institutions Entrepreneurship and Inovation
Intermittent
Institutional environment and public policy greatly affect incentives determining the direction of entrepreneurial activity and innovation that are the engines of economic growth. In societies with poor institutions, entrepreneurial talent is mostly directed towards seeking rents rather than generating productive innovations. But even in modern capitalist economies entrepreneurial activity and innovation are strongly influenced by public policies, for example, those related to intellectual property rights. This course seeks to provide students with analytical frameworks that will enable them to understand how various formal and informal institutional arrangements and public policy decisions influence entrepreneurial activity and innovation and how this, in its turn, affects economic efficiency and growth potential of nations.

19-701 Introduction to the Theory and Practice of Policy Analysis
Intermittent: 12 units
This course reviews and critically examines a set of problems, assumptions and analytical techniques that are common to research and policy analysis in technology and public policy. Topics covered include the difference between science, trans-science and policy analysis, policy problems formulated in terms of utility maximization, issues in the valuation of intangibles, uncertainty in policy analysis, selected topics in risk analysis, limitations and alternatives to the paradigm of utility maximization, issues in behavioral decision theory, issues related to organizations and multiple agents, and selected topics in policy advice and policy analysis for the federal government. The objective is to look critically at the strengths, limitations and underlying assumptions of key policy research and analysis tools and problem framing and sensitize students to some of the critical issues of taste, professional responsibility, ethics, and values that are associated with policy analysis and research.

19-702 Quantitative Methods for Policy Analysis
Intermittent: 12 units
Economic framework for identifying and analyzing investment and operation options facing agencies and firms, (both in theory and in practice); economic efficiency, utilization, pricing, and investment; and multi-objective evaluation.

19-703 Special Topics: Applied Data Analysis 1
Intermittent: 6 units
Students will gain a basic understanding of the estimation, interpretation, and diagnostic assessment of the most widely used statistical models in the social sciences. This includes: graphical and inferential statistics, multiple regression with interactions, logistic regression, multi-level models, and panel data. Assignments include six data analysis projects in R. 19703 is part 1, 19704 is part 2.

19-704 Applied Data Analysis 2
Intermittent: 6 units
Students will gain a basic understanding of the estimation, interpretation, and diagnostic assessment of the most widely used statistical models in the social sciences. This includes: graphical and inferential statistics, multiple regression with interactions, logistic regression, multi-level models, and panel data. Assignments include six data analysis projects in R. 19703 is part 1, 19704 is part 2.
Prerequisite: 19-703

19-705 Workshop Applied Policy Analysis
Intermittent: 6 units
This workshop course is about learning how to structure messy un-structured policy problems. It is designed to provide experience in setting up, analyzing, and writing about policy problems of the type that are used in the EPP Part B qualifying exam. Over the course of the semester, the class works through six or seven policy case problems. Much of the work is done in small groups. The principal focus is on integrating the qualitative and quantitative aspects of the problems and on identifying and practicing general problem-solving strategies.

19-707 Special Topics: Multiple Criteria Decision Making
Fall: 6 units
Problems with multiple, conflicting objectives are ubiquitous in the private and, especially, the public sector. The objective of this course is to provide an overview of the techniques for the analysis and resolution of multiple criteria decision making (MCDM) problems. Topics will include multiobjective programming, multiattribute utility theory and several MCDM methods such as the Analytical Hierarchy Process. The emphasis will be on theory and technique, but there will be several applications to demonstrate the methods.

19-713 Policies of Wireless Systems
Intermittent: 12 units
This course will address public policy issues related to wireless systems, and to the Internet. It begins by investigating policies related to a wide variety of emerging wireless systems and technologies, including wifi computer networks, broadband to the home, broadcast radio and television, and satellite communications. This can include the government role in facilitating the creation of infrastructure, in advancing competition among broadcasters and communications service providers, in managing spectrum, and in protecting privacy and security. The course will then address Internet policy issues, which can include Internet governance and the domain name system, taxation, privacy and security, and intellectual property. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. Note: ECE students must take this course under #18-650 only

19-714 Environmental Life Cycle Assessment
Spring: 12 units
Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.
Prerequisites: (12-421 or 12-706) and 12-712

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-716 Special Topics Science and Technology Policy, Analysis and Processes
Spring: 6 units
Science and technology policy is concerned with the allocation of resources for and encouragement of scientific and engineering research and development, the use of scientific and technical knowledge to enhance the nation's response to societal challenges, and the education of Americans in science, technology, engineering, and mathematics. This course will provide students with a better understanding of each of these areas and how decisions are made regarding science and technology at the national level and who influences those decisions. Upon completion of this course, students should have a deeper and more strategic understanding of how Washington works, how to analyze and present the results of science and technology policy analysis, and of long-term and emerging science and technology policy issues. Although the focus will be on the United States, these issues are as global as science and technology itself.

19-717 Sustainable Engineering Principles
Fall: 12 units
This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems. Publicly available data sets and computational models will be explored to assess sustainability. A team-based project is required.

19-718 Public Policy and Regulations
Spring: 6 units
Will provide an economic framework for identifying and analyzing investment and operation options facing agencies and forms (both in theory and practice); economic efficiency, utilization, pricing, and investment; and multi-objective evaluation. Intended for PhD's

19-722 Telecommunications Technology and Policy for the Internet Age
Intermittent: 12 units
Modern telecommunications is the nervous system of society. The Internet and wireless communications have transformed every aspect of our modern life. This course provides a comprehensive introduction to basic principles of telecommunications technology and the legal, economic, and regulatory environment of today's networks. Topics covered include the fundamentals of communication network technologies, including video, voice, and data networks; the rising dominance of wireless networks; principles behind telecommunications regulation from common carrier law and natural monopoly to information diversity, privacy and national security; traffic differentiation on the Internet and the debate over network neutrality; universal service and the digital divide; mergers, antitrust, and the changing industrial structure of the communications sector. We will explore current topical questions such as the future of competition; the shift of entertainment video from cable and satellite to Internet delivery; how cloud computing concepts are transforming networks; and communications support for the Internet of Things. Comparison with European approaches to communications regulation. Special emphasis on how new technologies have altered, and are altered by, regulation. Junior, Senior or graduate standing required.
Prerequisite: 73-102

19-724 Materials for Energy Storage
Intermittent: 6 units
This course will examine functional materials used to store and release electrical energy. An overview of the thermodynamics of power, energy and energy storage will be used to motivate subsequent investigations into the dominant methods in use today: electrochemical, electrical, and electromechanical (chemical/combustion and nuclear processes will not be covered). For each sub-topic, the physical and chemical mechanisms exploited will be discussed, followed by a detailed exposition of specific materials functionality and device applications. Particular focus will be given to several relevant emerging technologies: Li-ion batteries, hydrogen-based fuel cells (polymer proton exchange membrane and solid-oxide based systems), and large capacitors (both electrolytic and dielectric).

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-758 Special Topics: Organizational Theory for Engineers
Spring: 12 units
Why do so many technical problems of global importance persist even when there exists engineering solutions? This course will explore the organizational challenges that can hinder the deployment of engineering solutions towards solving some of our most critical global technical challenges. We will explore a variety of organizational theories such as institutional theory, network theory, social movement theory, and actor-network theory and then see how they are applied to a variety of engineering systems such as those around energy, mechanical design, water, information and communication technology, and other such civil infrastructure. By the end of the course, students will be able to a) learn how to read and synthesize organizational research from a variety of theoretical lenses, b) understand how such research can apply to a variety of engineering systems, and c) learn how to advance and conduct engineering research that incorporates an organizational perspective. Intended for graduate students and seniors; juniors with permission.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5

19-786 Spec Topic: Stochastic Discrete Choice Models: Estimation and Behavioral Theory
Fall: 12 units
This course will cover the rational and behavioral foundations of discrete choice models, current behavioral theories, and estimation methods. Content will include an overview of the history of thinking about discrete choice models, rational foundations, behavioral theories, signal detection theory, multinomial logit, mixed logit using restricted MLE and monte-carlo simulation, and experimental design. If time permits we will cover item-response models and Bayesian methods.

19-801 Special Topics in IT: IT Innovation and Business in Africa
Intermittent: 6 units
Africa is often called the global economy's last frontier. Although Africa remains by far the poorest continent, in recent years several African countries have enjoyed sustained political stability and economic growth. Information technology (IT) is playing a significant role in the development of these economies. This course will explore the underpinnings and prospects for the future of IT and its applications in sub-Saharan Africa. Focusing on the most recent literature and reports on economic and technology development in Africa, the aim will be to understand the critical factors that will determine how technology will develop in Africa and what business models are likely to succeed in creating economically viable IT enterprises in this rapidly changing part of the world. Student assignments will include readings, presentations, and projects on selected topics of relevance to the course goals and objectives. The course is intended for graduate students familiar with information technology and its current applications who are interested in Africa as a prospective place of employment and entrepreneurship in IT and its applications.

19-802 Special Topics: Bitcoin and Cryptocurrencies
Spring: 6 units
Provides an understanding of the technology, usability, business, and regulatory issues of digital currencies in the context of the cryptocurrency, Bitcoin. How does it work? How do people use it? Can I make money with it? Is it safe? Is it legal? To address these questions, we investigate Bitcoin's underlying technology; digital wallets; Bitcoin mining; cybersecurity; and regulatory issues.

Department of Materials Science and Engineering

Gregory S. Rohrer, Head
Location: Wean Hall 3327

Paige Houser, Academic Advisor
Location: Wean Hall 3317
materials.cmu.edu

Materials Science & Engineering (MSE) is an engineering discipline that applies the tools of basic and applied sciences and engineering to the manufacture and application of materials and devices. The four broad classes of Materials to which this paradigm is applied are metals, polymers, ceramics, and composites. Essentially every technology (historical, modern, and future) depends on materials development and innovation.

The overarching paradigm of MSE is to determine and to exploit the connection between processing, structure, and properties of materials to engineer materials that fit the performance criteria for specific applications, which are useful for the technological needs of our society. In addition to this product specific knowledge, MSE is concerned with the implications of materials production and their sustainable use on the environment and energy resources.

Graduates of the MSE department are pursuing careers in an expanding spectrum of companies, national laboratories, and universities. Their activities cover a wide range of materials related endeavors that include microelectronics, energy production and storage, biomedical applications, aerospace, information technology, nanotechnology, manufacturing and materials production. Many of our undergraduate alumni choose to attend graduate school; they are accepted into the top Materials graduate schools in the country.

The standard curriculum of the department provides fundamental training for all materials science and engineering areas (See www.cmu.edu/engineering/materials/undergraduate_program/curriculum). The core courses provide understanding and training on tools for working with the (atomic) structure of materials that governs their properties, the thermodynamic relationships that govern the stability of materials, and the rates at which changes take place in materials. Students complete their learning with a capstone design experience in the final year, which integrates their materials knowledge and training with engineering team skill development. To supplement the core course program, students may also participate in the current research programs of the faculty and conduct undergraduate research projects as part of their program of study.

While the core program is focused on the understanding of the internal or surface structure of materials in order to predict and engineer their properties, it is a flexible program that allows students to focus within a chosen material class, whether it is ceramics, semiconductors, metals, composites, magnetic or optical materials, bio-materials or polymers. The program also permits the option of cross concentration in the one or more of the areas of application such as electronic materials*, engineering design*, biomedical engineering*, environmental engineering*, manufacturing engineering*, mechanical behavior of materials*, biomedical and health engineering**, and engineering and public policy**, is also available. (*= Designated Minor, **= Double Major). Our curriculum is designed to provide a strong foundation in fundamental knowledge and skills that provide an excellent base for our graduates planning to continue on to graduate studies. For our graduates who seek employment in industry, the program provides the foundation on which a graduate can build his/her domain specific knowledge. For students that develop or seek opportunities in other disciplines after graduation, the MSE curriculum provides a modern liberal education combined with the engineering rigors, i.e. one that inculcates upon a thoughtful, problem-solving approach to professional life. It is thus the goal of our education to provide a global and modern education in Materials Science and Engineering to support our graduates during their careers in materials industries or as a foundation for further studies in any of the leading global institutions of graduate education.

Accreditation

The MSE Undergraduate Program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org.

Educational Objectives

The faculty of the Department of Materials Science and Engineering, in consultation with students, alumni and other interested parties, has decided that the overarching objective of the MSE curriculum is to provide an education that enables our graduates to be productive and fulfilled professionals throughout their careers.

Specifically, our program will produce graduates who:

1. are successful in a professional position and/or a top graduate school that builds upon their MSE background;
2. excel in professionalism and leadership in contemporary, interdisciplinary engineering practice based on materials, while accounting for the impact of their profession on an evolving, global society;
3. creatively advance our collective understanding of the principles of materials science and engineering and/or innovate the design of technological systems;
4. contribute effectively as an individual, team member, and/or a leader to effect global, economic, environmental, and/or societal impact.

Based on these objectives, our program is focused to allow our students to be successful regardless of their future career choice.

Student Outcomes

The Materials Science and Engineering Program has the following student outcomes to prepare graduates to attain the program educational objectives:

A. An ability to apply a knowledge of mathematics, science and engineering
B. An ability to design and conduct experiments, as well as to analyze and interpret data
C. An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
D. An ability to function on multidisciplinary teams
E. An ability to identify, formulate, and solve engineering problems
F. An understanding of professional and ethical responsibility
G. An ability to communicate effectively
H. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
I. A recognition of the need for, and ability to engage in life-long learning
J. A knowledge of contemporary issues
K. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Curriculum

Minimum units requrired for B.S. in Materials Science & Engineering	379

Standard Program

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
27-100	Engineering the Materials of the Future *	12
99-101	Computing @ Carnegie Mellon	3
xx-xxx	General Education Course	9

33-141	Physics I for Engineering Students	12
		46

Spring		Units
21-122	Integration and Approximation	10
xx-xxx	Second Introductory Engineering Course	12
33-142	Physics II for Engineering and Physics Students	12
09-101	Introduction to Experimental Chemistry	3
76-101	Interpretation and Argument	9
		46

Sophomore Year

Fall		Units
27-201	Structure of Materials	9
27-210	Materials Engineering Essentials	6
27-215	Thermodynamics of Materials	12
21-259	Calculus in Three Dimensions	9
09-105	Introduction to Modern Chemistry I **	10
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
39-210	Experiential Learning I	0
		56

Spring		Units
27-202	Defects in Materials	9
27-205	Introduction to Materials Characterization	3
27-216	Transport in Materials	9
27-217	Phase Relations and Diagrams	12
21-260	Differential Equations	9
39-220	Experiential Learning II	0
xx-xxx	General Education Course	9
		51

Junior Year

Fall		Units
27-301	Microstructure and Properties I	9
27-xxx	MSE Restricted Elective [1]	9
xx-xxx	Free Elective [1]	9
33-225	Quantum Physics and Structure of Matter or	9
or 09-217	Organic Chemistry I	
or 03-121	Modern Biology	
xx-xxx	General Education Course	9
39-310	Experiential Learning III	0
		45

Spring		Units
27-367	Selection and Performance of Materials	6
xx-xxx	General Education Course	9
27-xxx	MSE Restricted Elective [2]	9
27-xxx	MSE Restricted Elective [3]	9
xx-xxx	Free Elective [2]	9
36-220	Engineering Statistics and Quality Control	9
		51

Senior Year

Fall		Units
27-401	MSE Capstone Course I	6
27-xxx	MSE Restricted Elective [4]	9
xx-xxx	Free Elective [3]	9
xx-xxx	General Education Course	9
xx-xxx	General Education Course	9
		42

Spring		Units
27-402	MSE Capstone Course II	6
27-xxx	MSE Approved Technical Elective	9
xx-xxx	Free Elective [4]	9
xx-xxx	Free Elective [5]	9
xx-xxx	General Education Course	9
		42

* The Materials in Engineering course 27-100 may also be taken in the spring semester, and must be taken before the end of the sophomore year (the H&SS Elective in the Sophomore Spring may be moved to later in the program to accommodate the 27-100 course).

** These courses must be taken before the end of the sophomore year, but need not be taken in the same order or semester as listed above.

The recommended Physics sequence is 33-141 / 33-142 for Engineering students. However, 33-121 / 33-122 or 33-151 / 33-152 will also meet the CIT Physics requirement.

All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.

Notes on the Curriculum

Academic Advising

Paige Houser is the academic advisor for all MSE students.

Quality Point Average

In addition to the College requirement of a minimum cumulative quality point average of 2.00 for all courses taken beyond the freshman year, the Department requires a quality point average of 2.00 or higher in courses taken in the MSE department. Students may repeat a course to achieve the QPA requirement. Only the higher grade will be used for this departmental calculation.

MSE Approved Technical Elective

Students are required to take at least 9 units of approved technical electives. Students may take a course from another CIT department to fulfill this requirement or choose an additional 9 units of MSE Restricted Electives. Students who are pursuing an additional major or minor within CIT should check with their academic advisor regarding double counting of this course.

MSE Restricted Electives

Each student in the program must take at least 36 units of MSE restricted electives.

All 27-3xx, 27-4xx, 27-5xx, 27-6xx (with the exception of 27-699) and 27-7xx level and cross listed courses will fulfill the MSE Restricted Elective Requirement along with the following non-MSE courses:

		Units
06-609	Physical Chemistry of Macromolecules	9
06-619	Semiconductor Processing Technology	9
09-509	Physical Chemistry of Macromolecules	9
12-411	Project Management for Construction	9
12-631	Structural Design	12
18-310	Fundamentals of Semiconductor Devices	12
24-262	Stress Analysis	12
24-341	Manufacturing Sciences	9
33-341	Thermal Physics I	10
33-448	Introduction to Solid State Physics	9
42-411	Engineering Biomaterials	9

Integrated B.S./M.S. Program

Undergraduates who excel academically have the unique opportunity to receive simultaneously or sequentially both B.S. and M.S. degrees from the department. The primary purpose of the Integrated Master and Bachelor (IMB) Degree Program is to provide students with superior breadth and depth in technical material, which will better prepare them for careers in industry. Students interested in pursuing the IMB Degrees are encouraged to begin taking some of the required graduate courses before their last year. The MSE department offers two M.S. degrees: one in Materials Science and Engineering (MSE), a coursework degree, and one in Materials Science (MS), a coursework + research degree. The IMB Degree Program to obtain an M.S. in MSE (MS) degree normally requires two (three to four) additional full academic semesters of coursework (coursework + research) beyond the B.S. Degree Requirements (normally eight academic semesters). Experience has shown that students complete the IMB program in eight to ten full academic semesters after enrolling at CMU.

Degree Requirements

IMB students can be enrolled in either the M.S. in MSE (coursework) or the M.S. in MS (coursework + research) degree programs, depending on their preference.
Students must meet the requirements of either the M.S. in MSE or the M.S. in MS degree programs, as well as any specially stated rules below.

Eligibility

The IMB Program is available to all undergraduates who maintain a cumulative QPA of 3.0 or better, including the freshman year and the years in which they are enrolled in the IMB. Exceptions can be made by the Department on the basis of other factors, including extenuating (e.g., medical) circumstances, improvement in grades, strong recommendation letters, etc.
Students become eligible to apply to the program during the spring semester of their junior year (5th semester), or the semester in which they accumulate 280 or more units, whichever is earlier.

Enrollment

Students interested in the IMB program are not required to follow the formal application process for acceptance into the MSE graduate program. There is no requirement to provide a formal application, application fee, GRE scores, recommendation letters, official transcripts, or a statement of purpose. Interested students are encouraged request acceptance into the program by contacting the Department Head of MSE by email prior to the middle of the semester in which they become eligible.

Requirements to Enroll as a Graduate Student

If a student takes more than 8 semesters to complete both the B.S. and M.S. in MSE (coursework), then he or she must be a graduate student for at least one full-time 15-week academic semester (Fall or Spring) before graduating, whether or not they have already completed their B.S. degree.

If a student takes more than 8 semesters to complete both the B.S. and M.S. in MS (coursework + research), then he or she must be a graduate student for at least two full-time 15-week academic semesters (Fall or Spring) before graduating, whether or not they have already completed their B.S. degree.

Tuition Assistance

When a student is a full-time graduate student through the IMB program, the department is able to provide some tuition assistance through optional Teaching Assistantships.

Additional Information

Once the student has been accepted, the student should meet with his or her IMB academic advisor(s) to determine a course schedule.

The student must indicate to the departmental program coordinator at which point they intend, if necessary, to register as a graduate student.

Once a student in the IMB program has completed all of the requirements for the B.S. degree, he or she should become a graduate student.

To determine the most appropriate time for an undergraduate student to become a graduate student, he or she should consult with Enrollment Services to understand how becoming a graduate student will affect financial aid.

Faculty

CHRIS BETTINGER, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2010–

MICHAEL BOCKSTALLER, Professor – Ph.D., Max-Planck Institute for Polymer Research; Carnegie Mellon, 2005–

ITZHAQ COHEN-KARNI, Associate Professor – Ph.D., Harvard University; Carnegie Mellon, 2013–

ROBERT F. DAVIS, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

MARC DE GRAEF, Professor – Ph.D., Catholic University Leuven (Belgium); Carnegie Mellon, 1993–

ADAM FEINBERG, Professor – Ph.D., University of Florida; Carnegie Mellon, 2010–

WARREN M. GARRISON, Professor – Ph.D., University of California at Berkeley; Carnegie Mellon, 1984–

ROBERT HEARD, Teaching Professor – Ph.D., University of Toronto; Carnegie Mellon, 2003–

ELIZABETH A. HOLM, Professor – Ph.D., Univeristy of Michigan; Carnegie Mellon, 2012–

MOHAMMAD F. ISLAM, Professor of Materials Science and Engineering – Ph.D., Lehigh University; Carnegie Mellon, 2005–

DAVID E. LAUGHLIN, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1974–

NOA MAROM, Assistant Professor – Ph.D., Weizmann Institute of Science; Carnegie Mellon, 2016–

MICHAEL E. MCHENRY, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–

P. CHRIS PISTORIUS, Professor – Ph.D., University of Cambridge; Carnegie Mellon, 2008–

LISA M. PORTER, Professor – Ph.D., North Carolina State; Carnegie Mellon, 1997–

GREGORY S. ROHRER, Professor and Head – Ph.D., University of Pennsylvania; Carnegie Mellon, 1990–

ANTHONY D. ROLLETT, Professor – Ph.D., Drexel University; Carnegie Mellon, 1995–

PAUL A. SALVADOR, Professor and Executive Director of the Masters program in Energy Science, Technology and Policy – Ph.D., Northwestern University; Carnegie Mellon, 1999–

MAREK SKOWRONSKI, Professor – Ph.D., Warsaw University; Carnegie Mellon, 1988–

VINCENT SOKALSKI, Associate Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2013–

ELIAS TOWE, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2001–

BRYAN A. WEBLER, Associate Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2013–

JAY WHITACRE, Professor – Ph.D., University of Michigan; Carnegie Mellon, 2007–

Affiliated Faculty

ROSALYN ABBOT, Assistant Professor of Biomedical Engineering – Ph.D., Universtiy of Vermont;

AMIT ACHARYA, Professor, Civil and Environmental Engineering – Ph.D., University of Illinois, Urbana-Champaign; Carnegie Mellon, 2000–

JAMES BAIN, Professor, Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 1993–

JACK BEUTH, Professor, Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1992–

PHIL CAMPBELL, Research Professor, Institute for Complex Engineered Systems – Ph.D., The Pennsylvania State University; Carnegie Mellon, 2000–

KRIS NOEL DAHL, Associate Professor of Chemical Engineering and BioMedical Engineering and Materials Science and Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2006–

KAUSHIK DAYAL, Associate Professor of Civil and Environmental Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2008–

MAARTEN DE BOER, Professor of Mechanical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2007–

RANDALL FEENSTRA, Professor, Physics – Ph.D., California Institute of Technology Carnegie Mellon; Carnegie Mellon, 1995–

STEPHEN GAROFF, Professor, Physics – Ph.D., Harvard University; Carnegie Mellon, 1988–

ANDREW GELLMAN, Lord Professor, Chemical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

REEJA JAYAN, Assistant Professor, Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2015–

DAVID KINDERLEHRER, Professor, Mathematical Sciences – Ph.D., University of California, Berkeley; Carnegie Mellon, 1990–

JOHN KITCHIN, Associate Professor of Chemical Engineeering – Ph.D., University of Delaware; Carnegie Mellon, 2006–

TOMEK KOWALWESKI, Professor of Chemistry – Ph.D., Polish Academy of Sciences; Carnegie Mellon, 2000–

SHAWN LITSTER, Professor, Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2008–

SARA MAJETICH, Professor, Physics – Ph.D., University of Georgia; Carnegie Mellon, 1990–

CARMEL MAJIDI, Associate Professor of Mechanical Engineering – Ph.D., University of California; Carnegie Mellon, 2011–

JONATHAN MALEN, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2009–

KRZYSZTOF MATYJASZEWSKI, J.C. Warner Professor of Natural Sciences, Department of Chemistry and Materials Science and Engineering – Ph.D., Polytechnical University of Łódź, Poland; Carnegie Mellon, 1985–

MEAGAN MAUTER, Assistant Professor, Civil & Environmental Engineering and Engineering and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2015–

ALAN MCGAUGHEY, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

O. BURAK OZDOGANLAR, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–

RAHUL PANAT, Associate Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2017–

ROBERT SEKERKA, University Professor, Physics, Mathematics and Materials Science – Ph.D., Harvard; Carnegie Mellon, 1969–

ROBERT SUTER, Professor, Physics – Ph.D., Clark University; Carnegie Mellon, 1981–

VENKAT VISWANATHAN, Assistant Professor, Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2013–

LYNN WALKER, Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1997–

NEWELL R. WASHBURN, Associate Professor of Chemistry, Biomedical Engineering and Materials Science and Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

LEE WEISS, Research Professor, ICES – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1983–

MICHAEL WIDOM, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1985–

DI XIAO , Associate Professor of Physics – Ph.D., University of Texas, Austin; Carnegie Mellon, 2012–

LINING YAO, Assistant Professor of Human-Computer Interaction Institute and College of Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–

JIAN-GANG ZHU, Professor, Electrical and Computer Engineering – Ph.D., University of California at San Diego,; Carnegie Mellon, 1997–

Emeriti Faculty

RICHARD J. FRUEHAN, Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 1981–

THADDEUS B. MASSALSKI, Professor Emeritus of Physics, Materials Science and Engineering – Ph.D., D.Sc., University of Birmingham, England D.Sc. (h), University of Warsaw, Poland;; Carnegie Mellon, 1959–

PAUL WYNBLATT, Professor Emeritus of Materials Science and Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1981–

Department of Materials Science and Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

27-052 Introduction to NanoScience and Technology
Summer: 9 units
This course is offered within Carnegie Mellon's Advanced Placement Early Admissions (APEA) program. The course is primarily intended to provide an introduction to nanoscience and technology to a wide audience of students at the advanced high school to incoming freshmen level. The course goals are twofold: (1) to provide students with a holistic view of the objectives, opportunities and challenges of the emerging field of nanotechnology and 2) to sensitize students at an early stage of their career to the relevance of the connections among the traditional disciplines as a vital element to the progress in interdisciplinary areas such as nanotechnology. The course will cover: Introduction and fundamental science; Preparation of nanostructures; Characterization of nanostructures; Application examples, Social and ethical aspects of nanotechnology. Admission according to APEA guidelines.

27-100 Engineering the Materials of the Future
Fall and Spring: 12 units
Materials form the foundation for all engineering applications. Advances in materials and their processing are driving all technologies, including the broad areas of nano-, bio-, energy, and electronic (information) technology. Performance requirements for future applications require that engineers continue to design both new structures and new processing methods in order to engineer materials having improved properties. Applications such as optical communication, tissue and bone replacement, fuel cells, and information storage, to name a few, exemplify areas where new materials are required to realize many of the envisioned future technologies. This course provides an introduction to how science and engineering can be exploited to design materials for many applications. The principles behind the design and exploitation of metals, ceramics, polymers, and composites are presented using examples from everyday life, as well as from existing, new, and future technologies. A series of laboratory experiments are used as a hands-on approach to illustrating modern practices used in the processing and characterization of materials and for understanding and improving materials' properties.

27-201 Structure of Materials
Fall: 9 units
This course covers the fundamentals of crystallography and diffraction. Topics covered include: the periodic table of the elements, bonding in different classes of materials, Bravais lattices, unit cells, directions and planes, crystal geometry computations, direct and reciprocal space, symmetry operations, point and space groups, nature of x-rays, scattering in periodic solids, Bragg's law, the structure factor, and the interpretation of experimental diffraction patterns. 24 crystal structure types of importance to various branches of materials science and engineering will be introduced. Amorphous materials, composites and polymers are also introduced. This course includes both lectures and laboratory exercises.
Prerequisite: 21-122 Min. grade C

27-202 Defects in Materials
Fall: 9 units
Defects have a fundamental influence on the properties of materials, including deformation, electrical, magnetic, optical, and chemical properties, as well as the rates of diffusion in solids. As such, by the controlling the population of intrinsic and extrinsic defects, one can tailor the properties of materials towards specific engineering applications. The objective of this course, which includes classroom and laboratory sessions, is to define approaches to quantifying the populations and properties of defects in crystals. The course will be divided into three sections: point defects, dislocations, and planar defects. The formation of point defects and their influence on diffusion, electrical, and magnetic properties will be considered. The properties and characteristics of dislocations and dislocation reactions will be presented, with a focus on the role of dislocations in deformation. The crystallography and energetics of planar defects and interfaces will also be described, with a focus on microstructural evolution at high temperatures. Time permitting, volume defects or other special topics are also discussed.
Prerequisites: 21-122 Min. grade C or 21-120 Min. grade C or 27-201 or 27-215

27-205 Introduction to Materials Characterization
Spring: 3 units
The course introduces the modern methods of materials characterization, including characterization of microstructure and microchemistry of materials. A classroom component of the course will introduce the wide array of methods and applications of characterization techniques. Basic theory will be introduced where needed. Students will then be instructed in the use of several instruments such as AFM, SEM, and EDS, using a hands-on approach. All instruments are part of the existing lab facilities within MSE and CIT. The methods learned in this course will serve the student during several other higher level courses, such as the Senior level MSE Capstone Course (27-401).

27-210 Materials Engineering Essentials
Fall: 6 units
This course approaches professional skill holistically, having materials science and engineering students understand that being a professional includes having competencies and responsibilities that are personal, organizational and professional.
Prerequisites: 21-120 Min. grade C or 21-122 Min. grade C

27-211 Structure of Materials (Minor Option)
Fall: 6 units
This course is identical to 27-201, but without the 3-unit lab component.

27-212 Defects in Materials (Minor Option)
Spring: 6 units
THIS IS FOR THE MSE MINOR ONLY: Defects have a fundamental influence on the properties of materials, including deformation, electrical, magnetic, optical, and chemical properties, as well as the rates of diffusion in solids. As such, by the controlling the population of intrinsic and extrinsic defects, one can tailor the properties of materials towards specific engineering applications. The objective of this courseis to define approaches to quantifying the populations and properties of defects in crystals. The course will be divided into three sections: point defects, dislocations, and planar defects. The formation of point defects and their influence on diffusion, electrical, and magnetic properties will be considered. The properties and characteristics of dislocations and dislocation reactions will be presented, with a focus on the role of dislocations in deformation. The crystallography and energetics of planar defects and interfaces will also be described, with a focus on microstructural evolution at high temperatures. Time permitting, volume defects or other special topics are also discussed.

27-215 Thermodynamics of Materials
Fall: 12 units
The first half of the course will focus on the laws of thermodynamics and the inter-relations between heat, work and energy. The concept of an equilibrium state of a system will be introduced and conditions which must be satisfied for a system to be at equilibrium will be established and discussed and the concepts of activity and chemical potential introduced. The second half of the course will focus on chemical reactions, liquid and solid solutions, and relationships between the thermodynamics of solutions and binary phase diagrams.

27-216 Transport in Materials
Spring: 9 units
This course is designed to allow the student to become familiar with the fundamental principles of heat flow, fluid flow, mass transport and reaction kinetics. In addition, the student will develop the skills and methodologies necessary to apply these principles to problems related to materials manufacture and processing. Topics will include thermal conductivity, convection, heat transfer equations, an introduction to fluid phenomena viscosity, etc., Newtons and Stokes Laws, mass momentum balances in fluids, boundary layer theory, diffusion and absolute reaction rate theory. Where appropriate, examples will be taken from problems related to the design of components and the processing of materials.
Prerequisites: 27-215 and 27-210

27-217 Phase Relations and Diagrams
Spring: 12 units
Stability of structures. Hume-Rothery rules. Free energy-composition curves with applications to binary and ternary phase diagrams. Quantitative concepts of nucleation and growth with examples from solidification. Development of microstructures in various classes of phase diagram under near-equilibrium conditions. Atomic mechanisms of solid state diffusion and approach to equilibrium through diffusion.
Prerequisites: 27-215 and 27-201

27-227 Phase Relations and Diagrams (Minor Option)
Spring: 9 units
This course is identical to 27-217, but without the 3-unit lab component.

27-299 Professional Development I
Fall: 1 unit
This is a course that is designed to teach engineering business and professional skills to the MSE students. It is attended by sophomores, juniors and seniors and the courses Professional Topics I, II and III are given once per year on a three year cycle. Year 1: Work Place Skills, Leadership Skills and Teams Year 2: Project Management Year 3: Ethics, Business Planning, Lifetime Learning Although the course is not specifically designed as "metals, polymers, ceramics and composites", real world problems are used for examples and discussions. Assignments, when used, (for example, in project management or business planning) can be case studies or typical assignments a materials scientist may encounter during his/her employment.

27-301 Microstructure and Properties I
Fall: 9 units
The objective of this courses and its companion 27-302 is to convey some of the essential concepts in materials science and engineering that relate material properties (strength, magnetism, thermal expansion) to microstructure (crystal structure, dislocations structure, grain structure, precipitate structure, composite structure) in single phase materials. The relationships will be illustrated with examples of both idealized and technological materials. The course will draw upon many aspects of materials science such as defects, phase transformations etc. The course includes both lectures and laboratory exercises.
Prerequisites: 27-217 and 27-216

27-311 Polymeric Biomaterials
Spring: 9 units
This course will provide students with an introduction to polymers used in medical applications. Following a brief discussion of the physical properties of polymers and tissues, we will survey important classes of polymeric biomaterials, discussing material preparation, processing, properties and applications. Topics will include silicone elastomers, degradable hydrogels, ultra-high molecular weight polyethylene, polyurethanes, polyesters, and biopolymers such as silks and collagen. In addition, students will participate in a semester-long entrepreneurship project where they propose a new medical technology based on polymeric biomaterials. This semester we will discuss this primarily in the context of materials for wound healing applications. Student teams will perform market research on wound healing products, propose a novel bioactive dressing for wound healing applications, and identify methods for the testing and production of their product.

27-323 Powder Processing of Materials
Fall: 9 units
This course addresses the methods used in, and the principles that underlie, powder processing of metals and ceramics. Aspects of powder processing will be discussed in relation to the use of materials in engineering applications. The relationship between processing methods and materials performance in select applications will be discussed using specific materials examples including metals and ceramics. The course is broken down into three main parts: (1) understanding, selecting, and controlling powder characteristics; (2) powder handling, compaction, and forming techniques; and (3) drying, burnout, densification, sintering, and grain growth in powder compacts. Topics include chemical thermodynamics, reaction kinetics, surfaces, colloids, dispersions, process engineering, powder handling, powder compaction, shape forming, densification, and sintering.
Prerequisites: 27-100 and 27-216 and 27-215 and 27-202

27-324 Introduction to Polymer Science and Engineering
Fall: 9 units
This course introduces the fundamental properties of polymer materials and the principles underlying the design as well as the engineering and manufacturing of polymer materials. The basic characteristics of macromolecules will be discussed followed by an introduction to relevant forming technologies and their significance to material performance. Technologically relevant engineering properties of polymer materials will be introduced with focus on mechanical, electrical, and optical properties. Selected case studies and design projects will introduce students to the various stages of technical product development, i.e. problem analysis, material selection and processing plan. (

27-357 Introduction to Materials Selection
Spring: 6 units
The objective of this course is to teach the fundamentals of materials science as related to metals and metal alloys. The topics to be covered include crystal structure, defects, diffusion, binary phase diagrams, microstructure and processing, elastic and plastic deformation, equations of elasticity for isotropic materials, deformation of single crystal, slip systems, the tensile test, Von Mises yield criteria, strengthening mechanisms, phase transformations in steels, microstructures of steels, fracture and toughness, creep and corrosion.

27-367 Selection and Performance of Materials
Spring: 6 units
This course teaches the selection methodologies for materials and processes for satisfaction of a design goal. Topics such as performance under load, shape effects, material properties (intrinsic and as influenced by processing) are discussed and applied so as to determine the fitness of use of materials for applications. Expanded topics include economics, codes and standards, environmental and safety regulations, professional ethics and life cycle analysis where applicable. The course incorporates a project where virtual teams work to provide material selection for a specific application problem. Prerequisites: 27-100
Prerequisites: 27-301 and 27-100

27-399 Professional Development II
Fall: 1 unit
This is a course that is designed to teach engineering business and professional skills to the MSE students. It is attended by sophomores, juniors and seniors and the courses Professional Topics I, II and III are given once per year on a three year cycle. Year 1: Work Place Skills, Leadership Skills and Teams Year 2: Project Management Year 3: Ethics, Business Planning, Lifetime Learning Although the course is not specifically designed as "metals, polymers, ceramics and composites", real world problems are used for examples and discussions. Assignments, when used, (for example, in project management or business planning) can be case studies or typical assignments a materials scientist may encounter during his/her employment.

27-401 MSE Capstone Course I
Fall: 6 units
This is the first of 2 course that together fulfill the Capstone requirement. This capstone course introduces the student to the methodology used for projects and teams based research as practiced in the Materials Science and Engineering workplace. This is a project course that requires the knowledge relationship among processing, structure, and performance to address an important contemporary problem in materials science and engineering. Student taking this course will work in a team environment to complete a design project to resolve scientific and engineering issues relating to materials. Research topics will be selected from a list of material problems or research concepts generated from companies or academia - industry research partnerships. This course will establish the research goals, review applicable research methodologies, introduce project management skills and discuss ethical concepts as teams assemble and set their research directions. On the topic selected, the work product is a report that provides clear definition of the problem being addressed, sets out a methodology for the research, includes a literature review, and reports early experimentation results and provides recommendations for future work.
Prerequisites: 27-367 and 27-205 and 27-301

27-402 MSE Capstone Course II
Spring: 6 units
This is the spring extension of 27-401. Teams or team members that have the industry agreement and that wish to continue their research project may do so in this course. As with 27-401, all research is expected to be original, and proper scientific ethics, and methodologies are enforced for the research and reports. Team participation and communication is an important issue and the presentation and reports must be technical and professional in structure. The course requires full project management and accounting for the research being conducted. On the topic selected, the work product is a report that provides clear definition of the problem being addressed, a methodology for the research, literature review, experimentation and reporting of findings, conclusions based on findings, and recommendations for future work. Prerequisites:27-401
Prerequisite: 27-401

27-406 Sustainable Materials
Fall and Spring: 9 units
This course is intended to instill a sense of how materials properties and performance are conceived and brought to market specifically under sustainability constraints arising from the increasing demand of materials, Students will be introduced to the global nature of materials and will explore the global influences on the materials supply and value chains. The student will explore issues through the framework of the materials lifecycle including resource availability, manufacturing choices, and disposable options for materials in light of their use and selection for application. As a result, the student will be able to make more informed material selection or be able to use this information to identify critical research directions for future material development.

27-410 Computational Techniques in Engineering
Spring: 12 units
This course covers mathematical methods that allow formulation of engineering and science problems in a manner that makes them computationally tractable for numerical solutions. Numerical approaches to solving engineering or science problems allow one to perform computer simulations that can answer key questions without actual experimental effort (which can often be costly and time-consuming). The course is divided into two major modules. The first module develops foundational background in modeling, computers, error analysis, linear algebra, and curve fitting. The second module builds on the first to develop skills in numerical differentiation and integration, and continues with techniques for computational solution of ordinary and partial differential equations. Students will learn how to set up engineering or science problems in a manner that allows numerical solutions to be obtained by either writing simple computer programs or macros that interface with commercially available software packages such as MATLAB or Mathematica. The course is also cross-listed as 18-411

27-411 Engineering Biomaterials
Fall: 9 units
This course will cover structure-processing-property relationships in biomaterials for use in medicine. This course will focus on a variety of materials including natural biopolymers, synthetic polymers, and soft materials with additional treatment of metals and ceramics. Topics include considerations in molecular design of biomaterials, understanding cellular aspects of tissue-biomaterials interactions, and the application of bulk and surface properties in the design of medical devices. This course will discuss practical applications of these materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies. Must be a Junior or Senior in CIT or obtain permission of instructor.

27-421 Processing Design
Fall: 6 units
In this course, the concepts of materials and process design are developed, integrating the relevant fundamental phenomena in a case study of a process design. The course includes basic science and engineering as well as economic and environmental considerations. The case study is on environmentally acceptable sustainable steelmaking. Other case studies in materials processing could be used.

27-432 Electronic and Thermal Properties of Metals, Semiconductors and Related Devices
Intermittent: 9 units
Fall even years This is Part I of a two-part course (Part II is 27-433) sequence concerned with the electrical, dielectric, magnetic and superconducting properties of materials. Students taking Part I will develop an in-depth understanding, based on the modern theories of solids, of the electrical, electronic and thermal properties of metals and semiconductors and the principles of operation of selected products and devices made from these materials. Overarching and interrelated topics will include elementary quantum and statistical mechanics, relationships between chemical bonds and energy bands in metals and semiconductors, the roles of phonons and electrons in the thermal conductivity of solids, diffusion and drift of electrons and holes, the important role of junctions in the establishment and control of electronic properties of selected metal- and semiconductor-based devices. Examples of commercial products will be introduced to demonstrate the application of the information presented in the text and reference books and class presentations. Additional topics will include microelectro-mechanical systems and nanoelectronics.

27-433 Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices
Intermittent: 9 units
Fall odd years: 9 units This is Part II of a two-part course sequence (Part I is 27-432) concerned with the electrical, dielectric, magnetic and superconducting properties of materials. Students taking Part II will develop an in-depth understanding, based on the modern theories of solids, of the dielectric, magnetic and superconducting properties of materials and the principles of operation of selected products and devices made from these materials. Topics will include relationships between chemical bonds and energy bands in dielectric and magnetic materials; polarization mechanisms in materials and their relationship to capacitance, piezoelectricity, ferroelectricity, and pyroelectricity; magnetization and its classification among materials; magnetic domains; soft and hard magnets; and the origin, theory and application of superconductivity. Examples of commercial products will be introduced to demonstrate the application of the information presented in the text and reference books and class presentations.

27-445 Structure, Properties and Performance Relationships in Magnetic Materials
Spring: 9 units
This course introduces the student to intrinsic properties of magnetic materials including magnetic dipole moments, magnetization, exchange coupling, magnetic anisotropy and magnetostriction. This is followed by discussion of extrinsic properties including magnetic hysteresis, frequency dependent magnetic response and magnetic losses. This will serve as the basis for discussing phase relations and structure/properties relationships in various transition metal magnetic materials classes including iron, cobalt and nickel elemental magnets, iron-silicon, iron-nickel, iron-cobalt and iron platinum. This will be followed by a discussion of rare earth permanent magnets, magnetic oxides, amorphous and nanocomposite magnets. Polymers used in Electromagnetic Interference (EMI) Absorbers applications will also be covered.

27-454 Supervised Reading
Spring
This course provides the opportunity for a detailed study of the literature on some subject under the guidance of a faculty member, usually but not necessarily in preparation for the Capstone Course, 27-401/402.

27-499 Professional Development III
Fall: 1 unit
This is a course that is designed to teach engineering business and professional skills to the MSE students. It is attended by sophomores, juniors and seniors and the courses Professional Topics I, II and III are given once per year on a three year cycle. Year 1: Work Place Skills, Leadership Skills and Teams Year 2: Project Management Year 3: Ethics, Business Planning, Lifetime Learning Although the course is not specifically designed as "metals, polymers, ceramics and composites", real world problems are used for examples and discussions. Assignments, when used, (for example, in project management or business planning) can be case studies or typical assignments a materials scientist may encounter during his/her employment.

27-501 Invention & Innovation for Materials Intensive Technologies Part 1
Fall: 4.5 units
Two 4.5 unit classes that can be taken in sequence or as stand-alone mini's. Courses will be cross-listed between EPP and MSE. This course is intended to instill a sense of how technologies are conceived and brought to market. The students will be exposed to a variety of formalized invention and innovation processes/concepts and will be asked to complete projects that will pull from the full range of their engineering training. It is intended for seniors who are eager to creatively apply their learned knowledge skills, and who are interested in invention, innovation, and entrepreneurship. The first half (part 1 (27-501), mini 1) will focus on the process of invention for devices and technologies that are enabled by materials functionality. This will start by providing historical context and addressing the questions "What is invention?" This will be followed by an assessment of various systematic methods by which the process of invention is practiced, with a specific focus on materials intensive devices and products. The second half of the course (part 2 (27-502) mini 2) will examine innovation theory in the context of materials intensive technologies. Specifically, the concepts of incumbency, disruption, value chain, supply chain, funding models and paths to market will be addressed. In this class, significant time will be dedicated to covering the impact of international market and technology development.

27-502 Invention and Innovation for Materials Intensive Technologies Part 2
Fall and Spring: 4.5 units
ALL STUDENTS MUST HAVE TAKEN AND SUCCESSFULLY PASED 27-501 AS A PRE-REQ. Two 4.5 unit classes that can be taken in sequence or as stand-alone mini's. Courses will be cross-listed between EPP and MSE. This course is intended to instill a sense of how technologies are conceived and brought to market. The students will be exposed to a variety of formalized invention and innovation processes/concepts and will be asked to complete projects that will pull from the full range of their engineering training. It is intended for seniors who are eager to creatively apply their learned knowledge skills, and who are interested in invention, innovation, and entrepreneurship. The first half (part 1 (27-501), mini 1) will focus on the process of invention for devices and technologies that are enabled by materials functionality. This will start by providing historical context and addressing the questions "What is invention?" This will be followed by an assessment of various systematic methods by which the process of invention is practiced, with a specific focus on materials intensive devices and products. The second half of the course (part 2 (27-502) mini 2) will examine innovation theory in the context of materials intensive technologies. Specifically, the concepts of incumbency, disruption, value chain, supply chain, funding models and paths to market will be addressed. In this class, significant time will be dedicated to covering the impact of international market and technology development.

27-503 Additive Manufacturing and Materials
All Semesters: 9 units
This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

27-514 Bio-nanotechnology: Principles and Applications
Spring: 9 units
"Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of biological applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nanomaterials in cancer therapy."

27-515 Introduction to computational materials science
Fall: 9 units
This course introduces students to the theory and practice of computational materials science from the electronic to the microstructural scale. Both the underlying physical models and their implementation as computational algorithms will be discussed. Topics will include: Density functional theory Molecular dynamics Monte Carlo methods Phase field models Cellular automata Data science Coursework will utilize both software packages and purpose-built computer codes. Students should be comfortable writing, compiling, and running simple computer programs in C, C++, Fortran, MatLab, Python, or comparable environment. THIS COURSE IS FOR MSE UNDERGRADUATE STUDENTS ONLY.

27-519 Computational Thermodynamics
Spring: 9 units
Computational thermodynamics is a powerful tool of a Materials Engineer. We will examine how thermodynamic simulation software outputs an equilibrium calculation from a list of input conditions. This requires a description of Gibbs energy minimization calculations, Gibbs energy models, and the construction of these models from thermodynamic data. At the end of the class students should be able to use thermodynamic simulation software to solve engineering problems while recognizing its limitations. This class is for upper-level undergraduates and graduate students interested in these computational tools.

27-520 Tissue Engineering
Spring: 12 units
This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Prereqs: Cell biology and Biomaterials, or permission of instructor.

27-533 Principles of Growth and Processing of Semiconductors
Fall: 6 units
Development of a fundamental understanding of material principles governing the growth and processing of semiconductors. Techniques to grow and characterize bulk crystals and epitaxial layers are considered. The processing of semiconductors into devices and the defects introduced thereby are discussed. The roles of growth- and processing-induced defects in determining long term reliability of devices are examined.

27-542 Processing and Properites of Thin Films
Fall: 9 units
This course is designed to provide an introduction to the science and technology of thin films, with special emphasis on methods to produce thin films and relationships between growth conditions and thin film properties. Topics include (1) various methods of thin film production, such as evaporation, sputtering and chemical vapor deposition, (2) nucleation and growth processes, (3) dimensional, chemical, and structural characterization of thin films and (4) properties and applications, such as conductivity and thin film solar cells.

27-551 Properties of Ceramics and Glasses
Spring: 9 units
This course describes some of diverse properties of ceramics and glasses, with a focus on those relevant to modern engineering applications. It includes discussions of the underlying science of selected ceramic properties, such as thermal properties, including heat capacity and thermal expansion; mechanical properties, including strength, toughness, and environmental effects; electrical properties, including electronic and ionic conductivity; dielectric properties, including piezoelectricity and ferroelectricity; and optical properties, as they pertain to glasses and lasers. Numerous examples of current applications, such as lasers, sensors, fiber optics, multilayer capacitors, solid oxide fuel cells, or thermoelectrics, are discussed throughout the course to illustrate the engineering relevance of fundamental phenomena. This class will be co-taught with 27-751. Undergraduates taking the course will have separate homework and exams from the graduate students, and will be graded separately from the graduate students.

27-555 Materials Project I
Fall
This course is designed to give experience in individualized research under the guidance of a faculty member. The topic is selected by mutual agreement, and will give the student a chance to study the literature, design experiments, interpret the results and present the conclusions orally and in writing. Faculty advisor selection must be in consultation with the MSE Undergraduate Academic Advisor.

27-556 Materials Project II
Spring
Second semester of Materials Project. This course is designed to give experience in individualized research under the guidance of a faculty member. The topic is selected by mutual agreement, and will give the student a chance to study the literature, design experiments, interpret the results and present the conclusions orally and in writing. Faculty advisor selection must be in consultation with the MSE Undergraduate Academic Advisor.

27-561 Kinetics of Metallurgical Reactions and Processes
Fall: 6 units
This class uses examples from the ironmaking and steelmaking to illustrate different rate-determining reaction steps. Reaction times in ironmaking and steelmaking process vary quite widely; the fundamental origins of the large differences in reaction time are analyzed, after a brief overview of the main reactions and process steps in ironmaking and steelmaking. Particular skills to be practiced and developed include derivation of the mathematical relationships which describe the rates of metallurgical processes which involve heat transfer, and mass transfer for solid-gas, liquid-gas and liquid-liquid reactions; quantifying the expected rates of such reactions; identification of rate-determining steps, based on calculated rates and observed reaction rates; predicting the effects of process parameters such as particle size, stirring, temperature and chemical compositions of phases on the overall rate; and critical evaluation of kinetic data and models in scientific papers on metallurgical reactions.

27-565 Nanostructured Materials
Intermittent: 9 units
This course is an introduction to nanostructured materials or nanomaterials. Nanomaterials are objects with sizes larger than the atomic or molecular length scales but smaller than microstructures with at least one dimension in the range of 1-100 nm. The physical and chemical properties of these materials are often distinctively different from bulk materials. For example, gold nanoparticles with diameters ~15 nm are red and ~40 nm gold nanoparticles are purple whereas bulk gold has a golden color. The course starts with a discussion of top-down and bottom-up fabrication methods for making nanostructures as well as how to image and characterize nanomaterials including scanning probe microscopies. Emerging nanomaterials such as fullerenes, graphene, carbon nanotubes, quantum dots and nanocomposites are also discussed. The course then focuses on applications of nanomaterials to microelectronics, particularly nanoscale devices and the emerging field of molecular-scale electronics. The miniaturization of integrated systems that sense mechanical or chemical changes and produce as electrical signal is presented. The principles and applications of the quantum confinement effects on optical properties are discussed, mainly as sensors. The last part of the course is a discussion of nanoscale mechanisms in biomimetic systems and how these phenomena are applied in new technologies including molecular motors.

27-566 Special Topics in MSE:Using Matls Informatics to Assess Societal Impact of Matls
Fall and Spring: 9 units
Using Materials Informatics to Assess Societal Impact of Materials: For years Material Science and Engineering in general has been taught with emphasis on the technology and then looks at how this technology fits in to society through applications. This course will attempt to puts forth an innovative approach, combining new data mining techniques, data analysis, and material fundamentals (materials informatics) to see if material failure patterns can be extracted from social media. The course will involve instruction on typical material issue that contribute to failures either geographically or temporarly. Students will also be introduced to informatics techniques related to data mining and large database analysis. The intent is to have a mix of lectures and practical project work. This course is primarily intended to be a course directed to CIT students in order to experience an understanding that engineering work is strongly connected to societal. Students that enroll should have completed their class in statistics.

27-568 Applied Nanoscience and Nanotechnology
Fall and Spring: 9 units
TBD

27-570 Polymeric Biomaterials
Spring: 9 units
This course will cover aspects of polymeric biomaterials in medicine from molecular principles to device scale design and fabrication. Topics include the chemistry, characterization, and processing of synthetic polymeric materials; cell-biomaterials interactions including interfacial phenomena, tissue responses, and biodegradation mechanisms; aspects of polymeric micro-systems design and fabrication for applications in medical devices. Recent advances in these topics will also be discussed. Pre-requisite: None.

27-582 Phase Transformations in Solids
Intermittent: 9 units
Spring even years: In this course the fundamental aspects of solid state phase transformations are presented. The nucleation (homogeneous and heterogeneous) and growth of diffusional and non-diffusional heterogeneous solid state transformations are discussed from the point of view of crystallography, thermodynamics and kinetics, as are the same aspects of homogeneous transformations. Details of such transformations as precipitation, cellular, atomic ordering, massive, spinodal decomposition, displacive, etc. are discussed with specific examples from the Materials Science literature.

27-588 Polymer Physics and Morphology
Intermittent: 9 units
This course introduces the fundamental concepts necessary to understand and determine the structure and properties of polymers in the solid state. The structure of polymers will be discussed with focus on the amorphous, crystalline and liquid-crystalline state. One aim is to provide a student intuition about the organization of polymer molecules in the solid state based on the polymer's chemical structure. Particular attention will be given to scattering techniques as a tool to determine polymer structures in solution and the solid state. The glass transition in amorphous polymers as well as the morphology and kinetics of crystal formation in semi-crystalline polymers will be discussed in detail. The second part of the course will focus on polymer multicomponent materials. Basic concepts of lattice models will be introduced and applied to predict the phase behavior of polymer blends.

27-591 Mechanical Behavior of Materials
Intermittent: 9 units
Spring odd years: Fundamentals of stress and strain. Linear elastic behavior. Tensile testing and yield criteria. Relationships between stress and strain for the case of plastic deformation. Theoretical strength. Tensile tests of single crystals and the idea of a slip system. Shear stress versus shear strain curves for single crystals and the effects of crystal orientation, temperature, atoms in solid solution and precipitates on the shapes of such curves. Taylor's connection between tensile curves of single crystals and those of polycrystalline samples. Dislocations and plastic deformation. Strengthening mechanisms including solid-solution strengthening, strengthening by precipitates, work hardening and grain size effects on strength. Approaches to quantifying the fracture resistance of materials, including the Griffith approach, the energy release rate approach and the stress intensity factor approach. Crack tip behavior including stresses and strains at crack tips and the plastic zone. Fracture mechanisms including ductile fracture, cleavage fracture and intergranular fracture. The fracture of highly brittle materials. Time permitting fatigue and creep of materials will be discussed.

27-592 Solidification Processing
Intermittent: 9 units
Spring odd years: The goal of this course is to enable the student to solve practical solidification processing problems through the application of solidification theory. The objectives of this course are to: (1) Develop solidification theory so that the student can understand predict solidification structure; (2) Develop a strong understanding of the role of heat transfer in castings; (3) Develop an appreciation for the strengths and weaknesses of a variety of casting processes. The first half of the course will be theoretical, covering nucleation, growth, instability, solidification microstructure: cells, dendrites, eutectic and peritectic structures, solute redistribution, inclusion formation and separation, defects and heat transfer problems. The second part of the course will be process oriented and will include conventional and near net shape casting, investment casting, rapid solidification and spray casting where the emphasis will be on process design to avoid defects.

27-620 Basics and Applications of Power Magnetic Devices
Intermittent: 12 units
This course will provide a sound background in the fundamentals of soft magnetic materials and the physics required for magnetic component design. Fundamental principles will be applied to practical component level design problems. A final design project will leverage analytical and/or finite element simulations. The course is targeted to masters-level students but will be accessible to advanced undergraduate and PhD level students.

27-675 Masters Report
All Semesters
This course is used to indicate whether a student has satisfied the final report requirement for the Master of Science in Materials Science Degree Program. Students in the program will be registered for the course in their final semester of the program.

27-698 Practical Materials Characterization Laboratory
Intermittent: 6 units
This course is designed to give masters students a practical exposure to materials characterization techniques. Students will learn the theory and background of several laboratory techniques, including Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), Atomic Force Microscopy (AFM) and thermal analysis techniques such at thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The course will consist of lectures, followed by laboratory sessions for practical use of the instrumentation. Lectures will provide the necessary background to understand how different materials characterization techniques work; Lab sessions will inform the student on standard operating procedures for the techniques discussed in the lectures.

27-699 Professional Skills in Materials Science and Engineering
Fall: 6 units
This course is intended for students in the masters program in Materials Science and Engineering. The course will expose students to important issues that materials scientists and engineers face when they enter the workforce. The course focuses on professional skills for materials scientists and engineers, covering communication skills, ethics and responsible conduct of research, and evaluating technical literature. The course will end with discussions on how materials science affects the global economy. Course activities will include in-class exercises and assignments based on case studies.

27-700 SPECIAL TOPICS: Energy Storage Materials and Systems
Fall and Spring: 12 units
Contemporary energy needs require energy storage and conversion for a range of mobile and stationary applications. This course will examine electrochemically functional materials, devices, and systems that are used to convert, store, and release electrical energy. The principles and mathematical models of electrochemical energy conversion and storage will be examined in depth; students will study thermodynamics and reaction kinetics pertaining to electrochemical reactions, phase transformations, transport, and processing relating to a wide range of related technologies. This course also will also cover the practical aspects associated with the application of batteries, fuel cells, supercapacitor technologies. Students are asked to conduct a class project that involves interacting with outside industry and culminates in a end-of-semester poster session.

27-703 Additive Manufacturing and Materials
All Semesters: 12 units
This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

27-704 Design Principles of Functional Coatings for Modern Applications
Fall and Spring: 6 units
Many modern technologies rely on the use of innovative, multi-functional coatings to ensure competitive advantage in the fast-changing global markets. Building such coatings requires advanced planning of the entire coating-substrate system, and of the manufacturing steps. This course will discuss the design principles of multi-functional coatings, present advanced coating architectures and review the relevant manufacturing steps. The course will be illustrated with design principles of functional coatings in three major industries: aerospace, automotive, and machining. We will identify the relevant key challenges, and follow the thinking process of the industry leaders addressing the challenge. Then, we will examine the developed coating solutions: multi-functional tribological coatings on cutting tools; thermal barrier coatings on nickel alloy turbine blades for aircraft and power generation; diamond like coatings and wear protective coatings for automotive diesel engines; and corrosion protection in the aerospace and in the automotive industries. The course will conclude with a discussion of new trends in surface engineering and in the design of multi-functional coatings, including self-healing, self-cleaning, and other smart coatings.

27-706 Hard and Superhard Materials
Fall and Spring: 6 units
This course will focus on the fundamental principles of hard and superhard materials. We will first discuss the origin of hardness across materials, and then describe important examples of materials prized for their intrinsic or extrinsic hardness. We will focus on the preparation, microstructure, and properties of materials such as diamond, cubic boron nitride and compound carbides. Then, we will emphasize the design of novel nano-structured and nano-composite materials and coatings, which are at the frontier of material science. Finally, the course will present examples of the architecture and processing methods used to generate hard materials and coatings in manufacturing automotive and aerospace industries.

27-709 Engineering Biomaterials
Fall: 12 units
This course will cover structure-processing-property relationships in biomaterials for use in medicine. This course will focus on a variety of materials including natural biopolymers, synthetic polymers, and soft materials with additional treatment of metals and ceramics. Topics include considerations in molecular design of biomaterials, understanding cellular aspects of tissue-biomaterials interactions, and the application of bulk and surface properties in the design of medical devices. This course will discuss practical applications of these materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies. This course is a project-based option for graduate students that is taught concurrently with 42-411. Open only to graduate students in CIT or by permission of instructor.

27-715 Applied Magnetism and Magnetic Materials
Spring: 12 units
In this course we address the physics of magnetism of solids with emphasis on magnetic material properties and phenomena which are useful in various applications. The content of this course includes the origins of magnetism at the atomic level and the origins of magnetic ordering (ferro-, ferri-, and antiferromagnetism), magnetic anisotropy, magnetic domains, domain wall, spin dynamics, and transport at the crystalline level. The principles of magnetic crystal symmetry are utilized to explore the various domains in ferromagnetic crystals, and tensors are used in the description of such magnetic properties as magnetocrystalline anisotropy, susceptibility and magnetostriction. To a limited extent, the applications of magnetism are discussed in order to motivate the understanding of the physical properties and phenomena.

27-718 Soft Materials
Fall: 12 units
The emphasis in this course will be on the emerging unifying physical principles that explain the macroscopic properties of a wide variety of soft materials, e.g., colloids, liquid crystals, surfactants, polymers, and biological structures. At the end of the course, students should understand the concepts, experimental techniques, and open questions in the field. The course is interdisciplinary, and it is expected that enrollment will cover a wide spectrum of students. Therefore, the essential concepts will be taught as necessary. Prerequisites: Graduate standing or permission of instructor.

27-719 Computational Thermodynamics
Spring: 12 units
Computational thermodynamics is a powerful tool of a Materials Engineer. We will examine how thermodynamic simulation software outputs an equilibrium calculation from a list of input conditions. This requires a description of Gibbs energy minimization calculations, Gibbs energy models, and the construction of these models from thermodynamic data. At the end of the class students should be able to use thermodynamic simulation software to solve engineering problems while recognizing its limitations. This class is for graduate students interested in these computational tools.

27-720 Tissue Engineering
Spring: 12 units
This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Prereqs: Cell biology and Biomaterials, or permission of instructor.

27-721 Processing Design
Fall: 6 units
In this course, the concepts of materials and process design are developed, integrating the relevant fundamental phenomena in a case study of a process design. The course includes basic science and engineering as well as economic and environmental considerations. The case study is on environmentally acceptable sustainable steelmaking. Other case studies in materials processing could be used.

27-722 Basics and Applications of Power Magnetic Devices
Intermittent: 12 units
This course will provide a sound background in the fundamentals of soft magnetic materials and the physics required for magnetic component design. Fundamental principles will be applied to practical component level design problems. A final design project will leverage analytical and/ or finite element simulations. The course is targeted to masters-level students but will be accessible to advanced undergraduate and PhD level students.Primary learning objectives are: 1) Establish a fundamental knowledge base of the relevant materials science and physics principles that dictate performance of soft magnetic materials. 2) Establish a strong foundation in the fundamentals of applied electromagnetics required for intelligent application of finite element simulations and other analytical models for magnetic component design. 3) Provide students with experience in performing magnetic component design including material selection and component optimization through assigned problems and a final project.

27-724 Materials for Energy Storage
Intermittent: 6 units
This course will examine functional materials used to store and release electrical energy. An overview of the thermodynamics of power, energy and energy storage will be used to motivate subsequent investigations into the dominant methods in use today: electrochemical, electrical, and electromechanical (chemical/combustion and nuclear processes will not be covered). For each sub-topic, the physical and chemical mechanisms exploited will be discussed, followed by a detailed exposition of specific materials functionality and device applications. Particular focus will be given to several relevant emerging technologies: Li-ion batteries, hydrogen-based fuel cells (polymer proton exchange membrane and solid-oxide based systems), and large capacitors (both electrolytic and dielectric).

27-725 Materials for Nuclear Energy Systems
Spring: 6 units
Students in this course will learn about Materials that are used in nuclear energy systems. The course will cover the full range of materials that are relevant to nuclear energy with a focus on materials subject to irradiation (glasses, steels, nickel alloys, and zirconium alloys). Applications of materials will include waste storage, reactor vessels, turbines, pumps, piping, and fuel elements. For the materials used in each application, the selection and performance criteria will be considered as well as the underlying structure, thermodynamic, and kinetic processes that influence materials properties. The effects of irradiation on materials properties and performance will be examined. Key properties include strength, fracture toughness and corrosion resistance. Many of these properties continue to change over the long service periods expected of components. In addition to lectures and homeworks, each student will complete a detailed case study in which they examine a particular material and application.

27-727 Mechanical Behavior in Extreme Enviroments
Spring: 6 units
The purpose of this course is to discuss the mechanical behavior of materials used in extreme environments in the production and distribution of energy. The focus will be on the production and refining of oil, conventional power plants and nuclear power plants. The course will begin with a discussion of the materials used in these applications and this discussion will focus on compositions, heat treatment, microstructure and nominal mechanical properties after heat treatment. The materials will include low alloy steels, stainless steels, nickel base alloys and zirconium alloys used as fuel cladding in nuclear reactors. The mechanical behavior discussed will be the behavior of materials at high temperatures, various types of stress corrosion cracking and the toughness of steels used at low temperatures. In addition, various forms of embrittlement associated with long service times at elevated temperatures will be discussed. These will include hydrogen attack, temper embrittlement due to segregation of impurities and alloying elements, the formation of phases which result in embrittlement and embrittlement due to irradiation in nuclear reactors. Many of these materials are expected to be in service for many years so, where time permits, methodologies used to predict mechanical properties after long times in service will be discussed.

27-729 Solid State Devices for Energy Conversion
Intermittent: 6 units
Intensive research efforts have yielded promising new materials approaches to 'alternative' energy conversion technologies, such as solar cells or photovoltaics; thermoelectric materials, which convert waste heat to electricity; metal/semiconductor superlattices for thermionic energy conversion; and fuel cells. At the same time, notable advances have been made in devices that substantially enhance our energy efficiency: e.g., chemical sensors and light-emitting diodes for solid-state lighting. In all of these devices, interfaces between dissimilar materials often govern and/or limit the behavior. In addition to the basic structures and operating principles, this course will cover practical materials interface issues, such as electrical transport, thermal stability, contact resistance, and bandgap engineering, that significantly affect the performance of a variety of energy conversion and energy-saving devices.

27-731 SPECIAL TOPICS: Hard and Superhard Materials
Intermittent: 6 units
This course will focus on the fundamental principles hard and superhard materials and coatings. We will first discuss the origin of hardness across materials, and then describe important examples of materials prized for either their intrinsic or extrinsic hardness. We will focus on the preparation, microstructure, and properties of materials such as diamond, cubic boron nitride and compound carbides. Additionally, we will emphasize the design of novel nano-structured and nano-composite materials and coatings, which are at the frontier of materials science. Finally, the course will present examples of the architecture and processing methods used to generate hard materials and coatings in manufacturing, automotive and aerospace industries.

27-740 Practical Methods in Scanning Electron Microscopy
Spring: 6 units
This course is designed to provide instrument training on scanning electron microscopes in the Materials Characterization Facility (MCF). Emphasis will be placed on acquiring the basic skills needed to successfully operate this type of microscopes; this will be achieved by a combination of lectures and hands-on lab sessions. Lectures will provide the necessary background to understand electron scattering techniques, including electron diffraction, secondary and back-scattered electron imaging, electron back-scatter diffraction, and energy dispersive x-ray spectroscopy. Lab sessions will inform the student on standard operating procedures for the techniques discussed in the lecture portion of the course. At the end of the course, the student is expected to demonstrate the ability to independently use the scanning electron microscope for basic operations; successful demonstration of such skills will lead to certification for day-use of scanning electron microscopes in the MCF.

27-741 Practical Methods in Transmission Electron Microscopy
Fall and Spring: 6 units
This course is designed to provide instrument training on transmission electron microscopes in the Materials Characterization Facility (MCF). Emphasis will be placed on acquiring the basic skills needed to successfully operate this type of microscope; this will be achieved by a combination of lectures and hands-on lab sessions. Lectures will provide the necessary background to understand electron scattering techniques, including electron diffraction, bright field and dark field imaging, phase contrast microscopy, and energy dispersive x-ray spectroscopy. Lab sessions will inform the student on standard operating procedures for the techniques discussed in the lecture portion of the course. At the end of the course, the student is expected to demonstrate the ability to independently use the transmission electron microscope for basic operations; successful demonstration of such skills will lead to certification for day-use of transmission electron microscopes in the MCF.

27-752 Fundamentals of Semiconductors and Nanostructures
Spring: 12 units
This course is designed to provide students with a foundation of the physics required to understand nanometer-scale structures and to expose them to different aspects of on-going research in nanoscience and nanotechnology. Illustrative examples will be drawn from the area of semiconductor nanostructures, including their applications in novel and next-generation electronic, photonic, and sensing devices. The course begins with a review of basic concepts in quantum physics (wave-particle duality, Schrödinger's equation, particle-in-a-box, approximation methods in quantum mechanics, etc.) and then continues with a discussion of bulk three-dimensional solids (band structure, density of states, the single-electron effective-mass approximation). Size effects due to nanometer-scale spatial localization are then discussed within a quantum-confinement model in one-, two-, and three- dimensions for electrons. An analogous discussion for photons is also presented. The basic electronic, optical, and mechanical properties of the low-dimensional nanostructures are then discussed. A select number of applications in electronics, photonics, biology, chemistry, and bio-engineering will be discussed to illustrate the range of utility of nanostructures. Upon completion of the course, students will have an appreciation and an understanding of some of the fundamental concepts in nanoscience and nanotechnology. The course is suitable for first-year graduate students in engineering and science (but advanced undergraduates with appropriate backgrounds may also take it with permission from the instructor). Pre-requisites include 09-511, 09-701, 09-702, 18-311, 27-770, 33-225, 33-234 or familiarity with the material or basic concepts covered in these courses.

27-756 Masters Project
All Semesters
Individual research project, including laboratory, theroetical, library or design work followed by a written or oral report on the work accomplished.

27-759 Molecular Engineering
Spring: 12 units
Unprecedented control over molecular architecture has led to next-generation materials for a broad range of applications. The goal will be to provide students with an understanding of how to design and synthesize organic materials for specific technologies using an approach that integrates content from fundamental polymer science in the context of engineering. Emphasis will be placed on understanding composition-structure-function relationships and how molecular parameters and processing strategies can be tuned to optimize performance. The course will utilize a combination of textbook material as well as articles from the recent scientific and patent literature. Feedstocks, materials, processes, and products will be viewed through of life cycle assessments with an emphasis on sustainability. Learning Objectives: At the end of this course students will: (1) gain experience in applying their knowledge of polymer chemistry in preparing materials via radical and condensation reactions in technological applications; (2) learn engineering paradigms related to surface tension, adsorption, film formation, viscoelastic properties of complex fluids, thermodynamics, transport phenomena, and electronic materials used to design advanced materials systems; (3) gain hands-on experience in the preparation, characterization, and testing of advanced materials.

27-761 Kinetics of Metallurgical Reactions and Processes
Fall: 6 units
This class uses examples from the ironmaking and steelmaking to illustrate different rate-determining reaction steps. Reaction times in ironmaking and steelmaking process vary quite widely; the fundamental origins of the large differences in reaction time are analyzed, after a brief overview of the main reactions and process steps in ironmaking and steelmaking. Particular skills to be practiced and developed include derivation of the mathematical relationships which describe the rates of metallurgical processes which involve heat transfer, and mass transfer for solid-gas, liquid-gas and liquid-liquid reactions; quantifying the expected rates of such reactions; identification of rate-determining steps, based on calculated rates and observed reaction rates; predicting the effects of process parameters such as particle size, stirring, temperature and chemical compositions of phases on the overall rate; and critical evaluation of kinetic data and models in scientific papers on metallurgical reactions.

27-763 Foundations of Electron Microscopy
Fall: 12 units
This course provides an in-depth overview of both scanning and transmission electron microscopy methods used in materials research for the characterization of microstructure and crystallography. The course begins with basic quantum mechanics at the level needed to describe electron scattering phenomena in solids, and introduces the basic Schrodinger equation along with several numerical procedures for its solution. Topics covered will at a minimum include: atomic scattering and form factors, dynamical electron scattering, conventional and convergent beam electron diffraction, defect contrast imaging, electron back-scatter diffraction, electron channeling and channeling contrast imaging, Monte Carlo simulations of electron trajectories, inelastic scattering, and an introduction to 3D characterization techniques, including serial sectioning and tomography. Throughout the course, the emphasis will be on the underlying models; students will be expected to participate in practical simulation sessions.
Prerequisite: 27-740

Course Website: http://www.cmu.edu/blackboard

27-766 Diffusion in Materials
Fall: 6 units
This course is designed to allow the student to become familiar with the fundamental principles diffusion in solid materials. The course will include the treatment of diffusion from an atomic scale to micro-structural scales in metals, ceramics, glasses and polymers. In addition, the student will develop skills and methodologies necessary to apply mathematical methods to solve differential equations of relevance to diffusion problems including separation of variables, Laplace transforms ad Green's functions. An introduction will be given to the application of numerical solutions. Where appropriate, examples will be taken from problems related to the design of components and the processing and performance of materials.

27-768 Applied Nanoscience and Nanotechnology
All Semesters: 12 units
No course description provided.

27-782 Phase Transformations in Solids I
Spring: 12 units
Special topics in applied thermodynamics, with particular emphasis on free energy-composition diagrams and their applications, are developed in some detail. The kinetic equations of both classical and non-classical nucleation theory are then derived. Special emphasis is placed upon the influence of the critical nucleus shape, and the nucleation site, upon nucleation kinetics. The limited experimental evidence available for testing nucleation theory is critically examined. The principal relationships for diffusional growth are next deduced. The structure of interphase boundaries is considered both theoretically and experimentally and its influence upon growth kinetics is demonstrated through comparisons of calculated and measured growth kinetics in model alloy systems. 4 hrs. lec.

27-788 Defects in Materials
Fall: 6 units
This course addresses the fundamental properties of defects in crystalline solids, as well as their effects on properties and behavior of materials. Primary attention is devoted to point and line defects. Somewhat less comprehensive coverage is given to extended defects, including grain boundaries, interphase boundaries and surfaces. 4 hrs. lec.

27-791 Mechanical Behavior of Materials
Spring: 12 units
The intent of the course is to introduce various measures indicative of the performance of materials in applications. Properties often used in selecting materials will be introduced, and connections between these properties and microstructure will be developed. Mechanical properties are emphasized in this course. 4 hrs. lec.

27-792 Solidification Processing
Spring: 12 units
The goal of this course is to enable the student to solve practical solidification processing problems through the application of solidification theory. The objectives of this course are to: (1) Develop solidification theory so that the student can understand predict solidification structure; (2) Develop a strong understanding of the role of heat transfer in castings; (3) Develop an appreciation for the strengths and weaknesses of a variety of casting processes. The first half of the course will be theoretical, covering nucleation, growth, instability, solidification microstructure: cells, dendrites, eutectic and peritectic structures, solute redistribution, inclusion formation and separation, defects and heat transfer problems. The second part of the course will be process oriented and will include conventional and near net shape casting, investment casting, rapid solidification and spray casting where the emphasis will be on process design to avoid defects.

27-795 TBA
Intermittent: 12 units
This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

Course Website: http://materials.cmu.edu

27-796 Structure of Materials
6 units
The skills and ideas necessary to understand the atomic structure of crystalline materials are presented. The objective is for the student to be able to describe crystal structures based on their symmetry (Bravais lattices, point groups and space groups)as well as packing configurations and to understand how diffraction is used to experimentally probe crystal structures.

27-797 Bonding of Materials
6 units
Models for cohesive forces in crystals are reviewed; both quantitative and phenomenological descriptions of secondary, ionic, metallic, and covalent bonds are discussed. A band structure language is developed starting from free electron and LCAO models of metals and covalently bonded crystals, respectively. 4 hrs lecture
Prerequisites: 33-225 or 33-234

27-798 Thermodynamics I
Fall: 6 units
The laws, concepts, and definitions of classical thermodynamics as well as selected relationships that matter exhibits will be covered and applied to gas, liquid and crystalline systems. Concepts and classifications of thermodynamic systems, variables and relationships will be presented and discussed. General criteria and conditions for equilibrium will be developed and applied. The basic concepts of statistical thermodynamics will be introduced and applied to the interpretation of entropy. Phase equilibria of unary systems and the nature of real gases will be explored.

27-799 Thermodynamics II
Fall: 6 units
The course will apply thermodynamic fundamentals covered in Thermodynamics I (27-798) to multi-component materials systems. The course will also cover equilibrium phase diagrams (binary and ternary), predominance diagrams, chemical reactions, thermodynamics of surfaces and electrochemistry.

27-991 Materials Science and Engineering Teaching Internship
Fall and Spring
Students enrolled in the MSE Ph.D. program are required to complete at least 12 units of a teaching internship at some time between their third and seventh semesters. Students should discuss the appropriate time to apply for and fulfill this requirement with their advisor. The requirements and units will vary depending on the instructor and class and might vary from directing labs experiments, grading, holding office hours or recitations, background research, preparing course demos, or giving guest lectures. The class instructor will also assign the teaching intern's grade. Students will apply for internships before each semester; the department Head will make the course assignments before the start of each semester. No more than 24 units of 27-991 can count toward the coursework requirement of the Ph.D. program. Passing of the Research Performance Evaluation (RPE) is required in order to eligible.

Department of Mechanical Engineering

Allen Robinson, David and Susan Coulter Head of Mechanical Engineering and Raymond J. Lane Distinguished Professor of Mechanical Engineering

Location: Scaife Hall 401
www.cmu.edu/me

General Overview

Mechanical engineers use their knowledge of mechanical systems to describe phenomena, propose solutions to problems, and build those solutions. Concerned with the principles of force, energy and motion, they use their knowledge of physical systems, design, manufacture, and operational processes to advance the world around us. Mechanical engineers work in a variety of sectors: small start-up companies, multi-national corporations, government agencies, national laboratories, consulting firms, and universities.

The Carnegie Mellon Mechanical Engineering curriculum emphasizes engineering theory, hands-on experience, and technical skills. Our students learn how to solve practical problems and analyze situations by converting ideas into reliable and cost-effective devices and processes.

A strong foundation in mechanical engineering fundamentals culminates in a design capstone class where student teams develop prototypes for new products. These projects expose students to the design process, from concept to product, and emphasize effective communication and presentations skills.

Our curriculum is intended to allow ample opportunity for students to pursue areas of personal interest. A student may choose to pursue a minor offered by departments in other colleges, or one of the designated minor programs offered in the College of Engineering, or to pursue an additional major. Students are encouraged to participate in research with department faculty members, explore their chosen field through internships, and take advantage of opportunities to study abroad and be exposed to other cultures. Students may also choose to pursue the Integrated Master's/Bachelor's Program (IMB) which allows students to earn both a bachelor's and a master's degree with an additional semester or year of study.

Mechanical Engineering students access TechSpark for hands-on projects in multiple courses. TechSpark is the cornerstone of the College of Engineering's maker ecosystem having an integrated set of resources where faculty and students create and develop new ideas, concepts, and products for technology innovation. The space houses a simulation cluster, 3D printers, laser machines, electronics stations, PCB fabrication, manual & CNC mills, metal welding, wood working & CNC Router, polymer composite fabrication, paint booth, and more to allow students, faculty, and staff to design and prototype in a multi-disciplinary environment.

Accreditation

The Mechanical Engineering Undergraduate Program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org (http://www.abet.org).

Educational Objectives

According to ABET (http://www.abet.org), which evaluates applied science, computing, engineering and technology programs for accreditation, "program educational objectives are broad statements that describe what graduates are expected to attain within a few years of graduation."

The core objective of our undergraduate program is to provide our students an education that enables them to be productive, impactful, and fulfilled professionals throughout their careers. In light of this vision, the objectives of the Bachelor of Science in Mechanical Engineering at Carnegie Mellon are to produce graduates who:

- distinguish themselves as effective problem solvers by applying fundamentals of Mechanical Engineering.
- are innovative and resourceful in their professional activities.
- excel in multidisciplinary team settings.
- become leaders in their organizations, their profession and in society.
- conduct themselves in a professional and ethical manner in the workplace
- excel in diverse career paths within and beyond the engineering profession, including in industry and academia.

Educational Outcomes

The undergraduate curriculum in the Department of Mechanical Engineering offers students significant opportunities to pursue directions of personal interest, including minors, double majors, participation in research projects, and study abroad. Design and teamwork experiences occur at regular intervals in the curriculum, and graduates have significant hands-on experience through laboratories and projects.

The faculty of the Department has endorsed the following set of skills, or outcomes that graduates of the program are expected to have:

- an ability to apply knowledge of mathematics, science, and engineering
- an ability to design and conduct experiments, as well as to analyze and interpret data
- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- an ability to function on multidisciplinary teams
- an ability to identify, formulate, and solve engineering problems
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a recognition of the need for, and an ability to engage in life-long learning
- a knowledge of contemporary issues
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Curriculum

Minimum units required for B.S. in Mechanical Engineering: 382

The following template outlines the four-year B.S. program through the standard and recommended course sequence. To ensure that prerequisites are completed and to prevent scheduling conflicts, students should discuss any changes to this sequence with their department academic advisor.

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
24-101	Fundamentals of Mechanical Engineering	12
33-141	Physics I for Engineering Students	12
99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
		46

Spring		Units
21-122	Integration and Approximation	10
xx-xxx	Second Introductory Engineering Course	12
xx-xxx	Physics II/Chemistry/Computer Science*	
xx-xxx	General Education Course	9
		31

Sophomore Year

Fall		Units
21-259	Calculus in Three Dimensions Students are encouraged to take 24-282 or 21-254 instead of 21-259. These courses will eventually replace the 21-259 requirement.	9
24-221	Thermodynamics I	10

24-261	Statics	10
xx-xxx	Physics II/Chemistry/Computer Science*	10-12
24-xxx	Machine Shop/Intro to CAD/ISC**	1-2
xx-xxx	Lab requirement ***	
xx-xxx	General Education Course	9
39-210	Experiential Learning I	0
		49-52

Spring		Units
21-260	Differential Equations	9
24-231	Fluid Mechanics	10
24-262	Stress Analysis To accommodate the new Introduction to Scientific Computing course in the curriculum and maintain the 382 minimum units, starting Spring 2020, 24-262 Stress Analysis will be a 10 unit course.	12
xx-xxx	Physics II/Chemistry/Computer Science*	10-12
24-xxx	Machine Shop/Intro to CAD/ISC**	1-2
xx-xxx	Lab requirement ***	
xx-xxx	General Education Course	9
39-220	Experiential Learning II	0
		51-54

* Physics II/Chemistry/Computer Science: Students should complete 15-110 (http://coursecatalog.web.cmu.edu/search/?P=15-110) Principles of Computing OR 15-112 (http://coursecatalog.web.cmu.edu/search/?P=15-112) Fundamentals of Programming and Computer Science, as well as 33-142 (http://coursecatalog.web.cmu.edu/search/?P=33-142) Physics II for Engineering and Physics Students by the end of their Sophomore year. The recommended Physics sequence is 33-141 (http://coursecatalog.web.cmu.edu/search/?P=33-141) / 33-142 (http://coursecatalog.web.cmu.edu/search/?P=33-142) for engineering students, however, 33-151 (http://coursecatalog.web.cmu.edu/search/?P=33-151) / 33-152 (http://coursecatalog.web.cmu.edu/search/?P=33-152) will also meet the CIT Physics requirement. The Chemistry requirement is filled with 09-105.

** Machine Shop 24-200, Introduction to CAD 24-202, and Introduction to Scientific Computing 24-281 should be completed by the end of sophomore year. If students take 24-282 Special Topics: Linear Algebra and Vector Calculus for Engineers or 21-254 (to be offered starting Spring 2020), the 24-281 requirement is waived because it will be incorporated into these classes.

*** Mechanical engineering undergraduates must satisfy a Science Laboratory requirement to graduate. The lab requirement may be fulfilled with one of the following courses:

09-101	Introduction to Experimental Chemistry	3
42-203	Biomedical Engineering Laboratory	9
03-124	Modern Biology Laboratory	9
33-100	Basic Experimental Physics	6
33-104	Experimental Physics	9

Junior Year

Fall		Units
24-302	Mechanical Engineering Seminar I - taken either fall or spring	2
24-322	Heat Transfer	10
24-370	Engineering Design I: Methods and Skills	12
24-351	Dynamics	10
36-220	Engineering Statistics and Quality Control Students are encouraged to take 19-250 or 36-225 instead of 36-220 to meet the engineering statistics requirement. 36-217 will also count for the statistics requirement.	9
xx-xxx	General Education Course	9
39-310	Experiential Learning III	0
		52

Spring		Units
24-321	Thermal-Fluids Experimentation	12
24-311	Numerical Methods	12
24-352	Dynamic Systems and Controls	12
xx-xxx	General Education Course	9
		45

Senior Year

Fall		Units
24-441	Engineering Design II: Conceptualization and Realization - required either fall or spring; alternate with xx-xxx 9 unit elective	12
or 24-671	Special Topics: Electromechanical Systems Design	
BME and Robotics Double Majors may use the capstone for their double major instead of the above listed MechE capstone design classes		
24-452	Mechanical Systems Experimentation	9
xx-xxx	Elective	9
xx-xxx	Elective	9
xx-xxx	General Education Course	9
		48

Spring		Units
24-441	Engineering Design II: Conceptualization and Realization - required either fall or spring; alternate with xx-xxx 9 unit elective. Or 24-631 Thermal Design, offered Spring ONLY.	12
or 24-671	Special Topics: Electromechanical Systems Design	
BME and Robotics Double Majors may use the capstone for their double major instead of the above listed MechE capstone design classes		
24-xxx	Mechanical Engineering Technical Elective	9-12
xx-xxx	Elective	9
xx-xxx	Elective	9
xx-xxx	General Education Course	9
		48-51

Notes on the Curriculum

1. Students need a minimum of 382 units to complete the B.S. degree
2. During the first year, students complete 24-101 Fundamentals of Mechanical Engineering and another introductory engineering course. Students who do not take 24-101 during their first year should take 24-101 Fundamentals of Mechanical Engineering during the fall semester of their sophomore year in place of the General Education Course. They can then replace that General Education Course in their junior or senior year.
3. Students must pass the following three courses before they begin the core Mechanical Engineering courses in the fall of their sophomore year:
   - 21-120 Differential and Integral Calculus
   - 21-122 Integration and Approximation
   - 33-141 Physics I for Engineering Students*
4. All Mathematics courses (21-xxx) required for the engineering degree must have a minimum grade of C in order to fulfill the graduation requirement for the BS engineering degree and to count as a prerequisite for engineering core classes. Students who substitute 24-282 Special Topics: Linear Algebra and Vector Calculus for Engineers for 21-259 are also required to have a minimum grade of C to fulfill this math requirement.
5. Students are required to complete an engineering statistics course. The department strongly encourages students to take ***19-250*** or 36-225 instead of36-220, which may be scheduled in any semester. Students may also take 36-217 to fulfill this requirement.
6. The presentation skills requirement can be satisfied by completing one of the following options: 24-302 Mechanical Engineering Seminar I, 76-270 Writing for the Professions, 70-340 Business Communications
7. To fulfill the capstone design requirement, students must take either 24-441 Engineering Design II: Conceptualization and Realization or 24-671 Special Topics: Electromechanical Systems Design or ***24-631*** (spring only, starting Spring 2020). Students may take 24-441 or 24-671 in either fall or spring of senior year. BME and Robotics double majors/minors may use the capstone for their double major/minor instead of the above listed MechE capstone design classes.

Mechanical Engineering Technical Electives

Students must take at least one approved non-core Mechanical Engineering course labeled as “Mechanical Engineering Technical Elective” in the example course sequence. The course must be an approved 24-xxx course

(9-unit minimum) at the 300 level or above to fulfill the technical elective requirement. 24-292 Renewable Energy Engineering is the only 200 level course that may be used as a Mechanical Engineering Technical Elective.

Students can also take mechanical engineering graduate courses to fulfill the technical elective requirement. However, students must have the appropriate prerequisites and the instructor must approve taking the course. Undergraduates do not have priority for graduate level courses. Students can find a list of graduate courses we offer on the Carnegie Mellon Schedule of Classes https://enr-apps.as.cmu.edu/open/SOC/SOCServlet

Course offerings are variable, please check the Schedule of Classes (above) to see the most current list of classes.

Students cannot use research or project courses to fulfill the technical elective requirement. However, these courses, with limitations, will count as free elective units. Up to 27 units of project/research may be counted in the free electives. Project/research courses that do not fulfill the technical elective requirements are:

- 24-391/ 24-392 Mechanical Engineering Project
- 24-491/ 24-492 Department Research Honors
- 39-xxx CIT series courses

Free Electives

A Free Elective is defined as any graded course offered by any academic unit of the university (including research institutes such as the Robotics Institute (http://www.ri.cmu.edu) and the Software Engineering Institute (http://www.sei.cmu.edu)). Free electives offer students the opportunity to add additional majors and minors, pursue additional interests or deepen their experience in Mechanical Engineering. Typically, once the core requirements are completed, there remain about 45 units of free electives to reach the minimum of 382 to complete the degree.

Up to 9 units of Student Taught Courses (StuCO) and Physical Education courses, or other courses taken as Pass/Fail, may also be used toward Free Electives.

Quality Point Average Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.00 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. The Mechanical Engineering Department requires that students attain a quality point average of 2.00 or higher for all required Mechanical Engineering core courses.

Pursuant to university rules, students can repeat a course in which a grade below C was attained in order to achieve the QPA requirement. When a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. For all required Mechanical Engineering core courses, the highest grade obtained between the original and the repeated class will be used to calculate the Mechanical Engineering OPA.

Credit Overload Policy

Mechanical Engineering students can register for a maximum of 54 units per semester. A student can request additional units from the Undergraduate Education Committee based on their QPA. The policy is outlined in the Mechanical Engineering Undergraduate Handbook at www.meche.engineering.cmu.edu/_files/documents/handbooks/ug-handbook19.pdf

Double Majors and Minors

Mechanical Engineering students may pursue double majors and minors in a variety of subjects, taking advantage of the free elective courses to satisfy the requirements for the major or minor. The College of Engineering has added designated minors to promote flexibility and diversity among engineering students. Common double majors for Mechanical Engineering students include Engineering and Public Policy, Biomedical Engineering and Robotics.

A complete description of majors and minors in engineering can be found on the College of Engineering website (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/majors-minors.html).

Internships and Co-operative Education Program

The Mechanical Engineering Department considers experiential learning opportunities important educational options for its undergraduate students. Students in Mechanical Engineering are encouraged to undertake professional internships during summer breaks.

Another option is cooperative education, which provides a student with an extended period of exposure with a company. All co-ops must be at least 6 consecutive months in length, and must be a full-time, paid position with a single company.

Study Abroad

In today’s global society, a study abroad experience can be an integral part of an undergraduate engineering education. An academic experience abroad is encouraged and assistance is provided for course choices and curriculum sequencing.

Integrated Master's/Bachelor's Program (IMB)

Interested undergraduates may plan a course of study that leads to both the Bachelor's and Master's in Mechanical Engineering. Beyond eight semesters, at least one semester of full-time graduate student status is required. Please refer to the Integrated Master’s/Bachelor’s Degree Program section in the Graduate Handbook for 2019-2020 (https://www.meche.engineering.cmu.edu/education/graduate-programs/handbooks.html) for additional information.

Full-Time Faculty

AMIR BARATI FARIMANI, Assistant Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2018–

MARK BEDILLION, Associate Teaching Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016–

SARAH BERGBREITER, Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2018–

JACK LEE BEUTH, Professor of Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1992–

JONATHAN CAGAN, Interim Dean of the College of Engineering; George Tallman and Florence Barrett Ladd Professor of Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1990–

MAARTEN P. DE BOER, Professor of Mechanical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2007–

NESTOR GOMEZ, Visiting Assistant Teaching Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–

DIANA HAIDAR, Assistant Teaching Professor of Mechanical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 2017–

ENI HALILAJ, Assistant Professor of Mechanical Engineering – Ph.D., Brown University; Carnegie Mellon, 2018–

B. REEJA JAYAN, Assistant Professor of Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2015–

AARON M. JOHNSON, Assistant Professor of Mechanical Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2016–

LEVENT BURAK KARA, Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2007–

PHILIP R. LEDUC, William J. Brown Professor of Mechanical Engineering – Ph.D., The Johns Hopkins University; Carnegie Mellon, 2002–

SHAWN LITSTER, Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2008–

CARMEL MAJIDI, Associate Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2011–

JONATHAN A. MALEN, Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2009–

ALAN J.H. MCGAUGHEY, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

JEREMY J. MICHALEK, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

O. BURAK OZDOGANLAR, Ver Planck Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–

RAHUL PANAT, Associate Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2017–

ALBERT PRESTO, Associate Research Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2012-–

YOED RABIN, Professor of Mechanical Engineering – D.Sc., Technion-Israel Institute of Technology; Carnegie Mellon, 2000–

ALLEN L. ROBINSON, David and Susan Coulter Head of Mechanical Engineering; Raymond J. Lane Distinguished Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1998–

EDWARD STEPHEN RUBIN, Alumni Chair Professor of Environmental Engineering and Science – Ph.D., Stanford University; Carnegie Mellon, 1969–

SHENG SHEN, Associate Professor of Mechanical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2011–

KENJI SHIMADA, Theodore Ahrens Professor of Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1996–

SATBIR SINGH, Associate Teaching Professor of Mechanical Engineering – Ph.D., University of Wisconsin at Madison; Carnegie Mellon, 2012–

PAUL S. STEIF, Associate Department Head and Professor of Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1983–

RYAN SULLIVAN, Associate Professor of Mechanical Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 2012–

REBECCA TAYLOR, Assistant Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2016–

CONRAD TUCKER, Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2019–

VENKAT VISWANATHAN, Associate Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2014–

VICTORIA WEBSTER-WOOD, Assistant Professor of Mechanical Engineering – Ph.D., Case Western Reserve University; Carnegie Mellon, 2018–

KATE S. WHITEFOOT, Assistant Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2016–

YONGJIE ZHANG, Professor of Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2007–

DING ZHAO, Assistant Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2018–

Emeriti

ADNAN AKAY, Lord Emeritus Professor of Mechanical Engineering – Ph.D., North Carolina State University; Carnegie Mellon, 1992–

NORMAN CHIGIER, Emeritus Professor of Mechanical Engineering – Sc.D., University of Cambridge; Carnegie Mellon, 1981–

JERRY HOWARD GRIFFIN, William J. Brown Emeritus Professor of Mechanical Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 1981–

WILFRED THOMAS ROULEAU, Emeritus Professor of Mechanical Engineering – Ph.D., Carnegie Institute of Technology; Carnegie Mellon, 1954–

SHI-CHUNE YAO, Emeritus Professor of Mechanical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1977–

Department of Mechanical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

24-050 Study Abroad
Fall
No course description provided.

24-101 Fundamentals of Mechanical Engineering
Fall and Spring: 12 units
The purpose of this course is to introduce the student to the field of mechanical engineering through an exposition of its disciplines, including structural analysis, mechanism design, fluid flows, and thermal systems. By using principles and methods of analysis developed in lectures, students will complete two major projects. These projects will begin with conceptualization, proceed with the analysis of candidate designs, and culminate in the construction and testing of a prototype. The creative process will be encouraged throughout. The course is intended primarily for CIT freshmen. 3 hrs. lec., 2 hrs. rec./lab.

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-104 Maker Series I: Intro to Modern Making
Fall and Spring: 3 units
The course familiarizes students with the safe operation of fabrication tools, including 3D printer, laser cutter, hand tools and power tools through structured activities. Included as preparation for modern making, a significant portion of the course is dedicated to learning the use of SolidWorks 3D CAD software. The acquisition of these skills culminates in the development and fabrication of a prototype solution to a real-world problem.

Course Website: http://www.cmu.edu/me

24-105 Special Topics: Maker Series: Intro to Laser Cutting & Engraving
Fall and Spring: 1 unit
This course teaches the safe operation of the laser cutter-engraver machine through structured hands-on activities. A significant portion of this course is dedicated to learning joinery, color mapping, and material selection for prototyping. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects. 1-unit micro (2-weeks)

24-200 Machine Shop Practice
Fall and Spring: 1 unit
24-200 Machine Shop Practices Fall and Spring Semesters, 1 units, 6 week mini course This course familiarizes students with the operation and safety of machine tools. This gives students knowledge of what goes into engineering designs in building a prototype and also enables them to operate shop machinery as a part of future courses. Prerequisite: Undergraduate Mechanical Engineering standing 2 hours lab Machine Shop Practices should be completed prior to Design II 24-441.

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-202 Introduction to Computer Aided Design
Fall and Spring: 1 unit
Introduction to computer aided mechanical design using SolidWorks 3D CAD software. Includes the creation and analysis of components and assemblies, generation of drawings, and exporting for manufacture. Two hours of guided computer lab work each week. Prerequisite: Undergraduate Mechanical Engineering standing

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-203 Special Topics: Maker Series: Intro to Manual & CNC Machining
Fall and Spring: 3 units
This course teaches safe operation of manual and CNC machining equipment. A focus of this course will be developing design-build skills for prototyping. A significant portion of the course is dedicated to learning CAM programming and PCB design software for rapid fabrication of 2D and 3D parts. The skills learned in this course can be applied to quickly fabricate durable components for design projects, research equipment, and extracurricular activities.

24-205 Special Topics: Maker Series: Intro to Welding
Fall and Spring: 1 unit
This course teaches the safe operation of MIG welding equipment through structured hands-on activities. A significant portion of the course is dedicated to learning workpiece setup, material selection, and quality assessment for building structures. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects. 1-unit micro (2-weeks)

24-206 Special Topics: Maker Series: Intro to Wood Working
Fall and Spring: 1 unit
This course teaches the safe operation of wood working equipment, including table saw, panel saw, and miter saw through structured hands-on activities. A significant portion of the course is dedicated to learning optimal workflow, tool selection, and equipment selection for building structures. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects. 1-unit micro (2-weeks)

24-207 Special Topics: Maker Series: Intro to CNC Router
Fall and Spring: 1 unit
This course teaches the safe operation of a CNC router machine through structured hands-on activities. A significant portion of the course is dedicated to software for fabrication of 2D and 3D parts. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects. 1-unit micro (2-weeks)

24-212 Special Topics: Maker Series: Make It Move
Fall and Spring: 9 units
This course explores many types of mechanisms for movement and their optimal applications. A significant portion of class will be dedicated to hands-on labs, during which objects are dissected to reveal their methods of movement. Springs, gears, motors, pneumatics, levers, wheels, bearings, and other components will be analyzed for their roles in energy storage, power delivery, and motion. These lessons will culminate in a complete design project, for which students will use rapid fabrication equipment to make a prototype that moves.
Prerequisites: 24-104 or 24-101

Course Website: https://www.meche.engineering.cmu.edu/

24-213 Special Topics: Citizen Science: Sensors, Makers and the Environment
Spring: 9 units
This course will introduce students to technical aspects of citizen science, using air pollution as a case study. Students will learn about important air pollutants and the environmental regulations that govern these pollutants in the U.S. Students will be introduced to data quality requirements for applications ranging from regulatory pollutant monitoring to education/outreach. Students will also learn about operating principles for both laboratory- and consumer-grade pollutant monitoring equipment. The class will culminate in a project where student teams will design, construct, and test a low-cost air pollutant monitoring system. The groups will then deploy these sensor packages to collect and present their data. The project will use the TechSpark maker space. It is primarily aimed at non-engineering majors.

24-221 Thermodynamics I
Fall: 10 units
Temperature and thermometry; equations of state for fluids and solids; work, heat, and the first law; internal energy, enthalpy, and specific heats; energy equations for flow; change of phase; the second law, reversibility, absolute temperature, and entropy; combined first and second laws; availability; power and refrigeration cycles. Applications to a wide range of processes and devices. 3 hrs. lec., 1 hour recitation
Prerequisites: (33-121 or 33-151 or 33-141 or 33-106) and 21-122 Min. grade C and 24-101

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-231 Fluid Mechanics
Spring: 10 units
Hydrostatics. Control volume concepts of mass, momentum, and energy conservation. Euler's and Bernoulli's equations. Viscous flow equations. Head loss in ducts and piping systems. Dimensional analysis and similitude as an engineering tool. Measurement techniques. 3 hrs. lec., 1 hr. rec.
Prerequisites: (33-141 or 33-106 or 33-151) and 21-122 Min. grade C

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-261 Statics
Fall: 10 units
This course is the first in a two-semester sequence on the solid mechanics of engineering structures and machines. The course begins with a review of the statics of rigid bodies, which includes the identification of statically indeterminate problems. Two- and three-dimensional statics problems are treated. Thereafter, the course studies stresses and deflections in deformable components. In turn, the topics covered are: simple tension, compression, and shear; thin-walled pressure vessels; torsion; and bending of beams. For each topic, statically indeterminate problems are analyzed and elementary considerations of strength are introduced. 3 hrs. lec., 1 hr. rec./lab.
Prerequisites: 21-122 Min. grade C and (33-151 or 33-141 or 33-106 or 33-121)

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-262 Stress Analysis
Spring: 12 units
This course is the second in a two-semester sequence on the solid mechanics of engineering structures and machines. The basic topics of uniaxial tension/compression, torsion, and flexural deformation from 24-261 are reviewed. Combined loadings and stresses are then treated, which lead to a consideration of failure criteria. Two-dimensional elasticity and the finite element method are introduced. Stress concentrations are quantified analytically, numerically, and with the use of engineering handbooks. Cyclic failure criteria are introduced, and both static and cyclic failure criteria are applied to results from numerical analysis. 3 hrs. lec., 1 hr. rec./lab.
Prerequisites: (33-141 or 33-151 or 33-106) and 24-261

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-280 Special Topics: C++ Programming for Engineers
Fall and Spring: 9 units
Using the C++ programming language as a platform, this course serves as an intermediate-level programming course with a strong emphasis on software requirements for engineering applications. Students will refine and enhance their coding skills while applying their mathematical, analytical and design backgrounds. Topics covered include data structures, algorithm design, numerical computation, modular programming, data modeling, interactive graphics, object-orientation, and user interfaces, all in an engineering-specific domain.
Prerequisites: 15-110 or 15-112

Course Website: http://www.cmu.edu/me

24-281 Introduction to Scientific Computing
Fall and Spring: 2 units
This course provides an introduction to scientific computing with Matlab for engineers. The course introduces the basics of Matlab syntax and programming, data analysis, visualization, curve fitting and interpolation, symbolic computation, differential equations, and debugging. The use of Matlab in solving mechanical engineering applications will be demonstrated.

Course Website: https://www.meche.engineering.cmu.edu/

24-282 Special Topics: Linear Algebra and Vector Calculus for Engineers
Fall and Spring: 11 units
This course will introduce the fundamentals of vector calculus and linear algebra. The topics include vector and matrix operations, determinants, linear systems, matrix eigenvalue problems, vector differential calculus including gradient, divergence, curl, and vector integral calculus including integral theorems. Lecture and assignments will emphasize the applications of these topics to engineering problems. The content covered in 24-281 Introduction to Scientific Computing will be a part of this course. Student evaluation will include weekly homework assignments (requiring both written answers as well as Matlab scripts), two midterms and a final exam.
Prerequisite: 21-122

24-292 Renewable Energy Engineering
Intermittent: 9 units
Introduction to engineering principles of various renewable energy systems, including the following topics: background on climate change and carbon sequestration, engineering analysis of renewable energy systems such as solar photovoltaic, (solar thermal), wind power, hydropower, wave energy, bio mass energy, geothermal energy, and hydrogen based fuel cells. In addition, transitional energy systems such as nuclear power and advanced combined cycles will be introduced. Both engineering performance and present state of development will be discussed. Students will review and present their progress on various subjects, which will be selected based on personal interest.
Prerequisites: 33-106 or 33-141

Course Website: http://www.andrew.cmu.edu/user/satbirs/24292/

24-300 Fundamentals of CNC Machining
Fall and Spring: 1 unit
This course expands upon basic machining principles gained in 24-200 to translate into automated machining. Topics covered include advanced fixturing, CAM programming using Mastercam X7 to produce toolpaths for automated machining and set up and operation of 3 axis vertical CNC machining centers. This course will focus on the programming of these machine tools using geometry from CAD data. Students learn in this course how to do part orientation, plan operation ordering, tool selection, speeds and feeds, cut verification, and to assign all of the above to a specific geometry in the CAD model. Both 2½D and 3D machining will be practiced. 24-200 Machine Shop Practice is a pre-requisite for this course.
Prerequisite: 24-200

24-302 Mechanical Engineering Seminar I
Fall and Spring: 2 units
The purpose of this course is to help students develop good presentation skills and to provide a forum for presentations and discussions of professional ethics. Students will make at least two presentations, one of which is related to professional ethics. Student grades will be based on their presentation skills and their participation in class discussions. 1 hr. rec.
Prerequisites: Junior standing or permission of instructor

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-311 Numerical Methods
Spring: 12 units
Use of numerical methods for solving engineering problems with the aid of a digital computer. The course will contain numerical methods such as roots of equations, linear algebraic equations, optimization, curve fitting, integration, and differential equation solving. MATLAB will be used as the programming language. Programming cluster laboratory times will be available twice a week. Problems will be drawn from all fields of interest to mechanical engineers. 3 hrs. lecture plus lab
Prerequisite: 21-260

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-321 Thermal-Fluids Experimentation
Spring: 12 units
24-321 Thermal-Fluids Experimentation Spring: 12 units This is a capstone course for the thermal-fluids core-course sequence. This course covers techniques of measurement, uncertainty analysis, and realization of systems, which demonstrate fundamental principles in thermodynamics, fluid mechanics, and heat transfer. The principles of designing thermal experiments are also integrated into this course.
Prerequisites: 24-221 and 24-231 and 24-322

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-322 Heat Transfer
Fall: 10 units
Introduction to basic concepts of engineering heat transfer. Steady and transient heat conduction in solids, including the effect of heat generation. Finned surfaces. Correlation formulas for forced and free convection, condensation, and boiling. Design and analysis of heat exchangers. Radiation heat transfer. Problems in combined convection and radiation. Measurement techniques. 3 hrs. lec., 1 hr. recitation.
Prerequisites: 21-260 Min. grade C and 24-231 and 24-221

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-334 Introduction to Biomechanics
Fall: 9 units
This course covers the application of solid and fluid mechanics to living tissues. This includes the mechanical properties and behavior of individual cells, the heart, blood vessels, the lungs, bone, muscle and connective tissues as well as methods for the analysis of human motion.
Prerequisite: 24-231

Course Website: http://www.cmu.edu/me/

24-341 Manufacturing Sciences
Spring: 9 units
This course has two broad concerns: an introductory review of manufacturing systems organization and a review of common manufacturing processes from the point of view of design for manufacturability. The features of mass and batch production are quantitatively considered. The basic principles of group technology and production planning are outlined. The use of computers in manufacturing is described, together with a review of the current capabilities of industrial robots. Students will be involved in weekly seminars, which will describe the basic features of common manufacturing processes, including metal machining, metal forming, polymer processing, casting techniques, joining techniques, ceramic processing, and powder processing. Case studies from industry and films may be used. 3 hrs. rec.
Prerequisite: 24-262

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-351 Dynamics
Fall: 10 units
This first course on the modeling and analysis of dynamic systems concentrates on the motion of particles, systems of particles, and rigid bodies under the action of forces and moments. Topics include the kinematics of motion in rectangular, polar, and intrinsic coordinates; relative motion analysis with multiple reference frames; and planar kinetics through the second law, work-energy method, and impulse-momentum method. Time and frequency domain solutions to first and second order equations of motion are discussed. 3 hrs. lec. 1 hr rec.
Prerequisite: 24-261

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-352 Dynamic Systems and Controls
Spring: 12 units
This second course on the modeling and analysis of dynamic systems emphasizes the common features, which are exhibited by physical systems that include mechanical, hydraulic, pneumatic, thermal, electrical, and electromechanical elements. State equations and the concepts of equilibrium, linearization, and stability are discussed. Time and frequency domain solutions are developed. 4 hr. lec.
Prerequisites: (24-261 and 33-107 and 21-260) or (21-260 and 33-142 and 24-261) or (24-261 and 21-260 and 33-152) or (21-260 and 24-261 and 33-132)

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-354 Gadgetry: Sensors, Actuators, and Processors
Fall and Spring: 9 units
This course will introduce the components used in mechatronic design. Topics include microcontrollers, circuit design and analysis, and sensors and actuators commonly used in mechatronic systems. The course will contain a substantial hands-on component in which students will program microcontrollers to read sensors and drive actuators. This course will be a pre-requisite for an anticipated version of Design II focusing on Mechatronic Design, to be first offered in Fall 2017.
Prerequisites: (15-112 or 15-110) and (33-152 or 33-107 or 33-142)

Course Website: http://www.cmu.edu/me/

24-358 Special Topics in Culinary Mechanics
Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence food and the culinary arts. The aim of the course is to apply important aspects of mechanics to ideas in cooking. Specific topics include: (1) how do stress and strain affect food and its perceived taste; (2) what is the role of cell mechanics in the resulting micro structure of both consumed plant and animal tissues; (3) how can mechanics be used to alter nutrition; (4) what are the roles of common and uncommon mechanical tools such as a knife or mortar and pestle in food preparation. Emphasis will be placed on the biomechanics of edible matter across multiple length scales, including at the tissue, cellular, and molecular levels; additionally, impact on global health and engineering implications will be elucidated. During this course, we will introduce you to these concepts,train you to use them in real world applications, and allow you to pursue a creative group-defined project, which will be shared in both written and oral formats. We will integrate a hands-on kitchen experience in at least 3 specific laboratory classes so that students will get a true feel and understanding for culinary mechanics. We also will be visiting the restaurant of at least one first-rate Pittsburgh chef to gain real world insight into mechanics and cooking.

Course Website: http://www.cmu.edu/me/

24-370 Engineering Design I: Methods and Skills
Fall: 12 units
In this course, students will learn methods and skills for the engineering design process, consisting of four stages: concept design, detail design, analysis, and manufacturing. The course covers the engineering design process in a holistic fashion by discussing theories and practices of the four stages and inter-relating them. Hands-on assignments, including computational and physical projects, are given to enhance the learning outcome. After taking this course, students will be able to: express ideas in sketches; interpret and create engineering drawings; select and apply machine elements; model detailed shapes with CAD tools; analyze product performance with CAE tools; choose materials and manufacturing schemes, and create and test prototypes. Recommended: 24-200 (machine shop practice).
Prerequisites: 24-202 Min. grade C and 24-262

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-371 Special Topics: Design of Machine Elements
Spring: 9 units
In this class, the students will gain an understanding of the best practices in the design of machine elements such as shafts, gears, power screws, fasteners, brakes/couplings, flywheels, bearings, etc. The course material consists of the study of stress and deflection under common loading conditions, effect of material properties, static and fatigue failure models, cost considerations, and manufacturability in the context of the machine components. Student learning will be achieved through interactive lectures on underlying technical approaches in conjunction with a group project where students will be required to design and fabricate an ensemble of machine elements. Students will also learn about the strong connections between theory, analytical methods, available computational tools, and field design. Assessment of the learning objectives will happen via homework, class exams, and demonstration of the group project. This course builds upon the skills and methods taught in Design-I (24-370) and will help students prepare to enter the modern workplace where mechanical design takes place.
Prerequisite: 24-370

24-391 Mechanical Engineering Project
Fall and Spring
Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work. 9 hrs. lab.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html

24-392 Mechanical Engineering Project
All Semesters
Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html

24-421 Internal Combustion Engines
Fall: 12 units
This course discusses working principles of internal combustion engines found in many practical applications. Focus is given to understanding the design of air handing system, in-cylinder fuel/air mixing, geometric design of the combustion chamber, engine performance and calibration, and mechanism of pollutant formation and reduction. Introductory discussion of advanced automotive engine concepts, alternative fuels, gas turbine engines, rocket engines, and hybrid electric vehicles is also provided. The course relies on a number of lab experiments, analysis of actual experimental data, and a combination of analytical and numerical homework assignments. 3 hrs. lecture 2 hrs. lab
Prerequisites: 24-221 and 24-231

Course Website: http://www.andrew.cmu.edu/user/satbirs/24421/

24-424 Energy and the Environment
Fall: 9 units
Fuel cycles for conventional and non-conventional energy resources; relationships between environmental impacts and the conversion or utilization of energy; measures of system and process efficiency; detailed study and analysis of coal-based energy systems including conventional and advanced power generation, synthetic fuels production, and industrial processes; technological options for multi-media (air, water, land) pollution control; mathematical modeling of energy-environmental interactions and tradeoffs and their dependency on technical and policy parameters; methodologies for energy and environmental forecasting; applications to issues of current interest. Junior or Senior standing in CIT or permission of instructor. 3 hrs lecture

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-425 Combustion and Air Pollution Control
Intermittent: 9 units
Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and post-combustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples. 3 hours lecture Cross listed as 24-740 and 19440/19-740

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-441 Engineering Design II: Conceptualization and Realization
Fall and Spring: 12 units
Conceptualization and Realization Fall and Spring 12 units. This course guides students through the design process in the applied design of a practical mechanical system. Lectures describe the typical design process and its associated activities, emphasizing methods for innovation and tools for design analysis. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is typically completed in teams and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation. Frequently, a working model will also be required. Oral progress reports and a final written and oral report are required. 3 hrs. rec., 3 hrs lab Senior standing and Machine Shop Practice 24-200 required.
Prerequisites: 24-262 and 24-370

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-451 Feedback Control Systems
Fall: 12 units
Fundamentals of feedback control with emphasis on classical techniques and an introduction to discrete-time (computer controlled) systems. Topics include the following: frequency domain modeling and state space modeling of dynamical systems; feedback control system concepts and components; control system performance specifications such as stability, transient response, and steady state error; analytical and graphical methods for analysis and design - root locus, Bode plot, Nyquist criterion; design and implementation of proportional, proportional-derivative, proportional-integral-derivative, lead, lag, and lead-lag controllers. Extensive use of computer aided analysis and design software. 4 hrs lec.
Prerequisites: (15-110 or 15-112) and 24-352

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-452 Mechanical Systems Experimentation
Fall: 9 units
Experimentation in dynamic systems and controls. The course will cover translational and rotational systems. Topics will include mechanical elements, natural frequencies, mode shapes, free and forced response, frequency response and Bode plots, time constants, transient response specifications, feedback controls such as PID control, and stability for single-degree-of-freedom and multi-degree-freedom systems. The course will introduce and use state-of-the-art experimentation hardware and software. 24-352 Dynamic Systems and Controls- prerequisite- MSE is a fall only senior course.
Prerequisite: 24-352

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-491 Department Research Honors
Fall and Spring
This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html

24-492 Department Research Honors
Fall and Spring
This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html

24-614 Microelectromechanical Systems
Intermittent: 12 units
This course introduces fabrication and design fundamentals for Microelectromechanical Systems (MEMS): on-chip sensor and actuator systems having micron-scale dimensions. Basic principles covered include microstructure fabrication, mechanics of silicon and thin-film materials, electrostatic force, capacitive motion detection, fluidic damping, piezoelectricity, piezoresistivity, and thermal micromechanics. Applications covered include pressure sensors, micromirror displays, accelerometers, and gas microsensors. Grades are based on exams and homework assignments.
Prerequisites: 18-321 or 24-351

Course Website: http://www.cmu.edu/me/graduate/index.html

24-623 Molecular Simulation of Materials
Spring: 12 units
The purpose of this course is to expose engineering students to the theory and implementation of numerical techniques for modeling atomic-level behavior. The main focus is on molecular dynamics and Monte Carlo simulations. Students will write their own simulation computer codes, and learn how to perform calculations in different thermodynamic ensembles. Consideration will be given to heat transfer, mass transfer, fluid mechanics, mechanics, and materials science applications. The course assumes some knowledge of thermodynamics and computer programming. 4 hrs lec.
Prerequisites: 24-311 and 24-221

Course Website: http://www.cmu.edu/me/graduate/index.html

24-626 Air Quality Engineering
Intermittent: 12 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines. 12 units
Prerequisites: 36-220 and 24-231 and 09-105

Course Website: http://www.cmu.edu/me/

24-628 Energy Transport and Conversion at the Nanoscale
Spring: 12 units
Energy transport and conversion processes occur at the nanoscale due to interactions between molecules, electrons, phonons, and photons. Understanding these processes is critical to the design of heat transfer equipment, thermoelectric materials, electronics, light emitting diodes, and photovoltaics. The objective of this course is to describe the science that underlies these processes and to introduce the contemporary experimental and theoretical tools used to understand them. The course includes a laboratory that gives the students experience with modern transport measurement instrumentation and data analysis. Integrated literature reviews and a final project require students to apply learned fundamentals to understand state-of-the-art research and technology. 4 hrs. lecture
Prerequisites- 24-322 & 24-221 or equivalents
Prerequisites: 24-221 and 24-322

Course Website: http://www.cmu.edu/me/graduate/index.html

24-629 Direct Solar and Thermal Energy Conversion
Intermittent: 12 units
This course introduces graduates and senior undergraduates the principles and technologies for directly converting heat and solar light into electricity using solid-state devices. The first part of the course reviews the fundamentals of quantum mechanics, solid state physics and semiconductor device physics for understanding solid-state energy conversion. The second part discusses the underlying principles of thermoelectric energy conversion, thermionic energy conversion, and photovoltaics. Various solar thermal technologies will be reviewed, followed by an introduction to the principles of solar thermophotovoltaics and solar thermoelectrics. Spectral control techniques which are critical for solar thermal systems will also be discussed. By applying the basic energy conversion theory and principles covered in lectures, students will finish a set of 4 homework assignments. This course also requires one project in which students will work individually to review one present solar or thermal energy conversion technology 12 units

Course Website: http://www.cmu.edu/me/

24-632 Special Topics: Additive Manufacturing Processing and Product Development
Fall: 12 units
Introduction to additive manufacturing (AM) processing fundamentals and applications using Solidworks 3-D CAD software and a variety of polymer and metal AM machines. Includes a brief history of AM processing, a review of and technical fundamentals of current AM processes, a study of the current AM market, and future directions of the technology. Lab Sessions will support an open-ended product development project. Lectures on metals AM will address current research impacting industry. Students will also perform a literature review of papers on the state of the art. Basic Solidworks knowledge required.

Course Website: http://www.cmu.edu/me/

24-633 Additive Manufacturing Laboratory
Spring: 12 units
Hands-on laboratory projects will teach students about all aspects of metals additive manufacturing (AM). Students will learn how to use SOLIDWORKS for part design, create and transfer design files to the AM machines, run the machines to build parts, perform post-processing operations, and characterize AM parts. Students will work in teams and complete three separate lab projects, each utilizing a different material system, part design, AM process/machine, post-processing steps and characterization methods. A major lab report and presentation will be required for each of the three lab projects. The course includes weekly lectures to complement the laboratory component. Priority for enrollment will be given to students who have declared the Additive Manufacturing Minor.
Prerequisites: 39-602 or 24-632 or 27-503 or 27-765 or 39-601

24-635 Structural Analysis
Fall: 9 units
Classical and matrix-based methods of structural analysis; energy principles in structural mechanics. Basic concepts of force and displacement methods for analyzing redundant structural systems. Matrix methods utilizing the flexibility (force) and stiffness (displacement) concepts.
Prerequisite: 24-262

24-640 Climate Change Mitigation
Intermittent: 12 units
Have you ever thought about how we could address the climate change problem? In this course we will study the technological and policy options for responding to the threat of climate change. We will review climate-change science, understand the current systems for energy supply and use, and have a deep dive onto technological solution for low-carbon energy supply and use, as well as the policy frameworks that can help us reduce greenhouse gas emissions. 2hrs 40min of lectures per week.

Course Website: http://www.cmu.edu/me/graduate/index.html

24-643 Special Topics: Energy Storage Materials and Systems
Intermittent: 12 units
Contemporary energy needs require large scale electrochemical energy conversion and storage systems. Batteries are playing a prominent role in portable electronics and electric vehicles. This course introduces principles and mathematical models of electrochemical energy conversion and storage. Students will study thermodynamics, reaction kinetics pertaining to electrochemical reactions, phase transformations relating to batteries. This course includes applications to batteries, fuel cells, supercapacitors

Course Website: http://www.andrew.cmu.edu/user/venkatv/24643/

24-655 Cellular Biomechanics
Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence cell behavior and function, with a focus on the connection between mechanics and biochemistry. Specific topics include: (1) the role of stresses in the cytoskeleton dynamics as related to cell growth, spreading, motility, and adhesion; (2) the generation of force and motion by moot molecules; (3) stretch-activated ion channels; (4) protein and DNA deformation; (5) mechanochemical coupling in signal transduction. If time permits, we will also cover protein trafficking and secretion and the effects of mechanical forces on gene expression. Emphasis is placed on the biomechanics issues at the cellular and molecular levels; their clinical and engineering implications are elucidated. 3 hrs. lec.
Prerequisite: Instructor permission.

Course Website: http://www.cmu.edu/me/graduate/index.html

24-658 Image-Based Computational Modeling and Analysis
Spring: 12 units
Image-based computational modeling and analysis play an important role in mathematical modeling and computer simulation of many physical and biological phenomena. This course integrates mechanical engineering, biomedical engineering, material sciences, computer science, and mathematics together. Topics to be studied include scanning techniques, image processing, geometric modeling, mesh generation, computational mechanics, as well as broad applications in biomedicine, material sciences and engineering. The techniques introduced are applied to examples of multi-scale modeling and simulations in various research fields.

Course Website: http://www.cmu.edu/me/graduate/index.html

24-671 Special Topics: Electromechanical Systems Design
Fall and Spring: 12 units
This course guides students through the design process as applied to mechatronic systems, which feature electrical, mechanical, and computational components. Lectures describe the typical design process and its associated activities, emphasizing methods for analyzing and prototyping mechatronic systems. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is team-based and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation and a working prototype system at the end of the course. Oral progress reports and a final written and oral report are required.
Prerequisites: (24-354 or 16-311) and 24-370 and 24-352

Course Website: http://www.cmu.edu/me/

24-672 Special Topics in DIY Design and Fabrication
Fall: 12 units
The traditional principles of mass production are being challenged by concepts of highly customized and personalized goods. A growing number of do-it-yourself (DIY) inventors, designers, makers, and entrepreneurs is accelerating this trend. This class offers students hands-on experience in DIY product design and fabrication processes. Over the course of the semester, students work individually or in small groups to design customized and personalized products of their own and build them using various DIY fabrication methods, including 3D laser scanning, 3D printing, laser cutting, molding, vacuum forming, etc. In addition to design and fabrication skills, the course teaches students skills for communicating their ideas effectively through industrial design sketches and presenting their products with aesthetically refined graphics.

Course Website: https://www.andrew.cmu.edu/course/24-672/

24-677 Special Topics: Linear Control Systems
Fall: 12 units
This course offers a practical introduction to the analysis and design of model-based control for linear systems. Topics include modeling and linearization of multi-input multi-output dynamic systems using the state-variable description, fundamentals of linear algebra (linear space, linear transformation, linear dynamics), analytical and numerical solutions of systems of linear time-invariant differential and difference equations, structural properties of linear dynamic physical systems (controllability, observability and stability), canonical realizations, and design of state feedforward/feedback, optimal, and stochastic controllers and observers (pole placement, LQR, MPC, Kalman filter approaches). Students will learn how to design linear controllers and implement them to solve real-world problems in control and robotics.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html

24-680 Quantitative Entrepreneurship: Analysis for New Technology Commercialization
Intermittent: 12 units
This course provides engineers with a multidisciplinary mathematical foundation for integrated modeling of engineering design and enterprise planning decisions in an uncertain, competitive market. Topics include economics in product design, manufacturing and operations modeling and accounting, consumer choice modeling, survey design, conjoint analysis, decision-tree analysis, optimization, model integration and interpretation, and professional communication skills. Students will apply theory and methods to a team project for a new product or emerging technology, developing a business plan to defend technical and economic competitiveness. This course assumes fluency with basic calculus, linear algebra, and probability theory.
Prerequisite: 21-259

24-681 Computer-Aided Design
Intermittent: 12 units
his course is the first section of the two-semester sequence on computational engineering. Students will learn how computation and information technologies are rapidly changing the way engineering design is practiced in industry. The course covers the theories and applications of the measurement, representation, modeling, and simulation of three-dimensional geometric data used in the engineering designed process. Students taking this course are assumed to have knowledge of the first course in computer programming. 4 hrs lecture, 2 hrs computer cluster

Course Website: http://www.andrew.cmu.edu/course/24-681/

24-683 Design for Manufacture and the Environment
Fall: 12 units
Design for Manufacturing and the Environment examines influences of manufacturing and other traditionally downstream issues on the overall design process. Manufacturing is one facet that will be examined. Other downstream influences that will be studied include: assembly, robustness and quality, platform design, maintenance and safety, economics and costing, lean manufacturing and globalization. In addition, a core part of the course will focus on environment-based design issues. The class will study basic fundamentals in each of these areas and how they affect design decisions. Prerequisites: Senior standing in mechanical engineering, or permission of instructor

Course Website: http://www.cmu.edu/me/graduate/index.html

24-686 Special Topics in Advanced Mechanical Design
Intermittent: 12 units
This course will build expert foundational knowledge in mechanical design. Students will perform a series of multi-week modules in which they design, fabricate, and test high-performance mechanical components or assemblies individually or in small teams. Interactive lectures and topic readings on underlying technical approaches will occur simultaneously, thereby drawing a strong connection between theory, analytical methods, computational tools, and experience-based intuition. Modules will address optimal structures for tensile, bending, buckling, and torsion conditions, fatigue life, mechanism design, fluid power system design, and optimization of dynamical system properties. This course builds on the skills and methods taught in 24-370, Engineering Design I, and students are recommended to first take 24-370 and its prerequisites or similar courses at their undergraduate institution. Priority will be given to students who have already passed 24-200 Machine Shop Practice.
Prerequisite: 24-370

Course Website: http://www.cmu.edu/me

24-711 Fluid Dynamics
Fall: 12 units
This course focuses on development and application of control volume forms of mass, momentum and energy conservation laws, differential forms of these laws in Eulerian and Lagrangian coordinates, and Navier-Stokes equations. Students also explore applications to problems in incompressible and compressible laminar flows, boundary layers, hydrodynamic lubrication, transient and periodic flows, thermal boundary layers, convective heat transfer, and aerodynamic heating. 4 hrs. lec. Prerequisites: 24-701 or permission of the instructor.
Prerequisite: 24-701

Course Website: https://www.meche.engineering.cmu.edu/

24-718 Computational Fluid Dynamics
Fall: 12 units
This course focuses on numerical techniques for solving partial differential equations including the full incompressible Navier-Stokes equations. Several spatial-temporal discretization methods will be taught, namely the finite difference method, finite volume method and briefly, the finite element method. Explicit and implicit approaches, in addition to methods to solve linear equations are employed to study fluid flows. A review of various finite difference methods which will be used to analyze elliptic, hyperbolic, and parabolic partial differential equations and the concepts of stability, consistency and convergence are presented at the beginning of the course to familiarize the students with general numerical methods. Detailed syllabus of the course is provided on the URL given below. 4 hr. lec
Prerequisites: 24-231 and 24-311

Course Website: http://www.andrew.cmu.edu/user/satbirs/24718/

24-721 Advanced Thermodynamics
Intermittent: 12 units
The course covers advanced macroscopic thermodynamics and introduces statistical thermodynamics. Review of first and second laws. Axiomatic formulation of macroscopic equilibrium thermodynamics and property relationships. Criteria for thermodynamic equilibrium with application to multiphase and multi-component systems. Thermodynamic stability of multiphase systems. Elementary kinetic theory of gases and evaluation of transport properties. Statistical-mechanical evaluation of thermodynamic properties of gases, liquids, and solids. Students are expected to have an undergraduate level of understanding of Thermodynamics (comparable to 24-221). 4 hrs. lec.
Prerequisite: 24-221

Course Website: http://www.andrew.cmu.edu/user/venkatv/24721/

24-722 Energy System Modeling
Fall: 12 units
This course focuses on the thermodynamic modeling of energy systems with emphasis on energy/availability analysis techniques. These techniques are developed and applied to both established and emerging energy technologies, such as internal combustion engines, gas- and coal-fired power plants, solar and wind energy systems, thermochemical hydrogen production cycles, and fuel cells. The course will also consider the integration of components such as reformers and electrolyzers. Modern computational tools are used throughout the course. The course culminates with a group project that requires developing sophisticated, quantitative models of an integrated energy system. Students are expected to have completed an undergraduate course in thermodynamics comparable to 24-221.
Prerequisites: 27-215 or 24-221 or 06-221

Course Website: http://www.cmu.edu/me/graduate/index.html

24-727 Special Topics: Aerosol Measurement Technology
Intermittent: 12 units
This course explores modern methods and instrumentation used to characterize key physical and chemical properties of aerosol particles, and the fundamental principles underlying the technology. Topics include particle sampling and collection (aerosol inlets, impactors, cyclones, virtual impactors, collection on substrates, electrostatic precipitation), aerosol charging and neutralization, particle size measurements (electrical mobility, optically, and aerodynamically based), particle detection (optical and electrical), aerosol optical properties, and the characterization of particle chemical composition (online mass spectrometry, in particular). Methods for analyzing both individual and ensembles of aerosol particles are discussed and compared. Recent advances reported in the literature are explored through student-led presentations. Students write a term paper describing and justifying their choice of techniques to solve a realistic aerosol measurement need. While the focus is on atmospheric aerosol particles, industrial applications such as particle synthesis and characterization are also discussed.

Course Website: http://www.cmu.edu/me/

24-740 Combustion and Air Pollution Control
Intermittent: 12 units
24-740 Combustion and Air Pollution Control This course examines the generation and control of air pollution from combustion systems. The course's first part provides a brief treatment of combustion fundamentals, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, mass transfer, and flame structure. This foundation forms the basis for exploring the formation of gaseous (oxides of nitrogen, carbon monoxide, hydrocarbons, and sulfur dioxide) and particulate pollutants in combustion systems. The course then describes combustion modifications for pollutant control and theories for pollutant removal from effluent streams. The internal combustion engine and utility boilers serve as prototypical combustion systems for discussion. The course also addresses the relationship between technology and the formulation of rational regional, national, and global air pollution control strategies. Cross listed 19-740, 19-440, 24-425

Course Website: http://www.cmu.edu/me/graduate/index.html

24-751 Introduction to Solid Mechanics I
Fall: 12 units
This is the first course in a two-part professionally oriented course sequence covering a variety of important problems in solid mechanics. Topics covered typically include torsion of non-circular cross sections, the field equations of elasticity and boundary conditions, and a number of classical plane stress/ plane strain solutions in rectangular and polar coordinates. Emphasis is placed on not only elasticity theory and how classical elasticity solutions are derived, but also on their use in constructing and interpreting the results from finite element simulations of applied engineering problems. Where applicable, comparisons are also made between solutions derived via the full theory of elasticity and simplified solutions developed in strength of materials courses. 4 hrs. lec.

Course Website: http://www.cmu.edu/me/graduate/index.html

24-753 Special Topics: Principles of Soft-Matter Machines & Electronics
Fall and Spring: 12 units
This is an interdisciplinary course focused on principles, theoretical models, and material architectures relevant to applications of condensed soft matter to problems in engineering. Special attention will be given to the design of soft, elastically-deformable machines and electronics that are primarily composed of elastomers, gels, fluids, gas, and other non-rigid matter. Specific topics will include the mechanics of hyperelastic solids, statistical mechanics of polymers and polymer composites, energy-based modeling techniques derived from the Laws of Thermodynamics, and their applications in modeling soft multifunctional material systems. Additionally, we will explore emerging paradigms in soft robotics, wearable computing, and human machine interaction, including material architectures for artificial muscles, stretchable electronics, and sensorized robotic skin. This course will include extensive reading with problem set assignments, a take-home exam, and final report. Students need familiarity with undergraduate-level solid mechanics, vector mechanics, thermodynamics, and ODEs
Prerequisite: 24-751

24-755 Finite Elements in Mechanics I
Fall: 12 units
The basic theory and applications of the finite element method in mechanics are presented. Development of the FEM as a Galerkin method for numerical solution of boundary value problems. Applications to second-order steady problems, including heat conduction, elasticity, convective transport, viscous flow and others. Introduction to advanced topics, including fourth-order equations, time dependence and nonlinear problems. 12 Units
Prerequisite(s): Graduate standing or consent of instructor

Course Website: http://www.cmu.edu/me/graduate/index.html

24-760 Special Topics: Robot Dynamics and Analysis
Fall: 12 units
This course covers the dynamics of robotic systems with a focus on the mathematical structure of the dynamics and numerical analysis. Topics will start by reintroducing basic kinematics and dynamics in a more formal mathematical framework before moving on to contact conditions, friction, terramechanics, hybrid dynamical systems, timestepping simulation, and contact invariant optimization. After the course students will be able to write simulation and optimization methods for analyzing robotic systems. Students should have taken a prior course in dynamics, and be comfortable with linear algebra, multivariable calculus, and programming in Matlab.
Prerequisites: 24-351 or 16-711

Course Website: http://www.andrew.cmu.edu/user/amj1/classes/robotdynamics.html

24-771 Linear Systems
Fall: 12 units
Topics include review of classical feedback control; solution of differential and difference equations; Laplace and Z-transforms, matrix algebra, and convolution; state variable modeling of dynamic continuous and discrete processes; linearization of nonlinear processes; state variable differential and difference equations; computer-aided analysis techniques for control system design; state variable control principles of controllability, observability, stability, and performance specifications; trade-offs between state variable and transfer function control engineering design techniques; and design problems chosen from chemical, electrical, and mechanical processes. 4 hrs. lec. Prerequisite: An undergraduate course in classical control engineering or consent of the instructor.
Prerequisite: 24-451

Course Website: http://www.cmu.edu/me/graduate/index.html

24-774 Special Topics: Advanced Control Systems Integration
Fall: 12 units
This course focuses on the practical implementation of feedback / feedforward controllers. The entire controller design process is presented, including system modeling and identification, compensator design, simulation, and hardware prototyping. This is a project-based course in which students complete the controller design process on a nonlinear, MIMO hardware system. The goal is train students on the system integration skills necessary for success in industry or experimental laboratory work.
Prerequisites: 24-773 or 24-776 or 18-776

Course Website: http://www.cmu.edu/me/

24-780 Engineering Computation
Fall: 12 units
This course covers the practical programming and computational skills necessary for engineers. These include: (1) programming in C++, (2) visualization using OpenGL, (3) basic data structures, and (4) basic algorithms. The course covers computational techniques required for solving common engineering problems and background algorithms and data structures used in modern Computer-Aided Design, Computer-Aided Manufacturing, and Computer-Aided Engineering tools. The course also offers intensive hands-on computational assignments for practice of common applications.

Course Website: http://www.cmu.edu/me/graduate/index.html

24-781 Engineering Computation Project
Fall
24-781 This project course is the first section of the two-semester sequence of Computational Engineering Projects. The course provides the students with hands-on problem-solving experience by using commercial computational tools and/or developing their own custom software. Each student, individually or along with other students, will work on a project under the guidance of Carnegie Mellon faculty members and/or senior engineers from industry. Students may select a project topic from those presented by advising faculty members and/or industry engineers. Alternatively, a student may propose and work on his/her own project topic if he/she can identify a sponsoring faculty member or industry engineer.

Course Website: http://www.cmu.edu/me/graduate/index.html

24-782 Computational Engineering Project II
Spring
This project course is the second section of the two-semester sequence of Computational Engineering Projects. The course provides the students with hands-on problem-solving experience by using commercial computational tools and/or developing custom software. Each student, individually or along with other students, will work on a project under the guidance of Carnegie Mellon University faculty members and/or senior engineers from industry. Students may select a project topic from those presented by advising faculty members and/or industry engineers. Pending instructor permission, a student may alternatively work on his/her own project under the guidance of a sponsoring faculty member or an industry engineer. MCDSM students only. 12/24 hrs lab Prerequisite: 24-781
Prerequisite: 24-781

Course Website: http://www.cmu.edu/me/

24-787 Machine Learning and Artificial Intelligence for Engineers
Fall: 12 units
This course introduces fundamental machine learning and artificial intelligence techniques useful for engineers working on data-intensive problems. Topics include: Probability and Bayesian learning, generative and discriminative classification methods, supervised and unsupervised learning, neural networks, support vector machines, clustering, dimensionality reduction, regression, optimization, evolutionary computation, and search. The lectures emphasize the theoretical foundations and the mathematical modeling of the introduced techniques, while bi-weekly homework assignments focus on the implementation and testing of the learned techniques in software. The assignments require knowledge of Python including text and image input/output, vector and matrix operations, simple loops, and data visualization. Students must have undergraduate level experience with linear algebra and vector calculus.
Prerequisites: 15-112 and 21-341

Course Website: http://www.cmu.edu/me/graduate/index.html

24-788 Machine Learning and Artificial Intelligence for Engineers - Project
Spring: 12 units
This course provides an open-ended computational project experience in artificial intelligence and machine learning. This course will enable student teams to design, develop and test data-driven computational algorithms. Course objectives are: - Gain experience in data sciences and data-driven methods for engineering. - Learn advanced programming and computational system design. - Learn project planning and management, project evaluation, teamwork, technical communication. The projects will target problems involving experimental, simulated or crowd-sourced data. Each project will aim to build an artificial intelligence or machine learning system that accomplishes one or more of the following: Identify patterns in data, establish a mathematical model for the input/output relationships, classify data into distinct categories, use existing data to synthesize new solutions to a synthesis problem. Team activities include three presentations, two written reports, a final technology demo, and one final report in the form of an archival publication.
Prerequisites: 10-701 Min. grade C or 10-601 Min. grade C or 24-787 Min. grade C or 15-781 Min. grade C

Course Website: http://www.cmu.edu/me/

24-791 Graduate Seminar I
All Semesters
Graduate seminar speakers include faculty, students, and invited guests from industry and academia. Through seminars, students widen their perspectives and become more aware of other topics in mechanical engineering

Course Website: http://www.cmu.edu/me/graduate/index.html

Engineering Minors for Non-Engineering Students

Biomedical Engineering Minor

Professor Conrad M. Zapanta, *Associate Department Head of Undergraduate Education*
czapanta@cmu.edu
www.bme.cmu.edu

The minor program is designed for engineering students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is also open to students of all colleges and is popular among science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. Students pursuing the minor may contact the BME Associate Head for Undergraduate Education (https://www.cmu.edu/bme/People/Faculty/profile/czapanta.html) (http://www.bme.cmu.edu/people/staff.html#ADH)for advice. Students interested in declaring Biomedical Engineering minor should contact either the BME Associate Head for Undergraduate Education (https://www.cmu.edu/bme/People/Faculty/profile/czapanta.html)or the Biomedical Engineering Undergraduate Program Coordinator (https://www.cmu.edu/bme/People/Administration).

Requirements

Minimum units required for minor: 57

03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
42-xxx	BME Elective (>= 9 units), Any course offered by the Department of Biomedical Engineering numbered 42-300 or higher and worth at least 9 units	
xx-xxx	Elective I (>= 9 units) #	
xx-xxx	Elective II (>= 9 units) +	

Some Special Topics, newly offered or intermittently offered 42-xxx may be acceptable as electives. Students should consult with their advisors and petition the Biomedical Engineering Undergraduate Affairs Committee for permission to include such courses.

Notes

\# Elective I cannot be a required course in the student’s major. It may be

1. Any required or additional track elective course selected from any of the five Biomedical Engineering tracks. See the online catalog (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/Resources/catalog.html) for a listing of courses.
2. Any 42-xxx course with a 42-300 or higher number and worth at least 9 units.
3. 42-203 Biomedical Engineering Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). The course has a limited capacity and priority is given to students who have declared the Additional Major in Biomedical Engineering.**
4. One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units.

\+ Elective II must be a Biomedical Engineering Required or additional track elective.

** Priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.

Engineering Studies Minor

(for non-engineering students)

Kurt Larsen, *Director*
Location: Scaife Hall 120

Carnegie Mellon undergraduate students enrolled in colleges other than engineering can complete a Minor in Engineering Studies in addition to their regular majors. Students pursuing this minor are required to complete courses from at least two different engineering departments in order to assure some breadth of exposure to engineering. In addition, the minor provides students the opportunity to pursue an in-depth concentration in a particular field of engineering.

For the Minor in Engineering Studies, students must complete five engineering courses as follows and must earn a cumulative QPA of 2.00 in these five courses. Students may declare the minor by contacting the director after they have successfully completed one introductory engineering courses (from list #1 below).

Requirements

1. At least one and up to three of the following:

12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
18-100	Introduction to Electrical and Computer Engineering	12
19-101	Introduction to Engineering and Public Policy	12
24-101	Fundamentals of Mechanical Engineering	12
27-100	Engineering the Materials of the Future	12
42-101	Introduction to Biomedical Engineering	12
06-100	Introduction to Chemical Engineering	12

2. Four courses of at least nine units each. Students must demonstrate both breadth and depth by taking courses from at least two of the below departments; and at least two courses from the same department.

- Biomedical Engineering
- Chemical Engineering
- Civil and Environmental Engineering
- Electrical and Computer Engineering
- Engineering and Public Policy*
- Materials Science and Engineering
- Mechanical Engineering

Up to <u>one</u> of the following Robotics courses can count toward the ES minor. But it cannot be double-counted with the Robotics minor or double major.

1.

16-311	Introduction to Robotics	12
16-362	Mobile Robot Algorithms Laboratory	12
16-384	Robot Kinematics and Dynamics	12
16-385	Computer Vision	12
16-421	Vision Sensors	12
16-474	Robotics Capstone	12

<u>NOTE:</u> The following courses may NOT be included as part of the minor in Engineering Studies.

06-262	Mathematical Methods of Chemical Engineering	12
12-201	Geology	9
12-421	Engineering Economics	6
15-213	Introduction to Computer Systems	12
18-090	Twisted Signals: Multimedia Processing for the Arts	10
18-099	Special Topics: Mobile App Design & Development	12
18-200	ECE Sophomore Seminar	1

18-202	Mathematical Foundations of Electrical Engineering	12
18-213	Introduction to Computer Systems for a core major requirement (e.g. CS minor)	12
24-280	Special Topics: C++ Programming for Engineers	9
24-282	Special Topics: Linear Algebra and Vector Calculus for Engineers	11
24-311	Numerical Methods	12
42-202	Physiology	9

Double counting of core courses in student's primary major is not permitted.

*Because of the nature of the courses offered by Engineering and Public Policy, only two EPP courses (including 19-101) can be used toward the minor requirements. Most EPP courses (19-xxx) are not permissible for the minor; students need special permission to use 19-xxx toward this minor and should contact the director for prior approval. Students interested in EPP coursework should consider the Technology and Policy minor instead.

Technology and Policy Minor

(for non-engineering students)

Deanna H. Matthews, *Director*
Location: Baker Hall 129

The Technology and Policy Minor is administered by the Department of Engineering and Public Policy (EPP) for students who are majoring in areas other than engineering. The Technology and Policy Minor is designed to give students a basic understanding of the interactions between technology, society and policy and some project experience in problems involving technology and policy.

Pre-requisites

Students should have prerequisite knowledge in economics (73-102 Principles of Microeconomics or higher level economics course) and statistics (36-202 Statistics & Data Science Methods or higher level statistics course) in order to pursue the Technology and Policy Minor.

Course Requirements

19-101	Introduction to Engineering and Public Policy	12
19-301	Decision Making Methods for Engineers and Scientists or other approved Decision Science course	9
or 19-351	Applied Methods for Technology-Policy Analysis	
19-451	EPP Projects	12
or 19-452	EPP Projects	
xx-xxx	Two EPP Technology-Policy Electives	18

EPP Technical Electives include courses in CIT, MCS, or SCS that address problems at the society-technology interface and the means of analyzing these issues. A list of qualifying Technology-Policy electives is assembled each semester and is available from the EPP Department. Example Technology-Policy electives include:

19-211	Ethics and Policy Issues in Computing	9
19-365	Water Technology Innovation and Policy	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-424	Energy and the Environment	9

Students must earn a cumulative QPA of 2.0 in all courses taken for the minor. Required courses taken for a student’s primary major may not be counted toward the Technology and Policy Minor. Elective courses for a student’s primary major or courses fulfilling general education requirements may be counted, however.

Undergraduate Designated Minors in the College of Engineering

Overview

Undergraduate students in the Carnegie Institute of Technology can elect to complete an interdisciplinary Designated Minor in addition to their regular majors for B.S. degrees. Designated minors have been added to the curriculum of the Carnegie Institute of Technology to promote flexibility and diversity among the college's engineering students. Independent of a student's major, he or she is able to pursue a selected designated minor from the following list:

- Additive Manufacturing
- Audio Engineering
- Automation and Controls
- Biomedical Engineering
- Colloids, Polymers and Surfaces Technology
- Electronic Materials
- Global Engineering
- Materials Science and Engineering
- Mechanical Behavior of Materials

An engineering student may elect to complete a CIT designated minor. Generally, the student takes all the required courses in an engineering major but uses electives to take courses needed to fulfill the requirements of the designated minor. Upon completion of the requirements of a CIT designated minor and the engineering degree, the minor is a formally recognized on the student's transcript.

Each of the CIT designated minors is administered by a Program Committee consisting of faculty from all major engineering departments who serve as faculty advisors. Each Program Committee certifies the completion of requirements of the designated minor. But the student's major department is responsible for approving the degree with a designated minor after reviewing a student's entire academic record. Any substitution or departure from the published curriculum should be avoided. For example, non-technical courses may not be substituted for required technical courses or electives. Equivalent technical electives offered by a designated minor as substitutions for required courses in a major must be approved by the Head of the student's major department.

Although a student generally can complete a designated minor without increasing the number of required units for graduation, early planning in electing a designated minor is important. A student also may find that some minors are more compatible than others with his/her major because of different relations between various major and minor requirements. The requirements for these CIT designated minors are listed below.

Additive Manufacturing Minor

The objective of the Minor in Additive Manufacturing is to provide the student with a background in the engineering science that applies to additive manufacturing (also known as 3D printing), from part design through additive processes, to properties and component performance. Particular emphasis is given to metals additive manufacturing, due to its rapidly growing impact on manufacturing across multiple industries, and the need for talent in this area. The minor is open to students in all engineering majors.

Students may not use any given course to satisfy simultaneously requirements in both their enrolled major and in this minor. Graduate courses counted towards this minor may not be (double) counted for a graduate degree.

Minor Coordinators

Prof. Jack Beuth, Director
Dr. Sandra DeVincent Wolf, Assoc. Director
Prof. Anthony Rollett, Assoc. Director

Departmental Contacts

Biomedical Engineering	**Robert Tilton**
Chemical Engineering	**Aditya Khair**
Civil and Environmental Engineering	**Mitchell Small**
Electrical and Computer Engineering	**Diana Marculescu**
Engineering and Public Policy	**Deanna Hart Matthews**
Materials Science and Engineering	**Anthony Rollett**
Mechanical Engineering	**Jack Beuth**

Course Requirements

This minor requires a total of five (5) courses comprising of three core courses and two technical electives.

Three Core Courses 36 units

		Units
39-601	Special Topics: Additive Manufacturing Processing and Product Development	12
39-602	Additive Manufacturing and Materials	12
39-603	Additive Manufacturing Laboratory	12

Two Technical Electives

To select acceptable technical elective course options, please speak with your departmental contact, or see https://engineering.cmu.edu/education/undergraduate-programs/curriculum/additive-manufacturing-minor.html.

Audio Engineering Minor

Tom Sullivan, *Director and Faculty Advisor*

This sequence is for candidates who are engineering majors with interest in and/or have background in music, recording, sound-editing and/or other music technology areas; or majors from any discipline in the university who have the above interests and who can meet the prerequisite requirements for the engineering courses in the minor.

Note: Students who do not have the requisite engineering/science/math background should investigate the Minor in Music Technology offered by the School of Music.

Course Requirements

Minimum units required for minor: 73-79

The student must have taken the appropriate prerequisite courses for the listed courses.

Prerequisite Courses, 0-3 units

Beginning Piano is required of students who do not pass a piano proficiency test.

		Units
57-103	Elective Studio (Beginning Piano Class)	3

Music Courses, 40-43 units

Basic Harmony I is required of students who do not qualify for entrance into Harmony I, based on their scores on the theory placement test.

		Units
57-101	Introduction to Music Technology	6
57-149	Basic Harmony I	9
or 57-152	Harmony I	
57-173	Survey of Western Music History *	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6

* co-requisite 57-188.

(choose two of the courses below)		Units
15-322	Introduction to Computer Music	9
57-338	Sound Editing and Mastering	6
57-347	Electronic and Computer Music	6
57-438	Multitrack Recording	9

Technical Courses, 33 units

Other courses may be taken with the approval of the Audio Engineering Minor Advisor.

		Units
33-114	Physics of Musical Sound	9
18-493	Electroacoustics **	12
18-300	Fundamentals of Electromagnetics	12
18-341	Logic Design and Verification	12
18-370	Fundamentals of Control	12
18-491	Fundamentals of Signal Processing	12

** prerequisites 18-220 and 18-290.

(choose one of the courses below)		Units
15-210	Parallel and Sequential Data Structures and Algorithms	12
or 15-214	Principles of Software Construction: Objects, Design, and Concurrency	
18-320	Microelectronic Circuits +	12
18-349	Introduction to Embedded Systems **	12

** prerequisite 18-240 and 18-213.

\+ prerequisite 18-220.

Automation and Controls Minor

Erik Ydstie, *Director and Faculty Advisor*
Location: DH 4210A

The objective of the Designated Minor in Automation and Control Engineering is to expose CIT students to the breadth of knowledge required by the modern practice of control and automation. With this objective in mind, the requirements include not only two courses in control system analysis and design, but also courses on real-time computation, software engineering, hardware implementation, and applications. The minor is expected to attract primarily students from Chemical Engineering, Electrical and Computer Engineering, and Mechanical Engineering. The main interdisciplinary component of the minor is between engineering and computer science, although many opportunities exist for creating a program across several CIT departments.

Course Requirements

Minimum units required for minor: 54

The minor requires a minimum of six courses as described below:

Note: The course lists below are not necessarily current or complete. Appropriate courses not listed below may be counted toward the requirements for the minor upon approval by one of the departmental the faculty advisors. Students interested in the Automation and Control Engineering Designated Minor are encouraged to look for applicable courses each semester in CIT, CS, and Robotics.

One basic control course:		Units
18-370	Fundamentals of Control	12
24-451	Feedback Control Systems	12

One course on control system analysis and design:		
06-708	Advanced Process Dynamics and Control	12

One course on computing and software		
12-741	Data Management	6
Other courses as approved by Director and Faculty Advisor		

One course on hardware implementation:		
06-423	Unit Operations Laboratory	9
18-474	Embedded Control Systems	12
18-578	Mechatronic Design	12

One course on applications:		
06-606	Computational Methods for Large Scale Process Design & Analysis	9
16-311	Introduction to Robotics	12
16-761	Mobile Robots	12
24-351	Dynamics	10
xx-xxx	Independent project	12

One elective course:		
xx-xxx	Any course in the list above excluding the basic control course category	6-12
15-381	Artificial Intelligence: Representation and Problem Solving	9
15-385	Introduction to Computer Vision	6
15-413	SEE 17-413 Software Engineering Practicum	12
15-440	Distributed Systems-Time Software	12
18-349	Introduction to Embedded Systems	12
18-491	Fundamentals of Signal Processing	12
24-341	Manufacturing Sciences	9
Other courses as approved		

Biomedical Engineering Minor

Professor Conrad M. Zapanta, *Associate Department Head of Undergraduate Education*
czapanta@cmu.edu
www.bme.cmu.edu

The minor program is designed for engineering students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is also open to students of all colleges and is popular among science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. Students pursuing the minor may contact the BME Associate Head for Undergraduate Education (https://www.cmu.edu/bme/People/Faculty/profile/czapanta.html) (http://www.bme.cmu.edu/people/staff.html#ADH)for advice. Students interested in declaring Biomedical Engineering minor should contact either the BME Associate Head for Undergraduate Education (https://www.cmu.edu/bme/People/Faculty/profile/czapanta.html)or the Biomedical Engineering Undergraduate Program Coordinator (https://www.cmu.edu/bme/People/Administration).

Requirements

Minimum units required for minor: 57

03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
42-xxx	BME Elective (>= 9 units), Any course offered by the Department of Biomedical Engineering numbered 42-300 or higher and worth at least 9 units	
xx-xxx	Elective I (>= 9 units) #	
xx-xxx	Elective II (>= 9 units) +	

Some Special Topics, newly offered or intermittently offered 42-xxx may be acceptable as electives. Students should consult with their advisors and petition the Biomedical Engineering Undergraduate Affairs Committee for permission to include such courses.

Notes

\# Elective I cannot be a required course in the student's major. It may be

1. Any required or additional track elective course selected from any of the five Biomedical Engineering tracks. See the online catalog (https://www.cmu.edu/bme/Academics/Undergraduate%20Programs/Resources/catalog.html) for a listing of courses.
2. Any 42-xxx course with a 42-300 or higher number and worth at least 9 units.
3. 42-203 Biomedical Engineering Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). The course has a limited capacity and priority is given to students who have declared the Additional Major in Biomedical Engineering.**
4. One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units.

\+ Elective II must be a Biomedical Engineering Required or additional track elective.

** Priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.

Colloids, Polymers and Surfaces Minor

Dr. Ilhem Hakem, *Director*
Location: Doherty Hall 3207

The sequence of courses in the Colloids, Polymers and Surfaces (CPS) designated minor provides an opportunity to explore the science and engineering of fine particles and macromolecules as they relate to complex fluids and interfacially engineered materials. These topics are very relevant to technology and product development in industries that manufacture pharmaceuticals, coatings and paints, pulp and paper, biomaterials, surfactants and cleaning products, cosmetics and personal care products, food, textiles and fibers, nanoparticles, polymer/plastics, composite materials.

Course Requirements

Minimum units required for minor: 45

This minor requires a total of five classes with a minimum of 45 units. The following four courses are mandatory:

06-609/09-509	Physical Chemistry of Macromolecules	9
06-607	Physical Chemistry of Colloids and Surfaces	9
06-426	Experimental Colloid Surface Science	9
06-466	Experimental Polymer Science	9

In addition, the student must take one CPS related elective course from the following list:

06-612	Formulation Engineering	12
06-610	Rheology and Structure of Complex Fluids	9
09-502	Organic Chemistry of Polymers	9
27-565	Nanostructured Materials	9
27-588	Polymer Physics and Morphology	9

Other CPS electives are possible but must be approved by the Director of the CPS minor, Dr. Hakem

Electronic Materials Minor

Lisa M. Porter, *Director*
Location: Roberts Engineering Hall 145

Many of the technological changes in recent decades-notably the rise of digital data processing-has been made possible by continuing advances in the performance of electronic devices. These advances include continuous improvement in microprocessor performance, optical communication bandwidth, and magnetic disk storage capacity. Other new areas of innovation include the development of micromechanical systems and the development of flat panel display technology. These advances depend on interactions between engineers from many different disciplines. In particular, there is a strong interaction between device design and materials engineering and processing.

The Electronic Materials Minor is intended to provide students with a firm basis for the application of electronic materials in advanced systems. This minor is well suited for students who intend to pursue careers in the electronics industry (included, but not limited to, semiconductor integrated circuit design and manufacturing, and magnetic storage engineering). The minor also provides an excellent preparation for students interested in pursing graduate work in MSE, ECE, or Applied Physics.

This minor is primarily intended to offer ECE and MSE students an understanding of the important features that must be built into a material during processing so that it will function as required in an electronic or magnetic device. Other students interested in pursuing this minor should consult their advisors to determine whether it will be practical in their own curriculum. Such students are expected to take both 18-100 and 27-201 as introductory courses.

Course Requirements

Required units for minor: 66

The minor requires an introductory course together with a minimum of 45 additional units as specified below.

Required Introductory Courses:

18-100	Introduction to Electrical and Computer Engineering	12
27-201	Structure of Materials	9

45 Additional Units From the Following Electives List:

27-202	Defects in Materials (ECE students only)	9
18-310	Fundamentals of Semiconductor Devices	12
06-619	Semiconductor Processing Technology	9
27-542	Processing and Properites of Thin Films	9
27-533	Principles of Growth and Processing of Semiconductors	6
27-432	Electronic and Thermal Properties of Metals, Semiconductors and Related Devices	9

27-433	Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices	9
18-403	Microfabrication Methods and Technology	12
33-225	Quantum Physics and Structure of Matter	9
xx-xxx	An approved research project on electronic materials	6-12
xx-xxx	An approved special topics or graduate level class pertaining to electronic materials	6-12

Global Engineering Minor

Treci Bonime, Director
Office: Scaife Hall 120

Many engineers work on international projects or for multinational companies. Carnegie Mellon is an international community, with a significant fraction of international students and many events featuring foreign speakers and cultural experiences. This minor is intended for engineering students interested in broadening their background in international experiences and global awareness and engagement.

Course Requirements

International Management (1 course)

Complete one course in international management or business such as:

70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-381	Marketing I	9
70-430	International Management	9
Or approved equivalent		

Regional Specialization (1 course)

Complete one course in non-US History, international politics, or literature in a single region of the world. See the list at http://www.cit.cmu.edu/global/courses_degrees.html below for examples (Note: Please consult with the Global Engineering director before planning your course schedule, as some course information may have changed).

Ethics (1 course)

Any ethics course that provides some exposure to international ethics issues such as:

70-332	Business, Society and Ethics	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
Or approved equivalent		

Modern Languages

Demonstration of basic competency in a foreign language via one of the three options listed below:

- Complete one (1) Modern Languages course at the 200 level, with a minimum grade of C, or
- Achieve a score of 4 or higher in one foreign language Advanced Placement examination, or
- Demonstrate equivalent proficiency to the satisfaction of the Department of Modern Languages

Study/Work Abroad

Study or engineering internship work abroad for a semester or a summer. The region visited should be consistent with the language and regional culture/history studied.

Materials Science and Engineering Minor

Michael E. McHenry, *Director*
Location: Roberts Engineering Hall 243

Paige Houser, *Academic Advisor*
Location: Wean Hall 3317

The Designated Minor in Materials Science and Engineering provides the CIT student with a background in the field of Materials Science and Engineering. This minor is open to all CIT students, with the exception of MSE majors. All required and elective courses are taught within the MSE Department.

Course Requirements

Minimum units required for minor 45

The minor requires a minimum of 45 units, with two semester long required courses (the first being a sequence of two minis).

Prerequisites

Students wishing to take the MSE minor must have prerequisite thermodynamics and transport courses. The prerequisite MSE courses may be substituted for by a thermodynamics and transport course in another engineering discipline.

Core Courses (21 units)

27-211	Structure of Materials (Minor Option)	6
27-212	Defects in Materials (Minor Option)	6
27-227	Phase Relations and Diagrams (Minor Option)	9

The laboratories with these courses are not required as core but will be counted as elective units if desired.

Elective Courses (24 units minimum)

The student must select a minimum of 24 units from the following list:

27-100	Engineering the Materials of the Future	12
27-301	Microstructure and Properties I	9
27-311	Polymeric Biomaterials	9
27-323	Powder Processing of Materials	9
27-324	Introduction to Polymer Science and Engineering	9
27-357	Introduction to Materials Selection	6
27-367	Selection and Performance of Materials	6
27-582	Phase Transformations in Solids	9
27-433	Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices	9
27-432	Electronic and Thermal Properties of Metals, Semiconductors and Related Devices	9
27-421	Processing Design	6
27-445	Structure, Properties and Performance Relationships in Magnetic Materials	9
27-591	Mechanical Behavior of Materials	9
27-454	Supervised Reading	Var.
27-533	Principles of Growth and Processing of Semiconductors	6
27-555	Materials Project I	Var.
27-565	Nanostructured Materials	9
27-542	Processing and Properites of Thin Films	9
27-551	Properties of Ceramics and Glasses	9
27-566	Special Topics in MSE:Using Matls Informatics to Assess Societal Impact of Matls	9
27-592	Solidification Processing	9
42-444	Medical Devices	9

Mechanical Behavior of Materials Minor

Program Contacts

Warren M. Garrison, Jr., *Director*

Paige Houser, *Academic Advisor*

An understanding of mechanical behavior is important to both the development of new materials and the selection of appropriate materials for many applications. The mechanical behavior of materials is best investigated and understood by integrating solid mechanics with the microstructural basis of flow and fracture. The purpose of this minor is to allow a formal basis for students to pursue an integrated approach to the mechanical behavior of materials.

Although this minor is open to all CIT students, only students in the departments of Civil Engineering, Materials Science and Engineering, and Mechanical Engineering can take advantage of the double counting permitted for some courses in their department majors. Students in other departments may have difficulty in fulfilling the requirements in four years.

Department Contacts

Paul Sides, *Chemical Engineering*

Rachel Amos, *Electrical and Computer Engineering*

Paul S. Steif, *Mechanical Engineering*

Warren M. Garrison, Jr., *Materials Science and Engineering*

Course Requirements

Minimum units required for minor 51-54

The minor requires six courses: three core courses, two solid mechanics courses, and one materials science course. In satisfying these course requirements, each student must take three out-of-department courses. Each student is required to complete three core courses:

Core Courses:

27-201	Structure of Materials	9
27-591	Mechanical Behavior of Materials	9-12
or 27-791	Mechanical Behavior of Materials	
12-212	Statics	9
or 24-261	Statics	

Group A: Materials Science Courses

Each student must take one course from this list of Materials Science courses:

27-202	Defects in Materials [1]	9
27-357	Introduction to Materials Selection [2]	6
27-551	Properties of Ceramics and Glasses	9
42-411	Engineering Biomaterials	9

[1] 27-202 cannot be used by MSE students to satisfy the requirements of the minor.

[2] 27-357 cannot be used by MSE students to satisfy the requirements of the minor.

Group B: Solid Mechanics Courses

Each student must take two of the following Solid Mechanics courses:

12-231	Solid Mechanics	9
or 24-262	Stress Analysis	
12-635	Structural Analysis	9
or 24-351	Dynamics	

Students should check with the director of the program or their faculty advisor for an up-to-date list of relevant courses that will count towards this minor. For more information, please consult the Undergraduate Course Catalog and the current Schedule of Classes.

College of Fine Arts

Dan J. Martin, Dean (CFA 100)

Eric Anderson, Senior Associate Dean for Faculty Development and Governance (MM 110)

Kristen Kovak, Senior Associate Dean for Academics (CFA 100)
www.cfa.cmu.edu

Overview

The College of Fine Arts at Carnegie Mellon University was founded in 1905 as the first comprehensive arts learning institution in the United States. For 110 years it has educated outstanding artists, architects, designers, theater artists and musicians who have made important contributions to culture in the United States and the world. The alumni of the College of Fine Arts have shaped the worlds of television, stage, film, and electronic media; are collected in numerous international museums; have composed for and are performing in and conducting major symphony orchestras, choruses and opera companies throughout the world; have built notable buildings, pioneered innovative sustainable design strategies and created interactive software systems; created significant innovations in graphic and industrial design; and are professors and deans in major arts institutions.

The College of Fine Arts concentrates on the education of professionals in the arts in the broader context of Carnegie Mellon University. Beyond their education in their chosen field, through required and elective course work, students are involved with other disciplines within the College of Fine Arts and within the other colleges of Carnegie Mellon University. Further, the College's location in the Oakland District of Pittsburgh with its broad cultural resources (The Carnegie Museum of Art, the Carnegie Museum of Natural History, The Carnegie Library, the University of Pittsburgh, The Hillman Library, the Frick Fine Arts Building, and Phipps Conservatory and Botanical Gardens) places the College of Fine Arts at the center of a premier cultural environment.

The College of Fine Arts has a 9:1 student faculty ratio which provides a rigorous learning environment. It is a highly spirited federation of schools (Architecture, Art, Design, Drama and Music) made up of students and faculty who have an intense need to create and excel. Interacting among the schools, the University and the wider community are research centers such as the Frank-Ratchye Studio for Creative Inquiry, the Center for Building Performance and Diagnostics, Remaking Cities Institute, Center for Iranian Music, and the Center for Arts in Society. The intellectual and artistic life of the College is interwoven with a dense calendar of theater performances, concerts, exhibitions, film and media presentations and lectures by visiting artists, practitioners and scholars.

The College of Fine Arts offers a wide range of professionally oriented majors and minors in each of its schools. In addition, the College offers the Bachelor of Computer Science and Arts (BCSA), jointly with the School of Computer Science, the Bachelor of Humanities and Arts (BHA), jointly with the Dietrich College of Humanities and Social Sciences, the Bachelor of Science and Arts (BSA), jointly with the Mellon College of Science, the Engineering and Arts (EA) additional major, jointly with the College of Engineering, and the Master of Arts Management (MAM) and Master of Entertainment Industry Management (MEIM), jointly with the Heinz College of Public Policy and Management. These are presented only briefly below, but a complete listing of the graduation requirements for these programs may be found in the school descriptions later in this section and elsewhere in this volume.

Schools

School of Architecture

Office: CFA 201

The School of Architecture provides deep immersion in the discipline of architecture, intensified by the broader Carnegie Mellon culture of interdisciplinary innovation and creative inquiry. We define the discipline of architecture as the integrated pursuit of design creativity, historical perspective, social responsibility, technical expertise, and global environmental leadership. Though every School of Architecture student graduates with intensive architecture knowledge, no two graduates leave with the same education. In the twenty-first century, few architecture problems are straightforward. Our graduates excel in the roles architects have performed for centuries—and in new roles catalyzed by the depth and breadth of their education—to create and execute innovative solutions to a huge range of emerging global challenges. The school offers the following degree programs: Bachelor of Architecture (B.Arch), Bachelor of Arts in Architecture, Master of Advanced Architectural Design (MAAD), Master of Architecture (M.Arch), Master of Science and Ph.D. in Architecture–Engineering–Construction Management (MSAECM/PhD-AECM), Master of Science and Ph.D. in Building Performance and Diagnostics (MSBPD/PhD-BPD), Master of Science and Ph.D. in Computational Design (MSCD/PhD-CD), Master of Science in Sustainable Design (MSSD), and Master of Urban Design (MUD).

School of Art

Office: CFA 300

The primary mission of the School of Art is to develop in the individual student the skills, knowledge, and commitment required to work as an artist in society. The four-year undergraduate program leads to a Bachelor of Fine Arts degree in Art. Concentrations within the art major are offered in four areas: 1) Painting, Drawing, Print Media and Photography; 2) Electronic and Time-Based Work; 3) Sculpture, Installation, and Site Work; and 4) Contextual Practice. A Master of Fine Arts degree in Art is also offered.

School of Design

Office: MM 110

The School of Design combines its professional program with a sound education in the liberal arts, leading to careers in many fields of design. It offers the following degrees: Bachelor of Design with concentrations in Communications, Products, and Environments; M. Design in Design for Interactions; M.P.S. in Design for Interactions; M.A. in Design; Ph.D. in Transition Design.

School of Drama

Office: PCA 220

The School of Drama offers a highly focused, world-class theatre education with thorough preparation for sustained careers and innovation in today's widely-varied entertainment industries. The undergraduate programs lead to BFA degrees in Drama, with focuses in Acting, Music Theatre, Directing, Dramaturgy, Design, Production Technology and Management; MFA programs are offered in Scene, Costume, Sound, and Lighting Design; Directing; Dramatic Writing; and Production Technology and Management.

School of Music

Office: CFA 105

The School of Music has as its goal the preparation of musicians for careers in performance, composition, conducting, music education and music technology. The programs provide the opportunity to study with world-class artists utilizing the best aspects of conservatory training in the context of a major research university, combining the educational with the intensely professional. The Bachelor of Fine Arts is offered in Music Composition, Music Performance, and Music and Technology (a joint degree with the School of Computer Science and the Electrical and Computer Engineering Department) with minors in Collaborative Piano, Conducting, Music Education, Music Performance, and Music Technology available. The Master of Music is offered in Composition, Conducting, Performance, Music Education, and Music and Technology (a joint degree with Computer Science and the Electrical and Computer Engineering Department).

Academic Standards

Grading Practices

Grades given to record academic performance in the College of Fine Arts are detailed in the catalog section entitled "Undergraduate Academic Regulations." All courses taught by the schools in the College of Fine Arts follow the standard letter grade system of the university. Responsibility for the grade given the student rests entirely with the instructor and the school concerned. A permanent grade may not be raised by taking a second examination. Students who wish to repeat a course already passed must obtain approval from the Dean of the College. At the time of approval, the Dean will decide in the light of circumstances whether the new grade or the old grade will be the official grade used as the computing factor for honors. Both grades, however, will appear on the official transcript.

Academic Actions

The decision to impose academic action is first initiated at the conclusion of each semester by the School faculty most involved in the student's primary area of study and then presented at the end of the semester to the CFA Academic Advisory Committee for confirmation.

A student who is not making satisfactory progress toward meeting professional standards, or toward completing graduation requirements in a School, may have any of the academic actions listed below imposed by that School even though the student has received “passing” grades. Student Handbooks of the schools often provide more detail and should be read and understood by the student. Additionally, students enrolled in the BXA program are to be guided also by their academic requirements which is a QPA of 3.0 to remain in good standing or to return to good standing. See www.cmu.edu/interdisciplinary/programs/bhaprogram.html.

The academic actions listed below do not follow a particular sequence; any of the actions may be appropriately imposed at any time, and may be continued if deemed appropriate, upon recommendation of the School faculty concerned and confirmation by the CFA Academic Advisory Committee.

Warning

A Warning notifies the student of unsatisfactory performance and suggests that the student take steps to determine and correct the cause of the difficulty. A student must improve scholastic standing in the next semester in residence to an acceptable minimum level in order for consideration of a Warning to be removed. Refer to the school’s Student Handbook for details.

Probation

Probation is intended to notify a student of severe and/or continuous performance issues and to suggest that immediate steps are taken to correct the cause of the difficulty. A student will be placed on Probation for failure to meet the professional standards of the school. If during the next semester the student continues to not meet the school’s standards, the student may remain on Probation, be Suspended, or Dropped at the end of the semester. Either of these actions may be taken without any previous academic action. A student must improve scholastic standing in the next semester in residence to an acceptable minimum level in order for consideration of Probation to be removed. Refer to the school’s Student Handbook for details. Students who are on academic Probation have restrictions from participating in some school, college, and university activities, including eligibility for study abroad or school awards. Refer to school’s handbooks for specific information.

Final Probation

A student will be placed on Final Probation for significantly poor performance, or for continued failure to meet the professional standards of the School, as outlined under the previous section on Probation (and school’s Student Handbook). A student must improve scholastic standing in the next semester in residence to an acceptable minimum level in order for consideration of a Final Probation to be removed. Refer to the school’s Student Handbook for details. A student not meeting the acceptable levels of performance and professional standards may be Suspended or Dropped at the end of the semester. Either of these actions may be taken without any previous academic action. Students who are on academic Final Probation have restrictions from participating in some school, college, and university activities, including eligibility for study abroad or school awards. Refer to the school’s Student Handbook for specific information.

University Suspension

University Suspension is a forced, temporary leave from the university. There are three types of suspension for students:

- *Academic Suspension* is the result of poor academic performance or violation of academic regulations and is imposed by the student's college or academic department (see university and college academic policies).
- *Disciplinary Suspension* is the result of serious personal misconduct and is imposed by the Office of Student Affairs (see The Word/Student Handbook).
- *Administrative Suspension* is the result of failure to meet university financial obligations or failure to comply with federal, state or local health regulations and is imposed by Enrollment Services. (See Student Accounts Receivable Collection Policy and Procedures for financial obligations. Contact Student Health Services for information about health regulations.)

This document covers CFA Academic Suspension from the University. *(For more information on Disciplinary Suspension or Administrative Suspension visit the student life sections on the university website at www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html).*

A University Suspension is intended to allow a student time to address or rectify any issues impeding or affecting their performance and progress towards meeting the professional standards of the School. It is imposed for a history of poor performance that has created an impediment to acceptable academic achievement; a student is not making significant progress towards his/her degree; a student already on an action has a significantly poor semester (not achieving the requirements for academic action removal or worse). The student is required to withdraw from the university for a specific period as defined by the School. Re-admission is subject to the conditions specified in the suspension letter and approval of the senior associate dean for academics.

A student who has been suspended from the university is required to leave the campus, including dormitories and fraternity houses, within a maximum of two days after the action and to remain off the campus for the duration of the time specified.

Go to the university policy webpage on student life for more information on a University Suspension at www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html.

Drop from School

A student is Dropped from the School when it is clear that the student’s progress in professional training is insufficient to warrant continuing in the current professional field of study. This action is taken in the case of a student who has been lacking in some essential requirement in the chosen professional field, but whose general scholastic ability, habits and character justify an opportunity in some other field of education. This action terminates the student’s enrollment in the current School but is not intended to prejudice admission to another Department, School, or College of the University, or to another institution. This academic action allows the student three choices:

1. Transfer to another Carnegie Mellon University Department or School. The student takes responsibility to contact that Department or School of choice to discuss the possibility of applying for transfer.
2. Request for Transitional status in the College of Fine Arts for one semester (refer to the section on Transitional Students in the School’s Student Handbook). It is strongly recommended that the student make an appointment at the Carnegie Mellon Center for Student Diversity and Inclusion to pursue this option.
3. Withdraw from Carnegie Mellon University. A link to the application for Withdrawal/Leave of Absence form is embedded with the letter notifying the student of this academic action, and is also available at www.cmu.edu/hub

Appeal of Grades and Academic Actions

Refer to the School’s Student Handbook for policy and procedure details.

Returning from Suspension

In order to return from a suspension, a student must have approval from the following administrators:

- *Academic Suspension* - associate dean;
- *Disciplinary Suspension* - dean of student affairs;
- *Administrative Suspension* - vice president for campus affairs or his/her designate.

Dean's Honor List

Each semester the College of Fine Arts recognizes those students who have attained outstanding semester quality point averages by naming them to the Dean's List. To be eligible, students must complete at least 36 factorable units and have no conditional, missing or failing grades in core classes at the time when final semester grades are recorded. The top 35% of eligible students in each of the College of Fine Arts schools are named to the Dean's List.

Graduation Requirements

Because of the special nature of work in the College of Fine Arts, the first year in all schools should be considered probationary, a period in which a student and faculty can evaluate professional promise in terms of the college's standards. Graduation from the College of Fine Arts follows the general university guidelines. As part of a student's qualification for an undergraduate degree, the equivalent of two terms of full-time work must be pursued under the direction of faculty members in the college during the period immediately prior to the degree award. Courses completed at other institutions will not be acceptable as terminal credit for a degree. Exceptions to this stipulation can be recommended by a school faculty in unusual cases, but the concurrence of the College Council is necessary before final approval of an exception can be given.

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some programs may have additional QPA requirements in order to graduate.

Other graduation requirements in the College of Fine Arts are described in the curriculum of each school. Further questions about specific course requirements and the total number of units required should be directed to the respective school advisors.

Other Regulations Affecting Student Status

Schedule Changes

Courses may be added or dropped within the times stated in the college calendar. No courses may be added or dropped after the stated deadline dates except with the approval of the student's School Head and the Dean of the College. (See Undergraduate Academic Regulations (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateacademicregulations) for Add/Drop procedures.)

Withdrawal/Leave of Absence

Please refer to the Student Leave Policy.

Transitional Students

Transitional status is made available to students upon the advice of their advisors or upon their own request. A student must complete one full semester of study prior to declaring transitional status. The designation Transitional Student has been instituted by the Dean of the College of Fine Arts to assist students who have been judged unlikely to make satisfactory progress in their chosen professional field, or who on their own initiative, have changed their mind about their originally chosen field of study.
Being a Transitional Student gives them an opportunity to maintain a temporary relationship with the College of Fine Arts while re-orienting career plans and goals. It also gives them time to enhance their admissibility to another school in the college, another college in the university, or another institution. Ordinarily a student will be permitted to register as a Transitional Student for no more than one semester. If after one semester a Transitional Student has not been accepted into a new program, they may be asked to leave the College of Fine Arts.

Transfer Students

Undergraduate students seeking transfer within or to any school of the College of Fine Arts must file an application with the School and proceed with the established transfer application procedure, audition, portfolio review or ASAT requirements. Admission may dictate freshman status regardless of the student's prior college experience.

Materials

The college does not furnish students with any drawing materials, make-up materials, textbooks, or other expendable equipment except those in courses in which materials fees are charged to cover specific costs.

Retention of Students' Work

The college reserves the right to retain indefinite documentation of any student work the faculty may select. All work not retained by the faculty must be claimed at the time specified by the schools concerned. The college assumes no liability for student materials in its custody.

Student Defined Majors

The Student Defined Major program in the College of Fine Arts is designed for the exceptional student, whose area of artistic interest lies outside of any pre-existing program at the University. Student Defined Majors are expected to propose a comprehensive plan of study that combines all of their coursework into a singular focus for their research and artistic practice. To create a successful proposal, the student must engage in additional career and preparatory research outside of their normal coursework. Designing the independent degree program typically takes six months to one year to complete.

Students interested in pursuing this unique degree path should meet with their academic advisors to discuss feasibility. They will then work with the CFA Senior Associate Dean for Academics to ensure that their proposed coursework meets the rigorous requirements of a Carnegie Mellon degree. They will need approval from their academic advisor, faculty mentor(s), relevant Head(s) of School, (Senior) Associate Dean(s), and the Vice Provost for Education. If the proposal is approved and the student has successfully met the requirements of the new major, the degree conferred at graduation will be a *Bachelor of Arts* with a *Student Defined Major: *approved title*.* The CFA Office of the Dean, in consultation with the academic advisor, will determine final certification of the degree. Note that all academic actions and CFA policies still apply to Student Defined Majors.

To apply for a Student Defined Major in the College of Fine Arts, one:

1. Must be a student in good standing at the University.
2. Must have successfully completed at least one semester of study and have at least two semesters left prior to their intended date of graduation.
3. Must have a cumulative QPA of 2.75 or better. (A student whose QPA is under 2.75 may still submit a proposal, but is strongly advised against it. If the proposal is accepted by the CFA Senior Associate Dean for Academics, the student must apply for transitional status for the following semester and will have only one semester to improve his or her QPA to the 2.75 minimum. If the student is not successful in raising the QPA to the 2.75 minimum they will not be permitted to continue with the Student Defined Major. They must either be re-admitted back into their old program or seek admittance into another department or college.)
4. Must have a faculty mentor in the College of Fine Arts who has agreed to mentor the student through the completion of the degree. This mentor should be from the school where the student is taking the majority of their courses, and be approved by the CFA Senior Associate Dean for Academics. If a student wishes to work extensively across colleges, they will need a faculty advisor(s) from their additional area(s) of concentration as well as approval from an Associate Dean of each college involved.
5. Must successfully complete the proposal process and submit all approved documentation with necessary signatures to the CFA Office of the Dean, CFA 100, by May 1 to be effective in the fall semester, and by October 1 to be effective in the spring semester. (Proposals that come in after these dates will be considered, but may not be able to be processed until the following semester.)

Student Organizations

Professional and honorary societies for students in the College of Fine Arts are the American Institute of Architects, Architecture Peer Mentors, Architecture Student Advisory Council, the Design League, American Institute of Graphic Arts (AIGA), Industrial Designers Society of America (IDSA), United States Institute for Theatre Technology (USITT), Phi Mu Alpha Sinfonia (music fraternity for men), Sigma Alpha Iota (music sorority for women), Pi Kappa Lambda (honorary for students in music) and the Music Educators' National Conference.

BXA Intercollege Degree Programs

BACHELOR OF COMPUTER SCIENCE AND ARTS (BCSA), BACHELOR OF HUMANITIES AND ARTS (BHA), BACHELOR OF SCIENCE AND ARTS (BSA), ENGINEERING AND ARTS (EA) ADDITIONAL MAJOR

M. Stephanie Murray, *Director & Academic Advisor*
Location: Posner 150

www.cmu.edu/interdisciplinary

The **Bachelor of Computer Science and Arts** (BCSA) is a four-year intercollege degree-granting program designed for students interested in pursuing fields that comprehensively meld technology and the arts through courses offered in the College of Fine Arts and the School of Computer Science. It combines general education requirements, a concentration of courses in the College of Fine Arts, a concentration of courses in the School of Computer Science, and free electives.

The **Bachelor of Humanities and Arts** (BHA) is a four-year intercollege degree-granting program designed for students interested in blending studies in the College of Fine Arts and the Dietrich College of Humanities and Social Sciences. The BHA degree combines a general education requirement, a concentration of courses in the College of Fine Arts, a concentration of courses in the Dietrich College of Humanities and Social Sciences, and free electives.

The **Bachelor of Science and Arts** (BSA) is a four-year intercollege degree-granting program designed for students interested in combining studies in the College of Fine Arts and the Mellon College of Science. It combines general education requirements, a concentration of courses in the College of Fine Arts, a concentration of courses in the Mellon College of Science, and free electives.

The **Engineering and Arts** (EA) additional major is an interdisciplinary program designed for College of Engineering students interested in developing their skills and interests in an area of the College of Fine Arts while retaining their full engineering curriculum and licensure. It combines a BXA course requirement and a concentration of courses in the College of Fine Arts with a students primary engineering major.

Please refer to Interdisciplinary Programs (p. 791) in this catalog for details.

The Master of Arts Management Program

Location: 1116 Hamburg Hall

The search for both increased support and larger audiences has intensified over the last decade and now, more than ever, arts organizations seek skilled managers. To meet this need, the College of Fine Arts and the Heinz College's School of Public Policy and Management jointly developed the Master of Arts Management (MAM) Program to provide strong leadership in theater companies, dance companies, orchestras, opera companies, museums, galleries and arts policy organizations. In addition to the traditional two-year graduate degree structure, the Master of Arts Management Program provides undergraduate students the opportunity to complete the Bachelor of Fine Arts and Master of Arts Management degrees within a period of five years through the Heinz College's Accelerated Masters Program (AMP). MAM Program alumni can be found managing music and arts service organizations; marketing orchestras, theaters and dance companies; fund-raising for museums, opera companies, ballet companies and public television stations; and managing the finances of university arts departments and private businesses working in the arts and entertainment industry.

College of Fine Arts Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

62-002 CFA Elective
Intermittent: 9 units
TBA

62-010 Pittsburgh Filmmakers
Fall and Spring: 9 units
Any of Pittsburgh Filmmakers full semester course offerings are available for registration through the CFA Dean's Office. Visit https://filmmakers.pfpca.org/ for listings. Registration can only be done on or after your scheduled registration day. Spaces are limited. Stop by CFA 100 for details and to register.

Course Website: http://filmmakers.pfpca.org/

62-102 Modern Dance Workshop
Fall and Spring: 6 units
A modern dance class based on the philosophy of the Martha Graham technique. The class is designed to encourage exploration and discovery of the roots of physical movement and control. The class also covers fundamental and technical aspects of modern dance as a classical performing arts form.

62-105 Exploring Pittsburgh
Fall: 6 units
TBA

62-106 Architecture and the Arts
Fall: 9 units
This interdisciplinary course explores the entangled relationship between architecture and the arts, and their struggle between autonomy and engagement. It will be structured around a series of themes, drawings, and writings that reveal architecture's constantly changing involvement with art, culture, society, and related disciplines The course functions both an introduction to Architecture as Art for a general audience, as well as a critical introduction to architectural thinking and theory for architecture majors. The course will include slide lectures, readings, reading reports, discussions, and a series of research exercises to engage architecture and art more critically, and an exam. We'll examine the common roots, disparate characters, and inter-twined histories of architecture and the arts. We'll investigate not just buildings and art works, but ideas, drawings, images and other representations involved in the construction and reception of architecture that often relate closely to the arts. We'll look at shared terms like composition, rhythm, studio, and form. We'll define architecture in relation to categories such as fine and applied arts, high and low arts, visual and performing arts, and relate these to broad categories such as design, visual culture, and the liberal arts. We'll ask "why" we make architecture and art, rather than "how," and discuss how the human need for expression and meaning can augment the technical and constructed value of mere making or building. We'll debate how the discipline of architecture has been, and can continue to be framed as a fine art, but also act as a service profession, a political tool, a technical expertise, a research endeavor, or as a mode of cultural discourse.

62-110 Passport to the Arts
Fall and Spring: 9 units
Exploring Audience and Ideas in the Arts: "Passport" is an introductory level course that explores the philosophy of aesthetics through direct attendance at performances and exhibitions. The course is constructed in modules that represent each school within the College of Fine Arts (architecture, art, design, drama and music) building toward cross-disciplinary practice. Each module contains a guest lecture, event attendance, and follow-up discussion which serve as points of entry into each discipline as well as points of comparison within the arts as a whole. These three components provide a direct link between theory and practice allowing students to gain a critical vocabulary to discuss their experiences. Outside of class, supplementary readings, audience participation, and written reflections provide an opportunity for students to use course material to enrich their own artistic practice. Ultimately, students are asked to consider their roles as an artist: within their discipline, within the arts, and within the broader community. This course concludes with a final symposium/exhibition of participating students.

62-122 Digital Media I
Fall: 6 units
This course will engage in an overview of foundational workflows in digital media regarding two-dimensional representation techniques for spatial design processes. The course is divided into two topics with one assignment each: Technical Drawing and 2D Graphics. Students are required to submit work at the end of each class, in addition to self-guided work outside of class times: satisfactory completions of the two assignments, specific Lynda tutorials, final project, and final portfolio are required for the successful completion of the course. Through these deliverables, the course will inquire issues of 2D representation as it pertains to the effective communication of technical and conceptual information in spatial design processes. With digital media, designers now have an arsenal of tools that can subvert and augment traditional means of representation with exponentially greater fidelity and efficiency. Students will have an opportunity to practice these values and favor hybrid approaches that strive to blur the boundaries of analog and digital media, so as to learn how to be versatile in leveraging all forms of media for the design task at hand. Students are required to bring their own laptop computers with AutoCAD, Photoshop, Illustrator, and InDesign installed.

62-123 Digital Media II
Spring: 6 units
TBA

62-125 Drawing I
Fall: 6 units
62-125 is an introductory course in free-hand architectural drawing. Its central learning objective is building a capacity for visualizing three-dimensional space through hand-drawing. A parallel objective is fostering visual literacy: the ability to use line and tonal values to represent architectural space. Schedule and Content The course is taught in two three-week segments that alternate with the three-week segments of a parallel course Digital Media 1. It concludes with a final project that is shared with 48-100 Introduction to Architecture. The course has three themes that bridge over the two three-week segments. The first focuses on contour and cross contour to describe surface and space. At its completion, it addresses the appearance of architectural space in perspective. Exercises are inspired by the approach of Kimon Nicolaides, The Natural Way to Draw, to these same subjects. The second focuses on the projection of space using both freehand axonometric and perspective drawing. The third is centered on modeling surface and creating space by using tone. A sculptural approach adapted from Kimon Nicolaides is used and at the end applied to drawing architectural sections. This work is preparatory for the final project.

62-126 Drawing II
Spring: 6 units
TBA

62-135 The Basics of Self-Producing: How to put up your show in NYC and get it reviewed
Fall and Spring: 6 units
For any actor/writer/director/theatre artist in New York City, the time between jobs can feel stressful and frustrating. Self-producing is the quickest way to get your work on stage without permission from anyone else or having to adhere to anyone else's restrictions. From blurbs to budgets to rehearsal space to press releases to equity paperwork, this course covers everything you need to know in order to get your work produced and noticed in New York City without breaking the bank. This course will draw from readings on independent theatre, interviews with working independent producers in New York, and the working experience of Anderson Cook, author/producer of The Disembodied Hand That Fisted Everyone to Death - the Musical!, Blatantly Blaine, Pop Punk High, Donny and Kelly Save the Slumber Valley ASPCA, and more - all produced and reviewed in NYC.

62-141 Black and White Photography I
Fall and Spring: 10 units
This course will teach you the basic craft of photography from exposure of the negative through darkroom developing and printing to print finishing and presentation. Content includes student presentations, class discussions, shooting assignments, darkroom sessions and class critiques. We will concentrate not only on the technical aspects of photography, but also the aesthetics of seeing with a camera. The course concentrates on photography as a fine art — what is unique to it and the concerns that are shared with other visual arts, such as composition, tonal values, etc. and aims to equip students with an understanding of the formal issues and the expressive potentials of the medium. Lab fee and 35mm manual camera required. Each student is responsible for the cost of paper and film.

62-142 Digital Photography I
Fall and Spring: 10 units
This course explores digital photography and digital printing methods. By semester's end students will have knowledge of contemporary trends in photography, construction (and deconstruction) of photographic meaning, aesthetic choices, and the use of color. Students will learn how digital cameras work, proper digital workflow, RAW file handling, color management and Adobe Photoshop. Through the combination of the practical and theoretical, students will better define their individual voices as photographers. No prerequisites. Digital camera required.

62-145 Photojournalism
Fall and Spring: 10 units
Photojournalism is the use of documentary photography to inform mass audiences. This course will examine the role of the photojournalist in modern society, critically examine the use of photography in publication, and give students different types of photojournalistic assignments throughout the semester. The class will evolve to function as its own newsroom photo department.

62-150 IDeATe Portal: Introduction to Media Synthesis and Analysis
Fall: 10 units
To view the different section topics, visit https://courses.ideate.cmu.edu/62-150. Technologists, artists, and designers are engaging in new, interdisciplinary modes to consume, create, and reuse media. To do this, they thoughtfully collaborate and critically reflect on media creation, distribution, participation, interaction, and how media affects the audience. In this course, students will challenge themselves to work in these new modal contexts by thinking critically in a genre of exploration. They will formulate the intent of their creative work, articulate relationships to art/design practice and theory, and respond insightfully to creative, media-rich outcomes. The class will introduce core concepts through foundational texts, in-class exercises, collaborative projects, and group critique. Through hands-on media exploration, students will ground concepts such as embodiment, emergence, composition, participatory interfaces, and mediated experiences. Section A will be an Introduction to Textile Media. Section B, will be an Introduction to Mediascapes: 2D to 3D Spatial Environments. Section C will be an Introduction to Digital Storytelling + Archives. For more detail on these sections, please visit https://courses.ideate.cmu.edu/62-150

Course Website: https://courses.ideate.cmu.edu/62-150

62-165 Mutable Landscape:
Intermittent: 10 units
With camera in hand, students will explore, document and invent a sense of place in Pittsburgh. Informed by photographic history and landscape studies, students will develop their own portfolios of digital prints. As a CFA Interdisciplinary photography course, students will be encouraged to consider their photographs in the medium of their home department, and in some cases as a starting point for projects in other materials. No prerequisites.

62-175 Descriptive Geometry
6 units
This is a manual construction course for solving problems in three-dimensional geometry through working with two-dimensional planes using basic mechanical drawing tools. The course covers basic concepts of descriptive geometry; solving problems involving lines and planes in space and their spatial relationships; rotations in three dimensions; locating points and tangents on solids and surfaces; intersection of solids; shades and shadows; perspectives; and development of surfaces.

62-188 Introduction to Playwriting
Intermittent: 6 units
Add description

62-193 Intro to Screenwriting
Intermittent: 9 units
Ever watched a terrible movie and thought "I can do better than that?!" Or seen a beautiful film and had the opposite reaction: "I could never do that!" Then this is the class for you! This practical skills course will provide students with the tools they need to construct compelling, image-driven screenplays. Students will be writing throughout the semester, ultimately preparing them to complete a polished script of a short film as a final project. Assignments will include reading masterwork screenplays for in-class analysis. Class time will also be dedicated to roundtable readings & discussions of each other's writing.

62-194 Advanced Playwriting
Spring: 9 units
In this class students will fine-tune their individual voices as writers and break outside the conventional notions of what a play should be. Students will read texts by playwrights that experiment with structure and theatricality, partake in writing exercises meant to tap into creative impulses, and receive feedback on their plays throughout the semester.

62-195 Writing Satire for the Stage
Fall: 9 units
In this course, students will experiment with writing satire through creating sketches, plays, and other methods of performance. Students will read plays by Branden Jacobs-Jenkins, view sketches from The Second City, and see performance art by Young Jean Lee. The course will provide students with the basis of creating different forms of satire in ever-changing political climates.

62-196 Screenwriting
Spring: 9 units
This course is designed to give writers a variety of tools they can use in writing or rewriting a current project full-length screenplay. There will films assigned to watch and analyze. Either a first draft or a rewritten version of a full length screenplay is to be completed by the end of the semester. Prerequisite: None.

62-207 IDeATe: Variational Geometry I
Fall: 6 units
This course will introduce concepts and strategies for the modeling and development of complex computational geometry for 3D printing purposes and introduce algorithmic thinking using the Rhinoceros McNeel platform and Grasshopper plugin. This course is intended for students with no or little 3-D modeling skills to advance their abilities in modeling, digital prototyping and visual communication.

Course Website: http://ideate.cmu.edu/about-ideate/departments/college-fine-arts/ideate-variational-geometry-i/

62-208 Alternative Photography: Contemporary Antiquarian Printmaking
Intermittent: 5 units
This focused, making-based course explores antique, handmade printmaking/photography methods through contemporary techniques. Students will learn how to make light-sensitive papers, while creating their own negatives digitally, combining both processes in a traditional darkroom. Students will use the Van Dyke, Cyanotype, and Platinum printing methods from start to finish, creating handmade, unique images that are distinct from those made with digital processes alone.

62-214 Photography and the Narrative of Place
Intermittent: 5 units
This half-semester course will use photography to develop understandings of our surrounding environments. Students will choose a single location to work in, photographing and researching its function in the community, its history, and its relationship to broader concepts and similar spaces. Weekly assignments will require students to work with a variety of photographic methods to construct a narrative that derives meaning from the complex connections between people, objects and the spaces they inhabit. Throughout the course, students will strengthen their understanding of the ways in which these tangible and abstract elements of our environments work together through in-class exercises, weekly discussions and critiques. The course work will culminate in a portfolio of the completed project. The class will study work and books by notable and emerging figures in the medium, including Robert Adams, Carolyn Drake, Roy DeCarava, Rinko Kawauchi, Alec Soth, Carrie Mae Weems, Zoe Strauss, Gregory Halpern, and Susan Lipper. Required readings will include essays and short stories by Wendell Berry, Rebecca Solnit, Teju Cole, Joan Didion, and Georges Perec.

62-225 Generative Modeling
Fall and Spring: 9 units
This course introduces students to the fundamentals of generative modeling using computer aided design as practiced in the field of architecture. Core competencies will be developed through modeling projects and software intensive labs, while a broader critical framework for conceiving of contemporary and historical parametric practices will be encouraged through periodic lectures. Emphasis will be placed on careful consideration of digital mediums and developing a sense of craft related to digital modeling in the hope that students will become conscientious makers and consumers of digital content. Students will be encourage to understand and apply algorithmic problem solving to the many design constraints encountered in architecture. The course will explore the relationship of parametric workflows to design thinking and will situate contemporary trends in a broader framework of computational design. The course will also forefront complex form-making as a response to bio-mimicry, systems thinking, and mass-customization. Rather than positioning parametric modeling as a disruption of historical architectural design process, the course will encourage students to consider how new tools might augment the discipline's historical commitments to orthographic projection, perspectival drawing, and physical modeling.

62-235 Photographing America
Intermittent: 10 units
In this course, students will create an original photographic project that responds to a legacy of photography that has described and critiqued the United States of America, its aspirations, and its challenges. Through readings and class discussion, students will examine a range of projects that addresses notions of America or an American character, including writing and photography produced by both American and foreign observers, including Walker Evans, Robert Frank, Diane Arbus, Stephen Shore, Hank Willis Thomas, Justine Kurland, Vanessa Winship, and others. As students learn about how America has been seen, they will develop their own "American" body of work, culminating in a portfolio project. There is no prerequisite, but students must own a camera, know how to use it, and be familiar with Adobe Photoshop and digital output. Students who have not taken Digital I should contact the instructor before the course begins.

62-240 Unfolding Environments: The Intersection of Person and Place
Fall and Spring: 10 units
This course will use photography to explore our surrounding environments. Assignments will focus on editing and image sequencing, combining the practices of portraiture, landscape, still life and observational photography to create narrative work that explores the complex connections between people, objects and the spaces they inhabit. Throughout the course, students will strengthen their understanding of the ways in which these tangible and abstract elements of our environments work together, while also developing their technical abilities by working with color and black and white images and varied light sources. Students will also learn approaches to project development and digital workflow. Discussions, readings, gallery visits and critiques will provide an outline for completing assignments. The class will study work and books by notable and emerging figures in the medium, including Robert Adams, Rineke Dijkstra, Carolyn Drake, Roy DeCarava, Milton Rogovin, Judith Joy Ross, Rinko Kawauchi, Alec Soth, Larry Sultan, Carrie Mae Weems and Susan Worsham. Required readings will include essays and short stories by Wendell Berry, Rebecca Solnit, Robert Walser and Albert Camus.

62-241 Black and White Photography II
Fall and Spring: 10 units
This course allows you to gain experience with medium and large format film cameras while emphasizing aesthetic development and personal artistic growth. As an advanced student, you have access to an unusual assortment of panoramic and pinhole cameras that will change the way you make photographs, revealing unknown perspectives. Additional topics include digital process though negative scanning and inkjet printing, advanced monotone printing methods, and a focus on exhibition and folio presentation. Cameras will be supplied for this course.
Prerequisites: 60-141 or 62-141

62-245 Portrait Photography
Intermittent: 10 units
Portrait Photography explores the emotional and visual process of collaboration between subject and photographer that creates a photograph. We use cameras of all formats and levels of sophistication to create portraits in the studio and on location. Each photographer is challenged to find and exploit available light, and create artificial light to complete his or her vision. The class will explore a wide range of digital and darkroom strategies to support and add richness to their final prints. Through film and video photographers will meet some of the masters of this form like Arbus, Newman, Avedon, and Penn. Together we will take advantage of any opportunities to visit exhibitions and photographer's studios. Lab fee required. Prerequisites: As listed or consent of instructor.

Course Website: http://cfaphoto.cfa.cmu.edu/classesf17.html

62-247 Introduction to Hot Glass I
Fall and Spring: 3 units
In this introductory class, learn to gather clear molten glass from the furnace and then shape it into various forms, from paperweights to simple blown shapes, such as cups and bowls. Instruction focuses on a team approach to glassblowing, with an emphasis on safety, proper tool use, basic techniques, and materials. You'll never drink from a glass again without appreciating the energy and detail that went into making it! Little to no hot shop experience is required. You may also wish to take this class a second time in order to continue to develop and refine basic skills before moving on to Hot Glass 2. Each time you take it, your skill level, confidence, and passion for glass will grow. Class tuition includes 2 hours of open-studio time to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please go to CFA 100 to register. Course fee is $287.50. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org/

62-250 Beads, Beads, and more Beads
Fall and Spring: 3 units
Make colorful beaded necklaces or stunning drop earrings using components you've designed and created yourself! Many beads will be created over the course of 8 weeks as you learn the basic skills of heating Moretti (soft) glass, applying it to a mandrel, then using gravity and tools to shape it. First, learn to make round beads and alter their shape. Then, learn to add decorative color with techniques like encasing, dots, frits, trails, and more. While this class is for beginners, those with experience will focus on more advanced decorative techniques and shapes so they can take their beadmaking to the next level. Class tuition includes 2 hours of open-studio time to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $175. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

62-251 Pendant Passion
Fall and Spring: 3 units
Spend 8 weeks creating your own collection of unique Borosilicate (hard glass) pendants. Learn to melt and manipulate glass while absorbing a number of different flameworking techniques and building a solid flameworking foundation. Some of the many techniques covered include compression, donut hole, dot stacks, and wrap and rake. This class is suitable for all levels, whether you are a beginner or a more experienced flameworker seeking to hone your torch and pendant-making skills. Class tuition includes 2 hours of open-studio time to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $175. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org

62-252 Marble Madness
Intermittent: 3 units
Learn how to create a perfect sphere in soft Italian glass. You will begin with the basics of gathering and shaping the sphere. Then you will explore a number of decorative techniques and make various types of marbles from an onion skin, cat's eye, vortex and implosion to name a few. No experience is required but more advanced students will also benefit. The class fee includes 2 hours of open studio time per student to be used during the same class session. This will help students become familiar with the studio and learn the simple process of studio rental outside of class hours. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $175. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org

62-256 Introduction to Coldworking
Fall and Spring: 3 units
Learn about all of the equipment in the cold shop including belt sanders, flat grinders, dremels, lathes, the sandblaster, and the diamond saw. These tools can be used to create intricate patterns and textures on the surface of a variety of glass objects. You will complete several personalized projects. Students with no prior glass experience will be provided items to cold work, but students with eisting work they want to refine from other studios are welcome as well. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please register for this course in person at CFA Room 100. Spaces are limited. Course fee is $122.50. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

62-265 Alternative Photo Processes
Spring: 10 units
This experimental photo-printmaking hybrid introduces students to 19th century, non-silver and alternative photographic printing techniques. One-of-a-kind, hand-applied processes include: Van Dyke, cyanotype, salted paper, POP, albumen, platinum & palladium and bromoil. Students will produce large format imagery by use of traditional large format shooting, analogue negative enlarging and/or digital negative methods. In addition to the printing techniques, the class considers how to unite process with concept.
Prerequisites: 51-265 or 62-141 or 60-141

62-275 Fundamentals of Computational Design
Fall and Spring: 9 units
As analog mechanisms; as metaphors; as bodily extensions or prosthetics; as material systems; as building envelopes; as partners or slaves of humans. This course takes computers outside the box and outlines a journey of discovery revealing computation as the connective tissue encompassing multiple facets of architecture and design culture and experience. Addressing conceptual and practical aspects of the relationship between computation and design, the course explores the fundamentals of generative and rule-based systems for designing and making, environmental simulation and responsiveness, and basic approaches to creative data processing, visualization, and materialization.The course offers a holistic view of computation, exploring the different roles computing plays in the design of our artificial environments. The course is driven by themes, each combining state of the art examples, historical insight, and hands-on computational exploration.
Prerequisite: 48-100

62-306 Music-Cinema-Culture
Fall: 9 units
This course reviews the first 100 years of the twentieth century's only original art form whose advent has brought about tremendous social and cultural changes. Students screen selected films, learning first the basics of film theory, cinema's working structures and the function of music. Ultimately, they analyze, in the form of a written essay, the function and value of the music in a particular film and the cultural impact such music has had on society. The work of the course involves attendance at screening and active participation in analytical discussions. Students are expected to present one report consisting of a critical review of the reading assigned. A final examination dealing with some film theory, music, and cultural politics will conclude the course.

62-314 The Art of Personal Finance
Fall and Spring: 6 units
Money is an inevitable part of our everyday lives. Managing the money we earn and living within our means is essential to ensure that we have the freedom to do what we want to do with our lives. However, even if we successfully eliminate debt and save for the future, true financial freedom will not exist unless we have a plan to guide us on our way. In this course, students will create a simple one-page financial plan that they can use to guide them through their next several years as they cultivate the skills that will ensure their artistic success. Additionally, they will develop the tools needed to support the execution of the plan and create a sourcebook of information they can refer to in the future as their lives (and their financial plans) change. For DRAMA students only.

62-315 IDeATe: Shaping the Built Environment: Experiments in Geometry and Matter
Fall
Shaping the Built Environment is a project based design-research seminar immersed in physical prototyping. SBE investigates adaptive dynamic behaviors inspired by natural processes and biomimetics as a basis for design ideas. Students are introduced to computational design thinking, material research, performance based design and digital fabrication techniques. Design process is centered on contemporary digital modeling techniques to incorporate environmental information into iterative design processes and form making. The objective of this seminar is to speculate about translation of performative contingencies into shaping material systems informed by data sets and simulation. We engage design processes in which systems' performance metrics underpin creative exploration of organization and form. The seminar results in the design and prototype of an individually proposed project. Students are immersed in digital parametric tools and contemporary digital fabrication processes, including 3D printing, CNC milling, vacuum forming and mold casting.

62-325 View Camera
Intermittent: 10 units
The nature of a 4x5" view camera alters both the process of making a photograph and the qualities of the resulting image. The slow, even cumbersome, process of photographing with a large format camera encourages a methodical, studied approach. The larger negative size and the ability to control the exposure and development of each sheet of film make possible an image of extraordinary clarity and detail. Through a series of exercises followed by a self-selected project, students in this class will learn the technical aspects, and master the use of, the view camera. Topics include: perspective and focal plane control, bellows extension factor, and basic B&W sheet film handling and processing. Students should enter this course already possessing a working knowledge of photographic processing and printing. Prerequisites: 62-141 and any 200 level photo course or consent of instructor.
Prerequisites: 62-241 or 62-245 or 62-337 or 62-205 or 62-381 or 62-326 or 62-265 or 62-141

62-326 Photographic Narrative
Intermittent: 9 units
Most photographs tell stories. We see photographs in newspapers, magazines, snapshot albums, on the web, in books, and in posters. In these contexts photographs often work with words to convey meaning, whether they are shown with captions, news stories, or just with titles. Photographs can work without words, too, to create purely visual narratives. In this course, students will make two series of photographs: one that is fiction and one that is non-fiction. In addition to making photographs, students will determine the context in which their photo-stories will be seen. Students may make photo books, for example, or decide that their images will be seen on a website. While students are making photographs, we will explore the rich traditions of photo-graphic story-telling that range from the world-oriented work of photo-journalist W. Eugene Smith to the documentarians such as Walker Evans, Nicholas Nixon, and Alec Soth. We will look at photographers, too, who constructed private worlds, such as Duane Michals, Cindy Sherman, Bruce Charlesworth, and Laurie Simmons. As students explore both fiction and non-fiction through photographs, we will look at the interesting interplay between words and photographic images; how images are paced and scaled to create tempos; how photographs are sequenced to tell stories; and other formal elements involved in creating visual narratives. Prerequisite: a college level photography course or consent of instructor.
Prerequisites: 62-141 or 60-141 or 51-134

62-330 Filmothea: Seminar in Film Music
Summer: 9 units
The first 100 years of the 20th Century's only original art form, whose advent has brought about tremendous social and cultural changes. Students view selected films, learning first the basics of film theory, cinema's working structures and the function of music soundtrack. Ultimately, they are able to analyze in written essays and class discussions, the function and value of the music in a particular film and the cultural impact such music has had on society. The work of the course involves attendance at screening and active participation in the following analytical discussions. Students are expected to present two written reports on films/readings and sustain a final oral presentation.

62-332 Teaching and Learning
Spring: 6 units
In this course, students will learn about effective strategies for teaching architecture and the built environment. Topics include the cognitive differences between novices and experts, instructional techniques, and goal alignment. As part of the coursework, each student will implement these teaching strategies to design and teach a lesson. Elements of developmental psychology, learning theories, and classroom practices will inform the architectural education lesson. Teaching and learning techniques can be generalized for communication with clients, practice, and the community.

62-347 Hot Glass II
Fall and Spring: 3 units
Now that you're hooked on hot glass, how do you keep the momentum going? By enrolling in Hot 2, you will become more proficient working with glass. Refine and vary the cup and bowl shape in the first few weeks before moving on to more complex shapes. Explore basic methods of color application and learn how to troubleshoot common problems. Class tuition includes 1 hour of open-studio time per student (2 hours with a partner) to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. You may also wish to take this class a second time in order to continue to develop and refine basic skills before moving on to Hot 3. Hot I, 24 hours of hot shop experience, or instructor permission is required. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $287.50. Not eligible for PCHE cross registration. Course taught at the Pittsburgh Glass Center.
Prerequisite: 62-247

Course Website: https://www.pittsburghglasscenter.org

62-358 Art and Biology
Intermittent: 9 units
A studio-laboratory art-making course designed to explore interactions between art and biology. It is an opportunity for students interested in interdisciplinary concepts to work both in a studio art environment and a biological laboratory. Students have the opportunity to experiment creatively with scientific media such as electron and video-probe microscopy.

62-360 Photographers and Photography Since World War II
Spring: 9 units
Invented in 1839, photography was a form of visual expression that immediately attracted a large public following. Starting around 1900, photography was practiced with two dominant strands. One of these firmly believed in the power of photographs to provide a window on the world, and was led by Lewis Hine, whose documentary photographs for the National Child Labor Committee helped to ameliorate living and working conditions for thousands of immigrant children. The other strand adhered to the philosophy of Alfred Stieglitz who adamantly affirmed that photographs were first and foremost reflections of the soul and were art objects, equal to painting, drawing and sculpture. These two schools of thought guided photographers throughout the twentieth century. This course explores in depth the tremendous range of photographic expression since World War II and examines in particular the contributions of significant image-makers such as Helen Levitt, W. Eugene Smith, Robert Frank, Diane Arbus, Garry Winogrand, Charles "Teenie" Harris, Cindy Sherman, Carrie Mae Weems, Nan Goldin, James Nachtwey, and many others. Classes include a slide lecture, student presentation, and video segments that introduce a focused selection of images by major photographers in an attempt to understand their intentions, styles, and influences.

62-361 Trajectories in Photography: From its Prehistory to 1945
Fall: 9 units
This course explores the development and practice of photography in relation to the massive social and political changes of the 19th and early 20th centuries. Topics will address modernity's embrace of the visual: photography's role in the rationalization of geographies and peoples; the promises of photography as a new technology; the position of photography in relation to developments in art; the emergence of photojournalism and documentary photography and the use of photography for advocacy; photography in relation to mass media; the photography of spirits and costumed animals. The course draws from various disciplinary perspectives including art history, anthropology, history, and science and technology studies. The course will include instructor lecture and student presentation. Class discussion will be an integral aspect of the class. No prerequisites.

62-362 Activating the Body: Physical Computing and Technology in Performance
Intermittent: 10 units
Activating the Body: Physical Computing and Technology in Performance investigates the fundamentals of electronic computation through performative dialogue with human embodiment. In this advanced studio course, students explore the body and technology as sculptural elements to be manipulated. The course examines the basis of analog and digital computation alongside contemporary, avant-garde, and traditional sculpture, installation, performance, dance, and theater. Students learn the fundamentals of electrical flow and construct functional embodied digital gates, as well as higher-level manipulations of sensors and actuators using the Arduino platform. Major themes in contemporary creative practice are addressed through readings, viewings, field trips, and the creation of original work. Students broaden and deepen conceptual skills and increase the scale, ambition, and finish of creative output. Throughout the semester students complete a series of quick thematic exercises and larger-scale projects; these works are reviewed through individual meetings, group critique, and documentation. The course culminates in an end-of-semester showcase where students exhibit site-specific work on or off campus with the option to participate in the annual Subsurface event.

62-371 Photography, The First 100 Years, 1839-1939
Fall: 9 units
Photography was announced to the world almost simultaneously in 1839, first in France and then a few months later in England. Accurate "likenesses" of people were available to the masses, and soon reproducible images of faraway places were intriguing to all. This course will explore the earliest image-makers Daguerre and Fox Talbot, the Civil War photographs organized by Mathew Brady, the introduction in 1888 of the Kodak by George Eastman, the critically important social documentary photography of Jacob Riis and his successor, Lewis Hine, the Photo-Secession of Alfred Stieglitz, the Harlem Renaissance of James VanDerZee, the precisionist f64 photographers Ansel Adams, Imogen Cunningham, and Edward Weston, and other important photographers who came before World War II. The class will be introduced to 19th century processes, such as the daguerreotype, tintype, and ambrotype, as well as albumen prints, cyanotypes, and more.

62-375 Large Format Photography: The Antiquarian Avant-Garde
Intermittent: 10 units
This course takes part in the anti-digital movement by exploring the roots of photography. Students will shoot with an array of large format cameras and use 19th and 21st century processes to create one-of-a-kind photographic imagery. Course topics include view camera techniques, experimental printing processes, pinhole camera-less photography, and contemporary tin-types. Prerequisites: As listed or equivalent or consent of instructor.
Prerequisites: 62-141 or 60-141

62-376 Meaning in Images
Intermittent: 4.5 units
Images abound in our culture. This course takes a critical look at many different kinds of photographic images to understand how they operate in our culture to inform, persuade, and entertain various audiences. The content for this course will be generated from looking at, thinking about and discussing issues discovered while studying well-known to lesser-known images that range from photographs used in ad campaigns, to photographs that are used in scientific representation, to snapshots in family photo albums, to photographs that are used to show social injustices, to photographs that exist in museum collections. Readings will be assigned and short writing exercises will be required throughout the semester. In addition, photography assignments will be given. Design majors will have preference. Requirement: a digital camera.

62-418 Theater Architecture II
Spring
CMU's Theater Architecture Program is a multi-disciplinary collaboration of the College of Fine Arts' Schools of Architecture and Drama and Heinz College's Department of Arts Management. Founded in 2008, it is led by Hal H. Hayes, AIA, Studio Professor of Architecture, and Dick Block, Professor and Associate Head of Drama, with participation and collaboration by Drama & Architecture professor Cynthia Limauro and Heinz College associate dean Kathryn Heidemann. The program is an intensive semester comprised of a coordinated design studio in Architecture, a multi-disciplinary theater architecture seminar, live performance attendance, venue tours, research and analysis, and meetings with professionals in the design, construction and operation of theaters and performance production. The curriculum includes research into the history and development of theater building typology, contemporary best practices and future trends of theater architecture, space programming, planning and design of theater buildings. The theaters that are the subject of the design projects are based on real projects and include the active participation of the theaters' artistic and administrative leadership, the professional design teams engaged in the project, public officials and potential users of the proposed facility. Endowed support for the Theatre Architecture Program is provided by CMU Drama alumnus Len Auerbach, ASTC and J.R. Clancy, Inc.. Logistical support and project participation has been provided by Alvin Ailey American Dance Theater, Arup, H3 Hardy Collaborative, HOK, Jazz at Lincoln Center, The Joyce Theater, The New Hazlett Theater, New York City Economic Development Corp., Perkins + Will, Pittsburgh Cultural Trust, Pittsburgh Public Theater, Point Park University, Port Authority of NY and NJ, The Public Theater, Quantum Theater, Related Companies, San Francisco Symphony, Signature Theatre, SOM, Theatre For A New Audience.

62-420 Aesthetics and Critical Judgement
6 units
In this course, we will examine the question of how one judges a work of art. The course will provide an overview of the history of aesthetics in the Western tradition, and in the process we will examine the central questions of: defining beauty, evaluating the artistic object, determining what external factors are relevant to aesthetic judgments (time, culture, biography), and analyzing the inter-relationships between artist, audience, and artistic object. Beyond the knowledge gained, course objectives will include the cultivation of analytical skills in evaluating artistic expression and aesthetic theory, and the development of expository writing and speech skills in aesthetic analysis.

62-442 All about the Patterns
Intermittent: 3 units
Take your fusing to the next level by creating unique patterned glass. You will learn a variety of pattern bar techniques and how to incorporate each into fused platters or decorative wall hangings. Introduction to Fusing and Slumping or 24 hours of fusing experience with permission of the instructor is required. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $217.50. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

62-443 Intermediate Fusing
Intermittent: 3 units
We will focus on perfecting our glass cutting skills and knowledge while revisiting ideas and techniques from introduction to fusing and slumping. Students will learn new ways to make their work unique by exploring color, creating their own art glass and being introduced to pattern bars while continuing to explore the scientific properties of glass and why it behaves the way it does. Students will be allotted a small color credit to their PGC account in order to become familiar with the simple procedure of purchasing materials for studio rental outside of class. Introduction to Fusing and Slumping or 24 hours of fusing experience with permission of the instructor is required. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $217.50. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org

62-444 Scratch the Surface: Color Techniques
Intermittent: 3 units
Immerse yourself in a world of endless techniques of color applications. Students will begin building a solid foundation in flameworking while focusing on wrap & rake, pin-wheel designs, dot stacks and much, much more. While growing comfortable behind the torch a number of items will be made: marbles, pendants and small sculptures. Join us & get your creative juices flowing! students will be allotted a small color credit to their PGC account in order to become familiar with the simple procedure of purchasing materials for studio rental outside of class. Flame I, 24 hours experience or permission of the instructor required. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $175. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

62-445 Stained Glass Table Lantern
Intermittent: 3 units
Over the course of 8 weeks, you will create a three-panel stained glass table lantern using the Tiffany foiling method. This class is a great start for beginners. It will cover all the basics of stained glass while also offering a new approach for those with previous stained glass experience. Students will choose from preselected patterns that match their skill level and will leave the class with a finished project that will light up any room. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $217.50. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org

62-446 Hot Glass III
Fall and Spring: 3 units
This class encourages focus on the techniques that interest you as a developing glass artist while still allowing for instructor-guided direction and support to refine basic skills and methodology. As you create unique vessels, learn about a broad range of more complicated techniques, including the use of solid colors, mold-blowing, and the creation of compound shapes. This class can be repeated as content will vary by session. You may also wish to take this class a second time in order to further develop and refine skills before moving on to Hot 4. Basic materials are provided. You will be allotted a $15 materials credit to use during this class session in order to become familiar with the procedure of purchasing materials and securing studio rental beyond class hours. Hot 2, 48 hours of hot shop experience, or instructor permission is required. Registration takes place in CFA 100 on or after your scheduled registration day. Space is limited. Registration is first come, first served. Course fee is $287.50. Classes are taught at Pittsburgh Glass Center
Prerequisite: 62-347

Course Website: https://www.pittsburghglasscenter.org

62-447 Hot Glass Open Projects
Fall and Spring: 3 units
There will be no weekly demonstration by the instructor. Students in this class will be encouraged to pursue their own ideas and maximize the available work time each week. Students should come to class with projects in mind and questions for the instructor. 48 hours hot glass class/workshop experience required, or by permission of the instructor. Basic materials provided. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.
Prerequisite: 62-347

62-450 Flame I
Fall and Spring: 3 units
Learn flame shop essentials and introduces a variety of creative techniques while working with both Moretti (soft) and Borosilicate (hard) glass. Begin with a solid rod of glass and melt it into a molten ball that can be manipulated into little treasures, such as beads, pendants, marbles, chains, and sculptures. Over the course of 8 weeks, learn color application, hand control, and annealing. The instructor will also provide one-on-one troubleshooting. Class tuition includes 2 hours of open-studio time to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course fee is $175. Not eligible for PCHE cross registration. Course taught at the Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org

62-452 Flame II
Fall and Spring: 3 units
Build on what you learned in Flame 1: continue to develop hand and glass control, learn to effectively multitask, and develop a greater confidence with a variety of techniques. You'll discover new skills, including working with borosilicate tubing, color application and focusing on personal projects. Both group and one-on-one demonstrations will be provided as students work independently. Flame 1, 24 hours of flameworking experience, or permission from the instructor is required. Course is taught at the Pittsburgh Glass Center. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please go to CFA 100 to register. Course fee is $175. Not eligible for PCHE Cross Registration.
Prerequisite: 62-450

Course Website: https://www.pittsburghglasscenter.org/

62-453 Introduction to Fusing and Slumping
Fall and Spring: 3 units
Even though sheet glass is used, fusing has many dimensions. Harness the heat of the kiln and explore a wide selection of glass materials to produce an array of functional works of art. Learn multiple creative techniques, including full and tack fuses, the effective use of glass powders and frits, and the method by which faux murrine patterns are produced. Among the many topics covered will be kiln theory, glass compatibility, bubble control, kiln programs, and coldworking. Class tuition includes 1 session of open-studio time per student to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course Fee is $217.50. Not eligible for PCHE cross registration. Course taught at the Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org

62-455 Intro to Found Object and Life Casting
Fall and Spring: 3 units
Combine sculpting and building molds with the heat of the kiln to create cast glass sculptures. Learn kilncast by creating small 3D objects. Work with silicones and other mold making materials for the lost wax casting process and then make glass replicas of found objects. You will also explore life casting using alginate. This class will cover model construction, refractory molds, glass preparation, firing and resolving castings into finished works of art. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please go to CFA 100 to sign up. Spaces are limited. Course Fee is $217.50. Not eligible for PCHE cross registration. Course taught at the Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org

62-456 Fused and Slumped Glass-Phase II
Fall and Spring: 3 units
We will focus on perfecting our glass cutting skills and knowledge while revisiting ideas and techniques from introduction to fusing and slumping. This class will focus on your ideas and desired finished projects while raising the caliber of work you create. New techniques will be discussed as student designs require. 24 hours of fusing class/workshop experience required, or permission of the instructor required. Basic materials provided. Registration can only be done on your scheduled registration day and is done on a first come, first serve basis. Please register in person at CFA 100. Spaces are limited. Course Fee is $205. Not eligible for PCHE cross registration. Course taught at Pittsburgh Glass Center.
Prerequisite: 62-453

62-459 Intro to Stained Glass
Fall and Spring: 3 units
Explore the Tiffany method of stained glass while creating your very own panel from a variety of provided patterns. Learn the basic skills of cutting and shaping sheet glass, foiling the pieces, and soldering them together to create a mosaic-like whole. Once you master the pattern supplied and understand the intricacies of the process, you can begin to create luminous panels of your own design. Registration can only be done on or after your scheduled registration day. Please stop by CFA 100 to register. Registration is first come, first served. Course fee is $217.50. Class is held at Pittsburgh Glass Center.

Course Website: https://www.pittsburghglasscenter.org

62-464 Earring Clinic with Michael Mangiafico
Intermittent: 3 units
Explore the world of mandrel flameworked hanging style glass earrings through melting colorful soda lime glass that was manufactured in Italy. We will explore, make and incorporate traditional Venetian Zanferico that's fancy glass canes into delicate ornaments for the ears. Pursue the anatomy of a well-proportioned earring all the while playing with sparkly dichroic coated glass and learning how to put together a good loop for the pendant.

62-471 Photography/Print Workshop
Intermittent: 10 units
In this course in Photography and Print, students will develop semester-long individual projects in contemporary photography, printmaking, artists books and/or multiples. Students will work in photography (traditional, alternative or digital processes) or print media (silkscreen, lithography, intaglio, monotype, etc), considering the ways one extends into the other, and the way that lens-based imagery might intersect with the hand-made. Readings, regular discussion, critique, field trips, and visiting artists will enhance the conversation and research. As a workshop, this course is for students who are ready to explore their work more deeply and create ambitious self-driven projects

62-473 Books, Zines, and Multiples
Intermittent: 10 units
In this course, we will explore the possibilities for working with books, zines, and multiples as democratic prints, sculptural objects, site for time-based narratives, drawing, writing, documentation and so on. Students will be encouraged to experiment with a range of approaches to subject matter and form, with an eye on the relationship between originals and copies.
Prerequisite: 62-141

62-475 ACTIVATED ANAMORPHS: Performative Inhabitables and Interactive Prostheses
Fall and Spring: 10 units
This interdisciplinary studio course is centered around the relationship between wearable sculpture, prosthetic apparatus, DIY costume, movement, and identity-based performance. The course emphasizes hands-on experience, the development of visual skills, craftsmanship, conceptual development, and performance techniques. Class time will be spent designing and fabricating performative devices that alter, augment, mask, and transform the body and its inherent abilities. Various lectures, workshops, activities, presentations, and critiques will be included as an integral part of the learning process. Guest instructors from across the College of Fine Arts and outside of the institution will also provide lectures, and workshops that offer students multiple perspectives and techniques. Students will work in a variety of media, unveiling the meanings expressed through materials and investigating new ways to interact with our physical environment(s) through explorations in the adaptation, translation, enhancement, exaggeration, modification, and mutation of the human body. The course will involve student collaboration across disciplines, as well as rehearsals and public performances TBD.

62-478 IDeATe: digiTOOL
Fall and Spring: 6 units
This course serves as an introduction to the fundamental concepts, processes, and procedures to utilize digital and traditional equipment within the IDeATe facilities in Hunt Library. After completion, participating students should leave with a thorough understanding of the CNC workflow, 3D modeling, 3D printing, laser cutting, engraving, and basic finishing techniques. Students will learn how to operate in a safe, responsible, and efficient manner. This comprehension and experience proves useful for all creative disciplines, and participants are certified for future fabrication equipment access.

Course Website: https://courses.ideate.cmu.edu/62-478

62-483 Growing Theatre Community Outreach
Fall and Spring: 6 units
Growing Theater engages students and mentors in the development of a collaborative theater experience. Through Mentor Role Modeling, Growing Theater uses drama as a medium to expose at risk population of fifth graders from a local school to a supportive learning environment that is shared, creative, confident, patient and respectful. Growing Theater Mentors will broaden students' personal and professional outlooks by guiding through them this theatrical process. The resulting play is performed in May at CMU. This course is open to all students, not just Drama majors.

62-661 Interaction and Expression using Pausch Bridge Lighting
Fall and Spring: 3 units
Working in cross-disciplinary teams, students will explore light as art, interactive design and programming using a Pharos lighting control system. Students will explore the use of light and interaction using the actual controls within the Randy Pausch Memorial Bridge. Student teams will develop final projects that will be exhibited on the actual Randy Pausch Memorial Bridge.

62-707 Introduction to Computational Geometry and Algorithmic Modeling
Fall: 6 units
This course will introduce concepts and strategies for the modeling and development of computational geometry for 3d printing purposes and introduce algorithmic thinking using the Rhinoceros McNeel platform and Grasshopper plugin. This course is intended for students with no or little 3-D modeling skills to advance their abilities in modeling, digital prototyping and visual communication.

Course Website: http://ideate.cmu.edu/about-ideate/departments/college-fine-arts/ideate-variational-geometry-i/

62-708 Theater Architecture I
Spring: 6 units
CMU's Theater Architecture Program is a multi-disciplinary collaboration of the College of Fine Arts' Schools of Architecture and Drama and Heinz College's Department of Arts Management. Founded in 2008, it is led by Hal H. Hayes, AIA, Studio Professor of Architecture, and Dick Block, Professor and Associate Head of Drama, with participation and collaboration by Drama & Architecture professor Cynthia Limauro and Heinz College associate dean Kathryn Heidemann. The program is an intensive semester comprised of a coordinated design studio in Architecture, a multi-disciplinary theater architecture seminar, live performance attendance, venue tours, research and analysis, and meetings with professionals in the design, construction and operation of theaters and performance production. The curriculum includes research into the history and development of theater building typology, contemporary best practices and future trends of theater architecture, space programming, planning and design of theater buildings. The theaters that are the subject of the design projects are based on real projects and include the active participation of the theaters' artistic and administrative leadership, the professional design teams engaged in the project, public officials and potential users of the proposed facility. Endowed support for the Theatre Architecture Program is provided by CMU Drama alumnus Len Auerbach, ASTC and J.R. Clancy, Inc.. Logistical support and project participation has been provided by Alvin Ailey American Dance Theater, Arup, H3 Hardy Collaborative, HOK, Jazz at Lincoln Center, The Joyce Theater, The New Hazlett Theater, New York City Economic Development Corp., Perkins + Will, Pittsburgh Cultural Trust, Pittsburgh Public Theater, Point Park University, Port Authority of NY and NJ, The Public Theater, Quantum Theater, Related Companies, San Francisco Symphony, Signature Theatre, SOM, Theatre For A New Audience.

62-714 Galleries & Auction Houses: Economics of the Art Market
6 units
This class surveys the for-profit art gallery model. Topics include exploration of the business model and common practices of for-profit art galleries and the primary and secondary markets for art sales. Art Appraisals auctions and auction galleries artist procurement art collectors and investor cultivation as well as a profile of gallerists will be discussed in detail. Students will be required to work an art auction and attend the opening receptions for local exhibitions. There will be a non-required trip to the gallery districts of New York City to visit galleries and talk to gallery directors and staff. Corporate art collections will also be discussed as well as how to set prices artist commissions artist agreements consignment sales and inventory will also be topics covered by this course.

62-715 IDeATe: Shaping the Built Environment: Experiments in Geometry and Matter
Fall
Shaping the Built Environment is a project based design-research seminar immersed in physical prototyping. SBE investigates adaptive dynamic behaviors inspired by natural processes and biomimetics as a basis for design ideas. Students are introduced to computational design thinking, material research, performance based design and digital fabrication techniques. Design process is centered on contemporary digital modeling techniques to incorporate environmental information into iterative design processes and form making. The objective of this seminar is to speculate about translation of performative contingencies into shaping material systems informed by data sets and simulation. We engage design processes in which systems' performance metrics underpin creative exploration of organization and form. The seminar results in the design and prototype of an individually proposed project. Students are immersed in digital parametric tools and contemporary digital fabrication processes, including 3D printing, CNC milling, vacuum forming and mold casting.

62-718 Theater Architecture II
Spring
CMU's Theater Architecture Program is a multi-disciplinary collaboration of the College of Fine Arts' Schools of Architecture and Drama and Heinz College's Department of Arts Management. Founded in 2008, it is led by Hal H. Hayes, AIA, Studio Professor of Architecture, and Dick Block, Professor and Associate Head of Drama, with participation and collaboration by Drama & Architecture professor Cynthia Limauro and Heinz College associate dean Kathryn Heidemann. The program is an intensive semester comprised of a coordinated design studio in Architecture, a multi-disciplinary theater architecture seminar, live performance attendance, venue tours, research and analysis, and meetings with professionals in the design, construction and operation of theaters and performance production. The curriculum includes research into the history and development of theater building typology, contemporary best practices and future trends of theater architecture, space programming, planning and design of theater buildings. The theaters that are the subject of the design projects are based on real projects and include the active participation of the theaters' artistic and administrative leadership, the professional design teams engaged in the project, public officials and potential users of the proposed facility. Endowed support for the Theatre Architecture Program is provided by CMU Drama alumnus Len Auerbach, ASTC and J.R. Clancy, Inc.. Logistical support and project participation has been provided by Alvin Ailey American Dance Theater, Arup, H3 Hardy Collaborative, HOK, Jazz at Lincoln Center, The Joyce Theater, The New Hazlett Theater, New York City Economic Development Corp., Perkins + Will, Pittsburgh Cultural Trust, Pittsburgh Public Theater, Point Park University, Port Authority of NY and NJ, The Public Theater, Quantum Theater, Related Companies, San Francisco Symphony, Signature Theatre, SOM, Theatre For A New Audience.
Prerequisite: 62-708

62-775 ACTIVATED ANAMORPHS: Performative Inhabitables and Interactive Prostheses
Fall and Spring: 10 units
This interdisciplinary studio course is centered around the relationship between wearable sculpture, prosthetic apparatus, DIY costume, movement, and identity-based performance. The course emphasizes hands-on experience, the development of visual skills, craftsmanship, conceptual development, and performance techniques. Class time will be spent designing and fabricating performative devices that alter, augment, mask, and transform the body and its inherent abilities. Various lectures, workshops, activities, presentations, and critiques will be included as an integral part of the learning process. Guest instructors from across the College of Fine Arts and outside of the institution will also provide lectures, and workshops that offer students multiple perspectives and techniques. Students will work in a variety of media, unveiling the meanings expressed through materials and investigating new ways to interact with our physical environment(s) through explorations in the adaptation, translation, enhancement, exaggeration, modification, and mutation of the human body. The course will involve student collaboration across disciplines, as well as rehearsals and public performances TBD. This section is open to graduate students only.

Minors Offered by the College of Fine Arts

The College of Fine Arts offers minors in Architecture, Art, Design, Drama, and Music to students from other colleges at Carnegie Mellon University. These minors allow students at Carnegie Mellon to take courses and develop a direction for electives in any of the five schools in CFA. Students in the College of Fine Arts may also earn minors outside of their major within other schools in the College. They may also study any of the minors offered by the other colleges to the University at large, thus taking advantage of the broad educational opportunities available at Carnegie Mellon University.

Minors Offered by the College of Fine Arts:

- Architectural Design Fabrication (available only to B. Arch candidates)
- Architectural Representation and Visualization (available also to B. Arch candidates)
- Architectural Technology
- Architecture
- Architecture History (available also to B. Arch candidates)
- Art
- Building Science (available only to B. Arch candidates)
- Collaborative Piano (available only to Piano majors in the School of Music)
- Conducting (available only to students in the School of Music)
- Design
- Drama
- History of the Arts
- Media Design (IDeATe)
- Music
- Music Education (available only to students in the School of Music)
- Music Technology
- Music Theory
- Musicology
- Photography
- Sonic Arts (IDeATe)
- Sound Design (IDeATe)

Guidelines for students are: 1) except where so designated, CFA students are not eligible to earn a minor in their own school; students from outside CFA may earn a minor in any school in CFA; 2) faculty advisors in the student's home school (in consultation with the academic officer of the other unit involved) will advise students as to the structuring of the courses in each minor; 3) a minor is not to be considered an overload; rather, through the assistance of faculty advisors it should be integrated into a student's overall units required for graduation; 4) the advisors will also monitor the student's development in these minors and keep records in their files which indicate the fulfillment of the course requirements in the minors, as well as in the majors in the student's own school. Courses listed as possible for the minors may be available, but not all courses are offered every semester. Students should consult with their advisors.

Students interested in earning a minor in any of the CFA schools should contact: Architecture: Heather Workinger; Art: Keni Jefferson; Design: Melissa Cicozi; Drama: Amy Nichols; Music: Sharon Johnston.

Architecture Minors

This sequence is for candidates who intend to develop intellectual links to the architectural profession. The scope of courses offered includes a full spectrum of professional issues in architecture.

Prerequisite Courses 9 units

79-104	Global Histories	9
or 62-110	Passport to the Arts	

Required Courses 18–21 units

48-100	Architecture Design Studio: Foundation I	12
or 48-095	Spatial Concepts for Non-Majors	
48-240	Historical Survey of World Architecture and Urbanism I	9

Elective Courses* 27 units

48-120	Digital Media I	6
48-121	Drawing I	6
48-125	Digital Media II	6
48-126	Drawing II	6
48-126	Drawing II	6
48-175	Descriptive Geometry	9
48-215	Materials & Assembly	9
48-351	Human Factors in Architecture	9
48-324	Structures/Statics	9
48-452	Real Estate Design and Development	6
48-453	Urban Design Methods	6
48-383	Ethics and Decision Making in Architecture	6
48-xxx	Architecture History (Pre-Approval of coursework required)	9
48-xxx	Architecture Elective (Pre-Approval of coursework required)	9

Minimum Units: 54

*Students should consult the Architecture advisor regarding elective choices.

Minor in Architecture History

(available also to B. Arch Candidates)

This sequence is intended for candidates interested in the history of architecture in its many manifestations, including high style and vernacular buildings, western and non-western traditions, built and theoretical works, and rural to urban contexts. Non-architecture majors are required to take 54 units of architectural history. Architecture majors wishing to minor in Architectural History must fulfill the three core required courses in architectural history, plus four additional architectural history electives, for a total of 63 units. Students wishing to pursue the minor should meet with the Architecture advisor to determine if a course is eligible.

Required Courses 18 units

48-240	Historical Survey of World Architecture and Urbanism I	9
48-241	Modern Architecture	9

Elective Courses 36 units/45 units

Students wishing to pursue the minor should meet with the Architecture advisor to determine course eligibility for electives.

Minimum Units: 54 (non architecture majors)
Minimum Units: 63 (architecture majors)

Minor in Architectural Representation and Visualization

This sequence is for candidates who intend to develop particular skills in architectural representation. The Minor in Architectural Representation and Media is intended for those students that want to deepen their knowledge in architectural representation and media and for those who are interested in gaining advanced placement (AMP) in the M.S. programs offered by the School in the areas of Computational Design, Tangible Interaction Design and/or Emerging Media. It is earned by completing the four required media courses and then an additional three elective courses in these areas. Architecture majors wishing to pursue a Minor in Architectural Representation and Visualization must complete the required 33 units and at least an additional 30 units to fulfill the minor for a total of 63 units.

Required Courses 24 units

48-120	Digital Media I	6
48-125	Digital Media II	6
48-121	Drawing I	6
48-126	Drawing II	6

Elective Courses 30-39 units

48-568	Advanced CAD, BIM, and 3D Visualization	9
48-576	Mapping Urbanism	9
48-724	Scripting and Parametric Design	6
48-3xx	Architectural Drawing Elective (Pre-Approval of coursework required)	9
48-xxx	Architectural Representation/Visualization Elective: (Pre-Approval of coursework required)	9
48-xxx	Architectural Representation/Visualization Elective: (Pre-Approval of coursework required)	9

Minimum Units: 54 (non-architecture majors)

Minimum Units: 63 (architecture majors)

Minor in Architectural Technology

This sequence is for candidates who intend to develop intellectual links to the technical aspects of the profession. It is not available to B. Arch Candidates.

Prerequisite Courses 22 units

33-106	Physics I for Engineering Students	12
21-120	Differential and Integral Calculus	10

Elective Courses 32 units

48-116	Building Physics	9
48-215	Materials & Assembly	9
48-324	Structures/Statics	9
48-315	Environment I: Climate & Energy in Architecture	9
48-432	Environment II: Design Integration of Active Building Systems	9
48-752	Zero Energy Housing	9

Minimum Units: 54

Minor in Building Science

(Available only to B. Arch Candidates)

The Minor in Building Science is intended for those students that want to deepen their knowledge in the building sciences and for those who are interested in gaining advanced placement (AMP) in the M.S. programs offered by the School in the areas of Building Performance & Diagnostics and Sustainable Design. It is earned by completing the two required building technology and three environmental science courses and then an additional three elective courses in the building sciences.

Required Course 12 units

48-722	Building Performance Modeling	12

Elective Courses 45 units

48-795	LEED, Green Design and Building Rating in Global Context	6
48-721	Building Controls and Diagnostics	12
48-723	Performance of Advanced Building Systems	Var.
48-729	Productivity, Health and the Quality of Buildings	9-12
48-749	Special Topics in CD: Critical Perspectives and Technologies	6
48-752	Zero Energy Housing	9

Minimum Units: 54

Minor in Architectural Design Fabrication

(Available only to B. Arch Candidates)

The Minor in Architectural Design Fabrication is intended for those who wish to develop focused, disciplinary expertise in both analog and digital material methods for shaping the built environment and become involved in a community of practice dedicated to a rigorous pursuit of *making* as a mode of architectural research and cultural expression. It is also for students interested in gaining advanced placement in the SoA's Master of Advanced Architectural Design (MAAD) program.

Required Courses 33 units

48-545	Digital Fabrication	9
48-555	Introduction to Architectural Robotics	6
48-xxx	Advanced Synthesis Options Studio with Digital Fabrication Emphasis	18

Elective Courses 30 units

48-470	Exploring Pattern Through Lamination	9
48-473	Hand and Machine Joinery, New Directions	9
48-531	Fabricating Customization: Prototype	9
48-564	Furniture Design & Construction	9
48-xxx	Advanced Design Fabrication	3-9
xx-xxx	Pre-approved Design Fabrication Related Course	

Minimum Units: 63

Art Minor

Concept Studio (choose one) — 10 units

60-101	Concept Studio: The Self and the Human Being	10
60-201	Concept Studio: Space and Time	10
60-202	Concept Studio: Systems and Processes	10
60-280	Introduction to Contextual Practice	10

Media Studios (choose two) — 20 units

60-110	Electronic Media Studio: Introduction to the Moving Image	10
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-131	3D Media Studio I	5
60-132	3D Media Studio I	5
60-133	3D Media Studio II	5
60-134	3D Media Studio II 60-131 - 60-134 count as half a course each.	5
60-150	2D Media Studio: Drawing	10
60-160	2D Media Studio: Imaging	10
60-250	2D Media Studio: Painting	10
60-251	2D Media Studio: Print Media	10

Advanced Media (choose two) — 20 units

60-4xx	Advanced ETB: Electives	10
60-4xx	Advanced SIS: Electives	10
60-4xx	Advanced DP3: Electives	10
60-4xx	Advanced CP: Electives	10

Critical Studies (choose one) — 9 units

60-1xx	Art History Elective	9
60-2xx	Art History Elective	9
60-3xx	Art History Elective	9

Minimum units: 59

Media Design Minor – IDeATe

The minor in Media Design is offered by the School of Art as part of the Integrative Design, Arts and Technology (IDeATe) network. IDeATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in shared labs and maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of eight areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, and Physical Computing. For more information about the IDeATe network, please see Undergraduate Options (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateoptions/#ideate).

The Media Design minor serves students who are interested in digital mediation of experiences. It explores the interconnected development of technology and content in new media systems and the meaning that arises from the resulting forms. Students learn to design mediated experiences across different platforms, from mobile to large-scale installations. They study the structure and function of different components of mediated experiences. They learn how to synthesize those components and how to connect modular structures for the creation of transmedia experiences.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area	10
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
60-218	IDeATe Portal: Real-Time Animation	10
60-223	IDeATe: Introduction to Physical Computing	10
99-361	IDeATe Portal	9

IDeATe Media Design Courses - Minimum of 27 Units

		Units
05/18-540	Rapid Prototyping of Computer Systems	12
15-294	Rapid Prototyping Technologies	5
15-394	Intermediate Rapid Prototyping	5
16/54-375	IDeATe: Robotics for Creative Practice	10
24-672	Special Topics in DIY Design and Fabrication	12
48/53-558	Reality Computing	12
51-236	Information Design	9
51-400	Transition Design	9
51-421	Design Center: Data Visualization	9
53-312	Guest Experience in Theme Park Design	9
53-376	360 Story and Sound	12
53-642	Themed Entertainment Design Studio	12
54-399	Decoding Media	9
60-110	Electronic Media Studio: Introduction to the Moving Image	10
62-362	Activating the Body: Physical Computing and Technology in Performance	10
62-478	IDeATe: digiTOOL	6
67-240	Mobile Web Design & Development	9
76-374	IDeATe - Dietrich College Cuban Interactive Documentary Project	9
82-285	Podcasting: Language and Culture Through Storytelling	9

Double-Counting

Students may double-count up to two of their Media Design minor courses toward requirements for other majors or minors.

Design Minor

Minoring in Design is a great way for students to diversify their studies and incorporate design skills and thinking into their overall academic experiences. Students who are already School of Design majors are not eligible to earn a Design minor. The 54 required units must be unique to the Design minor. No courses may be double counted.

Requirements and Electives

For a design minor, students must complete 54 units: 36 units of required courses, plus 18 units of design electives.

Required Design Courses

Both of these:		
51-262	Design Center: CD Fundamentals: Design for Interactions for Communications (formerly CDF)	9
51-264	Design Center: Product Design Fundamentals: Design for Interactions for Products (formerly IDF)	9
Two of these:		
51-171	Placing	10

51-172	Systems	9
51-173	Design Center: Human Experience in Design	9
51-271	How People Work	9

Two Design Electives:

51-xxx	Design Elective	9
51-xxx	Design Elective	9

Applications

Students must submit transcripts, personal statements, and completed applications by the beginning of February, and submit portfolios or design projects by the beginning of March. They must also obtain permission to complete minors from their major advisors. The minor application form includes detailed requirements.

Admission depends mainly on a student's demonstration of design skills and aptitude. Students are notified of acceptance by the end of March.

If you are interested in applying for the Minor in Design, please contact Design Advisor, Melissa Cicozi (cicozi@cmu.edu). You can download the Design Project and Application at www.design.cmu.edu, or paper applications are available at the School of Design office, MMCH 110.

Drama Minor

The Drama minor provides students with a well-rounded opportunity to obtain preliminary professional exposure to the theatre arts. Courses may involve acting, directing, playwriting, design, production technology and management, and dramatic literature courses. Students also become involved with Drama productions by signing up for Production for Non-Majors, which involves evening crew work on various Drama productions.

Admission Requirements

1. Students must apply to enter the program in the office of the Drama Assistant Head & Director of Student Services, Amy Nichols, PCA 223.
2. The student must successfully pass one Drama course prior to being considered for minor status.

Required Courses 25 units

54-163	Production for Non Majors (needs to be taken twice for a total of 12 units)	6
54-175/176	Conservatory Hour	1
54-177	Foundations of Drama I	6
54-281	Foundations of Drama II	6

Students must meet with the School of Drama Production Manager (PCA 224) for assignments related to Production for Non-Majors.

Elective Courses 30 units

The remainder of the minor is fulfilled with Drama courses of the student's choosing, with approval from the Director of Student Services in the School of Drama, Amy Nichols. For certain courses, students may need instructor permission to register.

SAMPLE: Selected Elective Courses not requiring instructor permission:

54-187	Introduction to Playwriting	9
54-190	Advanced Playwriting	9
54-191	Acting for Non-Majors	9
54-193	Intro to Screenwriting	9
54-196	Screenwriting	9

SAMPLE: Selected Elective Courses requiring instructor permission:

54-109	Dramaturgy 1: Approaches to Text	9
54-121	Directing I: Sources	9
54-157	Production Science	6
54-169	Studiocraft 1	13
54-171	Basic Design 1	6

Additional Drama Courses are available by instructor agreement and may require an audition, interview, or portfolio review. Students should contact the Drama Assistant Head & Director of Student Services, Amy Nichols, to inquire about permission for specific courses in which they are interested.

Minimum units required: 55

Music Minors

This sequence is for candidates who are majors from any discipline in the university other than music who have some background in music and would like to know more about music.

Admission Requirements:

1. The student must apply to enter the program in the office of the Director of Student Services (CFA 108).

Prerequisite Course 0–3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

57-294	Beginning Piano Test	0
57-329	Beginning Piano for Minors	3

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-173	Survey of Western Music History	9
57-188	Repertoire and Listening for Musicians	1

Required Studio Courses (studio fee is charged) 24 units

57-1xx	Elective Studio	6
57-1xx	Elective Studio	6
57-1xx	Elective Studio	6
57-1xx	Elective Studio	6

Elective Courses 18 units

Elective courses are to be chosen from those courses listed for the School of Music in the current course catalog. Performance electives are encouraged. (An audition is required for all School of Music performance ensembles.)

Minimum units required: 67

Minor in Music Technology

This sequence is for candidates who are majors from any discipline in the university who have some background in music and would like to know more about music technology.

Note: Students in the School of Music have slightly different requirements for the Minor in Music Technology. See School of Music (http://coursecatalog.web.cmu.edu/collegeoffinearts/schoolofmusic/#minorinmusictechnologyforstudentsintheschoolofmusic).

Admission Requirements

The student must apply to enter the program in the office of the Director of Student Services (CFA 108).

Prerequisite Course 0–3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

57-294	Beginning Piano Test	0
57-329	Beginning Piano for Minors	3

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

57-152	Harmony I	9
57-161	Eurhythmics I	3

57-173	Survey of Western Music History	9
57-181	Solfege I	3
57-188	Repertoire and Listening for Musicians	1

Sound Recording Courses 21 units

57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Music Technology/Sound Courses (choose 3) 21 units

Choose three courses. One of the three courses must be either Introduction to Computer Music or Electronic and Computer Music. (Note that 15-112 is a prerequisite for 15-322; 57-101 or 57-171 is a prerequisite for 57-347.) Other courses may be taken with the permission of the music technology minor advisor.

15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music	9
15-323	Computer Music Systems and Information Processing	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-275	History of Sound Design	3
54-505	Ear Training	1
54-666	Production Audio	6
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-478	Survey of Historical Recording	6
60-352	NOISE: Toward a Critical Theory of Sound and Hearing	9

Minimum units required: 67

Minor in Music Theory

This sequence is for candidates who are majors from any discipline in the university who have some background in music and would like to know more about music theory.

Note: Students in the School of Music have slightly different requirements for the Minor in Music Theory. See School of Music (http://coursecatalog.web.cmu.edu/collegeoffinearts/schoolofmusic/#minorinmusictechnologyforstudentsintheschoolofmusic).

Admission Requirements

The student must apply to enter the program in the office of the Director of Student Services (CFA 108).

Prerequisite Course 0–3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

57-294	Beginning Piano Test	0
57-329	Beginning Piano for Minors	3

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

57-152	Harmony I	9
57-161	Eurhythmics I	3
57-173	Survey of Western Music History	9
57-181	Solfege I	3
57-188	Repertoire and Listening for Musicians	1

Required Theory Courses 21 units

57-151	Counterpoint in Theory and Application	6
57-153	Harmony II	9
57-408	Form and Analysis	6

Upper Level Theory Course (choose one) 6 units

See theory courses on the Music Support Courses Two-Year Rotation list. It is available on the Inside Music website:http://music.cfa.cmu.edu/. A graduate course may be taken with the permission of the instructor.

Elective Courses 18 units

Elective courses are to be chosen from those courses listed for the School of Music in the current course catalog.

Minimum units required: 70

Minor in Musicology

This sequence is for candidates who are majors from any discipline in the university who have some background in music and would like to know more about music history.

Admission Requirements

The student must apply to enter the program in the office of the Director of Student Services (CFA 108).

Prerequisite Course 0–3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

57-294	Beginning Piano Test	0
57-329	Beginning Piano for Minors	3

Required Music Courses 15 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3

Required Musicology Courses 36 units

57-283	Music History I	9
57-284	Music History II	9
57-285	Music History III	9
57-190	Repertoire and Listening for Musicians I	3
57-289	Repertoire and Listening for Musicians II	3
57-290	Repertoire and Listening for Musicians III	3

Upper Level Musicology Course (choose one) 6 units

See musicology courses on the Music Support Courses Two-Year Rotation list. It is available on the Inside Music website:http://music.cfa.cmu.edu/. A graduate course may be taken with the permission of the instructor.

Elective Courses 18 units

Elective courses are to be chosen from those courses listed for the School of Music in the current course catalog.

Minimum units required: 75

Sonic Arts Minor – IDeATe

The minor in Sonic Arts is offered by the School of Music as part of the Integrative Design, Arts and Technology (IDeATe) network. IDeATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in shared labs and maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of eight areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, and Physical Computing. For more information about the IDeATe network, please see Undergraduate Options (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateoptions/#ideate).

In the Sonic Arts minor, students create experimental music or explore new, technology-enabled applications and markets for sound design, music creation, and performance.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
18-090	Twisted Signals: Multimedia Processing for the Arts Recommended Portal Course for this area	10
16-223	IDeATe Portal: Creative Kinetic Systems	10
60-223	IDeATe: Introduction to Physical Computing	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
99-361	IDeATe Portal	9

IDeATe Sonic Arts Courses - Minimum of 27 Units

		Units
15-322	Introduction to Computer Music	9
15-323	Computer Music Systems and Information Processing	9
18-493	Electroacoustics	12
33-114	Physics of Musical Sound	9
53-376	360 Story and Sound	12
54-166	Introduction to Sound Design for Theatre	6
54-267	Conceptual Sound Design	9
54-509	Theatrical Sound System Design 2	9
57-337	Sound Recording	6
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-421	The Exploded Ensemble	6
57-425	Expanded Music Performance	9

Double-Counting

Students may double-count up to two of their Sonic Arts minor courses toward requirements for other majors or minors.

CFA Dean's Office Minors

Minor in the History of Arts

This minor of six or more courses as designated below, offers students flexibility to engage in a broad survey in the arts or can be tailored to reflect a more specific area of interest. For College of Fine Arts students, all courses meeting the requirements of the Minor in the History of the Arts must be taken outside of their major School, with the exception of the School of Architecture. Interested students should contact Patti Pavlus in the College of Fine Arts, Room 100.

Introductory Level Courses 27 units

(choose at least three, CFA students pick 3 outside of major)

48-240	Historical Survey of World Architecture and Urbanism I	9
48-241	Modern Architecture	9
54-239	History of Architecture and Decor 1: Ancients to Gothic	Var.
54-240	History of Architecture and Decor 2: Renaissance to the 21st Century	Var.
54-245	History of Clothing 1 (instructor permission only)	Var.
54-246	History of Clothing 2 (instructor permission only)	Var.
57-173	Survey of Western Music History (coreq: 57-188)	9
57-188	Repertoire and Listening for Musicians (coreq of 57-173)	1
60-105	Critical Theory in Art I (instructor permission only)	9

60-106	Critical Theory in Art II (instructor permission only; prereq: 60-105)	9
60-205	Critical Theory in Art III (instructor permission only)	9
60-206	Critical Theory in Art IV (instructor permission only; prereq: 60-205)	9

Intermediate/Advanced Level Courses 27 units

(choose at least three, CFA students pick 3 outside of major)*

48-348	Architectural History of Mexico & Guatemala	9
48-374	History of Architecture in the Islamic World- A Primer (prereq: 48-240)	9
48-440	American Regions & Regionalism: An Architectural History of Place, Time, and Cul (prereq: 48-240)	9
51-376	Semantics & Aesthetics	4.5
57-209	The Beatles	9
57-476	How Music Works: An Affective History	6
57-477	Music of the Spirit	6
57-478	Survey of Historical Recording	6
57-480	History of Black American Music	6
57-485	History of the Symphony	9
Art Critical Studies Electives: 60-352 to 60-398 (instructor permission only)		9
62-360/79-329	Photographers and Photography Since World War II	9
62-371/79-316	Photography, The First 100 Years, 1839-1939	9
79-395	The Arts in Pittsburgh	9
79-396	Music and Society in 19th and 20th Century Europe and the U.S.	9

Minimum units required for minor: 54

*Other courses not on this list may qualify as approved by CFA Dean's Office (College of Fine Arts, Room 100).

Minor in Photography

The Photography Minor exposes students to the breadth of offerings from traditional photography (i.e. film exposure and silver printing) to digital shooting and output. The student will become familiar with photography's craft, its history and significant practitioners, and develop their own distinct engagement with the medium.

Students may apply for the Photography Minor after they have taken a beginning photography course. Students will be admitted to the minor based on their aptitude, appropriate level of photography skills, and space availability within the program. Once admitted, students will be assigned a faculty advisor who will help them determine a sequence of courses that best fits their needs and interests.

Application Requirements

The application process for the Photography Minor requires submission of: a completed application form signed by the home department advisor, a personal statement, and a portfolio of photographs. Contact the CFA Photography Administrator, Jamie Gruzska, MM B18, for further information and an application form.

Photography Required Courses (3) minimum 27 units

62/60-141	Black and White Photography I *	10
62/60-142	Digital Photography I	10
62/60-241	Black and White Photography II	10

Photography Elective (1) minimum 9 units

Choose one (1) or more additional photography courses from the list below in consultation with the photo advisor; consult Jamie Gruzska for current offerings.

62-208	Alternative Photography: Contemporary Antiquarian Printmaking	5
62-214	Photography and the Narrative of Place	5
62-235	Photographing America	10
62-245	Portrait Photography	10
62-326	Photographic Narrative	9
62-375	Large Format Photography: The Antiquarian Avant-Garde	10
62-471	Photography/Print Workshop	10

Photo History Required Course (1) minimum 9 units

62-371	Photography, The First 100 Years, 1839-1939 *	9
or 62-360	Photographers and Photography Since World War II	

History, Theory, or Criticism of the Visual Arts Elective (1) minimum 9 units

Choose one (1) additional History, Theory or Criticism of the Arts course in consultation with the photo advisor. A second Photo History course (62-360 or 62-371) can be used for this requirement.

*or course approved by the photography advisor

Minimum units required for minor: 54

School of Architecture

Stephen R. Lee, AIA, LEED AP, Head
Location: CFA 201
www.soa.cmu.edu

The School of Architecture (SoA) provides deep immersion in the discipline of architecture, intensified by the broader Carnegie Mellon culture of interdisciplinary innovation and creative inquiry. We define the discipline of architecture as the integrated pursuit of design creativity, historical perspective, social responsibility, technical expertise, and global environmental leadership. Our undergraduate and graduate degree programs prepare students to be excellent, discipline-defining design thinkers in diverse global contexts.

This world-class architecture education is enhanced by our position within one of the world's leading research and entrepreneurship institutions, and by the foundational premise that architectural excellence demands both rigorous training in fundamentals and the development of unique specializations. Students may extend their core knowledge either through concentration in architecture subdisciplines like sustainable design or computational design, or through interdisciplinary interaction with CMU's other renowned programs—whether the sciences, the humanities, business, or robotics. Though every School of Architecture student graduates with intensive architecture knowledge, no two graduates leave with the same education.
In the twenty-first century, few architecture problems are straightforward. Graduates of SoA excel in the roles architects have performed for centuries —and in new roles catalyzed by the depth and breadth of their education —to create and execute innovative solutions to a huge range of emerging global challenges.

Bachelor of Architecture Program

The School of Architecture's NAAB-accredited five-year Bachelor of Architecture (B.Arch) (https://soa.cmu.edu/undergraduate) program leverages the unparalleled opportunities at Carnegie Mellon University. Our students graduate with a professional degree that prepares them to excel in practice—but that also launches them into key specialties within the profession. The B.Arch program begins with a highly scripted three-year sequence of foundation courses and studios—the fundamental, core architecture education essential for every professional. In the fourth and fifth years, students follow a path forged by their own interests, choosing an Advanced Synthesis Option Studio (ASOS) and electives each semester.

Though every School of Architecture student graduates with intensive architecture knowledge, no two graduates leave with the same education.

Each course required for the B.Arch program falls into one of seven categories, each pursuing a set of specific objectives for student learning:

- Studio: Architectural design studio (prescribed for the first three years and selective thereafter) is the backbone of every semester in the B.Arch program. Students learn to combine rigorously rational and resourcefully creative techniques to identify design problems, collect and analyze data, apply theoretical and practical strategies in creation of a design solution, and evaluate its results through extensive testing; and to describe and work at various points along the continuum between form-finding and form-making. (Courses: Foundation I & II, Elaboration I & II, Integration I & II, Advanced Synthesis Options Thesis/ Studio I & II)
- Critical Practice: A multifaceted field of practice, architecture interacts with dynamic social, organizational, economic, professional, and cognitive contexts. In this sequence, students learn to use methods from cognitive psychology to analyze the influence of human factors on design, construction and occupancy; to resolve ethical dilemmas with adjudication strategies based in architectural case study; to demonstrate critical awareness and broad understanding of the factors informing the intelligent resolution of architecture and construction; and to identify the roles of architects, urban designers and planners in shaping the built environment in a global context. (Courses: First Year Seminar: Architecture Edition I & II, Case Studies in Architecture and Urban Studies, Human Factors in Architecture, Real Estate Design and Development, Issue of Practice)
- Design Tools: Drawing and modeling both by hand and with the computer are core skills for developing powers of observation, the ability to think in three dimensions, and the communication of architectural ideas. By using a range of analog and digital design tools to engage in the act of making, students will be able to explore, analyze, formulate, fabricate, and represent ideas about the built environment. (Courses: Analog and Digital Media I, Analog and Digital Media II)
- Environmental Science: Environmental education is one of our highest priorities. In this sequence, students learn to describe first principles of and computational approaches to the lighting and thermal performance of buildings; to demonstrate qualitative and quantitative climate- and environment-responsive strategies (energy conservation, passive heating/cooling, daylighting, natural ventilation); to select, configure, and represent building service systems; and to maintain global awareness of high-performance systems-integration strategies. (Courses: Building Physics, Environment I: Climate & Energy, Environment II: Mechanical Systems for Buildings)
- History: In architectural history courses, students learn to identify chronologically and geographically diverse building styles, building types, and urban plans; to describe the cultural, intellectual and aesthetic contexts surrounding the creation of those buildings and sites; to write clearly and persuasively about the historic built environment; and to demonstrate critical thinking, quality research, and effective information management. In addition to the two-semester Historical Survey of World Architecture, each student completes one elective course on architectural history within the School of Architecture. A minor in architectural history is available to students completing four additional, approved, nine-unit architectural history courses beyond these three required courses. (Courses: Historical Survey of World Architecture and Urbanism, Modern Architecture, Architectural History III)
- Building Technology: We understand technical knowledge as design knowledge and place major emphasis on understanding the state-of-the-art and innovative building structure, enclosure, mechanical, lighting, and interior systems. Students learn to design gravity- and lateral load-resisting systems for buildings; to select, configure and size construction systems in wood, masonry, steel, and concrete; and to distinguish among construction materials with regard to their process of manufacture, their physical properties, their environmental performance, and their methods of selection and specification. (Courses: Materials and Assembly, Structures/Statics)
- General Studies: University coursework in mathematics, physical sciences, social sciences, writing, and history are prerequisite to the School's own offerings. (Courses: Exploring Pittsburgh, Interpretation and Argument, Computing @ Carnegie Mellon, Descriptive Geometry, Generative Modeling, Fundamentals of Computational Design, University Electives)

Curriculum

Minimum units required for Bachelor of Architecture 450

First Year: Foundation

48-100	Architecture Design Studio: Foundation I	15
48-025	First Year Seminar: Architecture Edition I	3
62-122	Digital Media I	6
62-125	Drawing I	6
62-106	Architecture and the Arts	9
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3

48-105	Architecture Design Studio: Foundation II	15
48-026	First Year Seminar: Architecture Edition II	3
62-123	Digital Media II	6
62-126	Drawing II	6
48-240	Historical Survey of World Architecture and Urbanism I	9
xx-xxx	University Elective	9

Second Year: Elaboration

48-200	Architecture Design Studio: Elaboration I	18
48-215	Materials & Assembly	9
48-116	Building Physics	9
62-225	Generative Modeling	9

48-205	Architecture Design Studio: Elaboration II	18
48-215	Materials & Assembly	9
48-241	Modern Architecture	9
62-275	Fundamentals of Computational Design	9

Third Year: Integration

48-300	Architecture Design Studio: Integration I	18
48-315	Environment I: Climate & Energy in Architecture	9
48-250	Case Studies in Architecture and Cities	9
xx-xxx	University Elective	9

48-305	Architecture Design Studio: Integration II	18
48-380	Real Estate Design and Development	6
48-381	Ethics and Practice	12
xx-xxx	University Elective	9
48-497	Thesis Prep (Optional)	3

Fourth Year: Advanced Topics

48-400	Advanced Synthesis Options Studio I	18
48-432	Environment II: Design Integration of Active Building Systems	9
48-xxx	Architectural History III (Elective)	9
xx-xxx	University Elective	9

48-410	Advanced Synthesis Options Studio II	18
48-xxx	Architecture Elective	9
48-xxx	Architecture Elective	9
xx-xxx	University Elective	9

Fifth Year: Advanced Topics

48-500	Advanced Synthesis Options Studio III	18
or 48-509	Architecture Design Studio: Thesis I/ Independent Project	
xx-xxx	University Elective	9
xx-xxx	University Elective	9

48-510	Advanced Synthesis Options Studio IV	18
or 48-519	Architecture Design Studio: Thesis II/ Independent Project	
48-519	Architecture Design Studio: Thesis II/ Independent Project	18
xx-xxx	University Elective	6-9
xx-xxx	University Elective	6-9

Minors in Architecture

Undergraduate Architecture students in the School of Architecture may, in addition to their primary degree, pursue minors within the subject of architecture. These are the minors in Architectural Design Fabrication, Architectural History, Architectural Representation and Visualization, and Building Science. Non-architecture majors may, in addition to their primary degree, pursue minors in Architecture, Architectural History, Architectural Representation and Visualization, and Architectural Technology.

The **Minor in Architecture** sequence is for candidates who intend to develop intellectual links to the architectural profession. The scope of courses offered includes a full spectrum of professional issues in architecture. (*Available to non-architecture majors only.)*

The **Minor in Architectural Design Fabrication** is intended for those who wish to develop focused, disciplinary expertise in both analog and digital material methods for shaping the built environment and become involved in a community of practice dedicated to a rigorous pursuit of *making* as a mode of architectural research and cultural expression. It is also for students interested in gaining advanced placement in the SoA's Master of Advanced Architectural Design (MAAD) program. *(Available to architecture majors only.)*

The **Minor in Architectural History** is intended for those students that want to deepen their knowledge in architectural history. *(Available to both architecture majors and non-architecture majors.)*

The **Minor in Architectural Representation and Visualization** is intended for those students who wish to develop particular skills in architectural representation, and for those who are interested in gaining advanced placement in the SoA's Master degree program in Computational Design (MSCD). *(Available to both architecture majors and non-architecture majors.)*

The **Minor in Architectural Technology** is intended for those who seek to develop intellectual links to the technical aspects of the profession. (*Available to non-architecture majors only.)*

The **Minor in Building Science** is intended for those students that want to deepen their knowledge in the building sciences, and for those who are interested in gaining advanced placement in the SoA's Master degree programs in Building Performance & Diagnostics (MSBPD) or Sustainable Design (MSSD). *(Available to architecture majors only.)*

Minors in Other Disciplines

Undergraduate architecture students may also earn minors in many of the departments or schools on campus. Generally, a student must take six courses within a specific department or concentration to receive a minor. Students interested in minors must contact the school or department of interest to determine specific requirements or prerequisites. Since students of architecture are required to take fifteen electives (135 units), students can easily complete a minor without adding additional coursework to their curriculum.

Graduate Degree Programs

Carnegie Mellon University is recognized for outstanding contributions to science, technology, management, policy, and the fine arts. The School of Architecture builds on a tradition of interdisciplinary study.

Our faculty's diverse set of backgrounds and commitment to professional practice and scholarly research make for a rich learning experience.

Our graduates hold positions in innovative design practices, research organizations, federal and municipal governments, the building and manufacturing industries, and at leading universities both in the US and abroad.

Our programs reflect a commitment to excellence. Students with motivation and ability receive an outstanding educational opportunity at Carnegie Mellon University's School of Architecture.

The School of Architecture offers seven (7) Master's degrees, and three (3) Doctoral degrees in the following areas of study:

Master of Advanced Architectural Design

The Master of Advanced Architectural Design (MAAD) (https://soa.cmu.edu/maad) is a post-graduate, studio-based program that engages emerging methods of design and fabrication through architectural design to speculate upon future modes of architectural practice, enhanced construction methods, and material culture within the built environment.

Master of Architecture

The Master of Architecture (M. Arch) (https://soa.cmu.edu/march) is a studio-based, first professional degree program to educate tomorrow's leaders in architecture-related careers. The M.Arch program is built on CMU's 100-year tradition of training architects in the practice of design and technical fundamentals. Our M.Arch program's strategically small size allows students to shape their individual educational agendas and career paths as they interact directly with leading-edge research projects in the school and community, and around the world. The National Architectural Accrediting Board (NAAB) granted the SoA's M.Arch program initial candidacy in 2018. Because NAAB's "Initial Accreditation" is retroactive, subject to fulfillment of the "Plan for Achieving Initial Accreditation" for the M.Arch, CMU currently anticipates (but does not represent or guarantee) that the degrees awarded from May 2019 onward will be accredited.

Master of Science/Doctor of Philosophy in Architecture–Engineering–Construction Management

A joint effort between the School of Architecture and the Department of Civil & Environmental Engineering, the Architecture–Engineering–Construction Management (AECM) (https://soa.cmu.edu/aecm) programs prepare building delivery professionals for careers in capital project delivery dealing with the entire life-cycle of capital projects, from pre-design to design, construction, commissioning, operation, and maintenance stages. Graduates are educated to become effective decision makers who can positively impact economic, environmental, and ethical aspects of the built environment through professional management strategies. Our graduates have successful careers in government, industry, business, and NGO (non-governmental organization) sectors, prospering in positions where design professionals continuously make large-scale capital project design, construction, and maintenance decisions.

Master of Science/Doctor of Philosophy in Building Performance and Diagnostics

Our graduate programs in Building Performance & Diagnostics (BPD) (https://soa.cmu.edu/bpd) have long led the world in advanced building technologies that sustainably reshape the built environment. BPD deals with the comprehensive integration of *building design* and *advanced technology*, as a means of producing high performance architecture. Led by the Center for Building Performance & Diagnostics (CBPD) (https://soa.cmu.edu/cbpd) and housed within the Robert L. Preger Intelligent Workplace (http://www.cmu.edu/greenpractices/greenign-the-campus/green-buildings/intelligent-workplace.html), students have the opportunity to gain both diversity and depth of knowledge from world-renowned and experienced faculty.

Master of Science/Doctor of Philosophy in Computational Design

One of the first and best-known Computational Design (https://soa.cmu.edu/computational-design) programs in the US, our legacy continues today. The Computational Design program takes a computer science view of design, applying both the science and art of computing to design problems, in relation to creation, presentation, analysis, evaluation, interaction or aesthetic expression; in real and imagined applications, both perceived and conceived. From the beginning, the program has benefitted from close cooperation with other units of the university, particularly the School of Computer Science and the Department of Civil & Environmental Engineering. Our visionary students continue to push for innovation and evolution of the state-of-the art in design technology.

Master of Urban Design

The Master of Urban Design (MUD) (https://soa.cmu.edu/mud) is a studio-based program distinguished by its emphasis on integrating socially engaged practice with new tools and techniques for representing, understanding, and designing cities; by the opportunity to work in trans-disciplinary teams at the intersection of the arts, humanities and technology across Carnegie Mellon's departments and colleges; and by its location in Pittsburgh—a thriving post-industrial laboratory.

Master of Science in Sustainable Design

The Master of Science in Sustainable Design (MSSD) (https://soa.cmu.edu/mssd) is a post-professional research-based graduate program focused on enabling deep expertise, critical thinking, and investigation of innovative sustainable strategies for the design of the built environment. The MSSD program explores technical and multicultural aspects of ecological thinking, while enabling actionable expertise in sustainable design methodologies. Based in the legacy of sustainability teaching at Carnegie Mellon University, the MSSD program prepares students to excel in research methods, and to become experts in integrative design thinking for the future of the built environment.

Advanced Standing in Master Degree Programs

The School of Architecture offers a unique opportunity to students who wish to pursue a Master's degree in an architecture-related field through the Accelerated Master's Program (AMP) (https://soa.cmu.edu/accelerated). Undergraduate students may apply to the AMP in their 4th year of their architecture education, and if accepted, can apply units earned in their 5th year of their undergraduate architecture degree to their graduate degree. This allows students to graduate with a Master's degree in an accelerated period of time.

Student Advising

At the end of each semester, the faculty reviews each student's progress in all courses. Reviews during the first year are intended to determine a student's capabilities in relation to the study of architecture at Carnegie Mellon University and the School works with each student to ensure placement within the university if a change is desired. Subsequent reviews monitor and ensure continued progress in all sequences of the program.

Students are urged to meet with their assigned faculty mentor, first-year faculty advisor, and/or senior academic advisor to review their academic progress and plans before each semester. Such meetings are important to take full advantage of elective possibilities within the curriculum, general progress toward graduation, and professional goal setting. Students may also check their progress using the online academic audit in the Student Information Online (SIO) and should review the audit results with the senior academic advisor.

Study Abroad

The School of Architecture strongly encourages students to study abroad. The perspective gained through immersion in another culture and language is invaluable. Study abroad can fall into four categories: University Direct Exchanges, University Sponsored Programs, External Programs, and Departmental Summer Programs.

To receive credit for courses taken away, the student must have a C or better (not C-) in the course and have an official translated transcript sent to the School of Architecture. Studio work conducted abroad must be presented to the School Head and Studio Coordinator for approval.

Students should make the decision to study away by the fall of their third year so they can plan their courses accordingly. Students are allowed one semester away for which they receive studio credit except for those students at approved yearlong direct exchange programs. To qualify for study away, a student must have completed the third-year of their program, have a minimum overall QPA of a 3.00 (or 2.75 for SoA summer study abroad) and be in good academic standing.

Summer Courses

Students can receive credit for passing comparable courses at other institutions with advanced approval from the School. A Transfer Credit Evaluation form must be completed by the Academic Advisor prior to enrollment at the other institution for a course to be considered for transfer.

Faculty

AZIZAN ABDUL-AZIZ, Data Analytics Professor

ÖMER AKIN, Professor Emeritus

MARY-LOU ARSCOTT, Studio Professor & Associate Head

MARTIN AURAND, Principal Architecture Librarian & Archivist

NICOLAS AZEL, Adjunct Faculty

AKHIL BADJATIA, Adjunct Faculty

NINA BAIRD, Assistant Teaching Professor

NINA BARBUTO, Adjunct Faculty

JOSHUA BARD, Associate Professor

HEATHER BIZON, Adjunct Faculty

DARAGH BYRNE, Associate Teaching Track

DANIEL CARDOSO LLACH, Associate Teaching Track

DONALD CARTER, Adjunct Faculty

ERICA COCHRAN HAMEEN, Assistant Professor

DOUG COOPER, Andrew Mellon Professor

LIZA CRUZE, Associate Studio Professor

DANA CUPKOVA, Associate Professor

GERARD DAMIANI, Associate Professor

STEFANI DANES, Adjunct Faculty

JEFFREY DAVIS, Adjunct Faculty

MARANTHA DAWKINS, Adjunct Faculty

JEREMY FICCA, Associate Professor, Director dFAB

LORI FITZGERALD, Adjunct Professor

NATHALIE FRANKOWSKI, Ann Kalla Co-Professor in Architecture

CRUZ GARCÍA, Ann Kalla Co-Professor in Architecture

RAY GASTIL, Director, Remaking Cities Institute

STEFAN GRUBER, Associate Professor

KAI GUTSCHOW, Associate Professor

VOLKER HARTKOPF, Professor Emeritus

HAL HAYES, Studio Professor

MATTHEW HUBER, Adjunct Faculty

ÖMER KARAGÜZEL, Assistant Teaching Professor

EDDY MAN KIM, Assistant Teaching Professor

JEFF KING, Adjunct Faculty

JONATHAN KLINE, Associate Studio Professor

RAMESH KRISHNAMURTI, Professor

KRISTEN KURLAND, Teaching Professor

KHEE POH LAM, Professor Emeritus

JOSHUA D. LEE, Assistant Professor

STEPHEN R. LEE, Professor & Head

CINDY LIMAURO, Professor of Drama

KATHERYN LINDUFF, Adjunct Faculty

VIVIAN LOFTNESS, University Professor, Paul Mellon Professor

JENNIFER LUCCHINO, Adjunct Faculty

JAKOB MARSICO, Adjunct Faculty

CHRISTINE MONDOR, Adjunct Faculty

ANDREW MOSS, Adjunct Faculty

IRVING OPPENHEIM, Professor

PAUL OSTERGAARD, Adjunct Faculty

JOSÉ PERTIERRA-ARROJO, Special Faculty

MATTHEW PLECITY, Adjunct Faculty

STEPHEN QUICK, Adjunct Faculty

SARAH RAFSON, Adjunct Faculty

ANNIE RANTTILA, Adjunct Faculty

NIDA REHMAN, Lucian and Rita Caste Assistant Professor in Architecture and Urban Design

MANUEL RODRÍGUEZ LADRÓN DE GUEVARA, Studio Instructor & Research Assistant

AZADEH OMIDFAR SAWYER, Assistant Professor

DIANE SHAW, Associate Professor

SCOTT SMITH, Adjunct Faculty

FRANCESCA TORELLO, Special Faculty

VALENTINA VAVASIS, Special Faculty

PEDRO VELOSO, Graduate Instructor

SPIKE WOLFF, Special Faculty, Curator

HEATHER WORKINGER MIDGLEY, Adjunct Faculty

School of Architecture Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

48-025 First Year Seminar: Architecture Edition I
Fall: 3 units
The main objective of this first-year seminar course is on how students learn, develop, and make decisions as they transition into architecture education. The goal of this course is to promote academic success and encourage connections within the SoA and the University at large. Teaching and learning strategies will be introduced to help support the transition into architecture and the development of independent critical thinkers. Students will be introduced to campus resources that support their academic/ social/personal integration into the campus community. Topical areas to be covered in the seminar will include teaching and learning strategies in architecture education, academic development, career planning, mentorships, academic and personal support services, and the aspects of professional practice in architecture. "

48-026 First Year Seminar: Architecture Edition II
Spring: 3 units
The first year seminar (part 2) introduces students to opportunities at Carnegie Mellon University and beyond. The goal of this course is to encourage students to pursue their interests inside and outside of the School of Architecture by introducing a range of opportunities, including study abroad experiences, internships, academic minors/additional majors, and graduate study. The introduction of the study abroad process and travel options will encourage students to consider a study away experience into their academic curriculum. Students will explore their additional academic interests by identifying their psychological preferences through the Myers-Briggs Type Indicator and matching these preferences with academic minors/additional majors at CMU. The presentation of the Intern Development Program (IDP) will engage students in considering future plans for earning IDP hours and understanding the process of securing an architectural internship. Students will be introduced to the process of developing an independent research project. Additional topical areas to be covered in the seminar will include an evaluation of the previous semester, scholarship/academic funding opportunities, graduate studies, and schedule planning for upcoming semesters.

48-065 Architectural Rapid Prototyping for Non-Architects
Intermittent: 9 units
The continuing development of rapid prototyping technologies has expanded the range of applications?and their accessibility. The ubiquity of the three dimensional printer is only a matter of time: today?s availability of the desktop 3D printer has made it conceivable that they will soon become as common as their two-dimensional counterparts. This course will test the current capabilities of the desktop 3D printer, and explore the ways in which it can be used to develop architectural massings and details. Through the iterative process, we will test your original designs at a number of scales, from site context to the building to the component. While there is no prerequisite for this course per se, it is expected that students understand the basic fundamentals of architectural drawing conventions (plans, sections, elevations), and/or are conversant in 3-D modeling programs (Sketchup, Revit, Rhino, etc). Preference will be given to those intending to graduate with a minor in Architecture.

48-095 Spatial Concepts for Non-Majors
Fall and Spring: 10 units
This course serves as an introduction to the spatial concepts of architecture for students from other disciplines. The course is focused entirely on project design work (this is not an historical survey, technical or lecture course). This course is very hands-on Projects will explore the design and experience of spatial environments through a series of creative investigations. The semester will be broken in to 3 parts:Intro/Exploration and a long term project. In Intro/Exploration, students will have many hands on opportunities to start to build a common language to describe spacial investigations as well as creating them. This will consist of short projects, with each design investigation progressively building upon the previous exploration; these early projects will consist of both individual and group work. They will focus on Making. The second half of the semester will consist of one long term project to be created individually, incorporating students? personal theories of architecture based on an overarching question. Studio work will be supported by group discussion based upon critical review of student work, readings, slide presentations, videos and films. There will also be a few field trips. Students are encouraged to explore their own areas of interest with respect to their work in class. Self-motivation, class attendance and an open mind is mandatory, however, no prior architectural, engineering or artistic experience is required. Students are expected to perform work both inside and outside of class. Students should be prepared to purchase various supplies throughout the course. This course is in partial fulfillment of requirements for an Architecture Minor.

48-100 Architecture Design Studio: Foundation I
Fall: 15 units
As the first architectural design studio course, the Foundation I studio establishes a fundamental understanding of representation and abstraction to which more of your own thoughts and ideas about spatial thinking can be added. This will involve, by means of the architectural studio, a reiterative investigation into the relationship of technique, form, and meaning through study, invention, testing, and evaluation. During this semester a series of short problems will be given to expose you to the complexities of visual communication and the design act; to develop skills of spatial manipulation; to give you the self-confidence in making valid decisions within set time limits; to develop the skills of graphic presentation necessary for interpreting and communicating your architectural intentions; and above all, to instill the ability to combine insight with the rigorous analytical study in a ?design process? that is efficient, personally effective, and which becomes second nature to you as a working process.

48-105 Architecture Design Studio: Foundation II
Spring: 15 units
The 48-105 studio, called Foundation II, is the second studio in CMU?s professional B.Arch program. It builds on the lessons from 48-100 about clear architectural communication and abstract spatial-definition, but adds a greater emphasis on the material and experiential understanding of how architecture is made and used. We continue to emphasize architectural drawing and models (both analog and digital) as the primary means of architectural communication, but also as a method of creatively exploring and rigorously testing fundamental architectural ideas. We investigate, research, analyze, diagram, and apply lessons from local architecture, and great architecture of the past, in studio, and in the parallel survey of architectural history. We introduce the use of ?systems,? ?computational thinking,? and ?rules? in the design process to create order, deal with a range of parameters, and satisfy specific performance criteria. Beginning with more abstract formal design exercises, and ending with the design of a small building, we explore how tectonics, joinery, materials, as well as site, orientation, context, and human use can be harnessed to inspire great design. The design process is still carefully controlled, but students are encouraged to begin to speculate and take careful risks.
Prerequisite: 48-100 Min. grade C

48-116 Building Physics
All Semesters: 9 units
This course is composed of two parts related to fundamental building physics concepts, namely, the lighting performance of buildings (first part)and the thermal performance of buildings (second part). In the first part, the course will introduce fundamental lighting principles in the context of performance-based architectural design and diagnostics. The course will cover relevant aspects of lighting environment that affect the physiological and psychological experience of buildings, performance metrics, design and benchmarking methods, and contemporary simulation tools. Topics include a review of physiological and psychological response to the visual environment, analytical and numeric methods for the prediction of lighting conditions in interior spaces, lighting engineering and design methods, and application of computer-aided lighting simulation tools in architectural design. In the second part, the course will introduce fundamental thermal principles in the context of performance-based architectural design and diagnostics. The course will cover relevant aspects of thermal environment that affect the physiological and psychological experience of buildings, performance metrics, design and benchmarking methods, and contemporary simulation tools. Topics include a review of basic theory of heat transfer, thermal dynamics, thermal comfort, analytical and numeric methods for the prediction of building thermal load and energy consumption, and application of computer-aided thermal simulation tools for building thermal design. Demonstration of a set of environmental measurement and sensing devices will also be included in the thermal part of this lecture. DIVA-for-Rhino and ArchSim-for-Grasshopper/Rhino software platforms will be used for lighting and thermal performance simulations
Prerequisites: 62-126 and 62-123 and 62-122 and 62-125

48-120 Digital Media I
Fall: 6 units
IDM is a required course for all first year architecture students. The course introduces students to a wide range of digital methods and concepts available to architects for design, representation, and documentation. The coursework is directly coordinated with Studio assignments providing the students with the opportunity to master their digital skills in a meaningful manner. Due to the amount of content covered there is no single text for this course, but the course is supported by materials created by the instructor. IDM addresses topics such as digital image editing, vector illustration, HTML coding, and 3D modeling.

48-121 Drawing I
Fall: 6 units
Architects draw and build models for a variety of reasons: to record and reference; to analyze and reveal order, intent, and relationships; to speculate; and to visualize new propositions. The study of architecture requires the connection between the mind, the eye and the hand, so that the nature of ideas and their relationship to physical form can be investigated. The connection of the mind, hand and drawing skills requires considerable time and effort. This course introduces why architects use these forms of representation. Students are introduced to how to do basic academic research as well direct assignments that apply the fundamentals of freehand drawings and drafting techniques as it pertains to plans, sections, elevations and paraline drawing, analytical diagraming and model making.

48-125 Digital Media II
Spring: 6 units
IDM2 is a required course for all first year architecture students. This course is the continuation of IDM. IDM2 introduces students to measured drafting and the process of creating a construction drawing set. The coursework is directly coordinated with Studio assignments providing the students with the opportunity to master their digital skills in a meaningful manner. Due to the amount of content covered there is no single text for this course, but the course is supported by materials created by the instructor. IDM2 addresses topics such as digital drafting, construction drawings, advanced 3D modeling and HTML programming.
Prerequisite: 48-120

48-126 Drawing II
Spring: 6 units
Drawing and Appearance? is a traditional course in free-hand architectural drawing. Its central learning objective is building a capacity for visualizing three-dimensional space through the making of hand-made drawings. Two secondary objectives foster visual literacy: the ability to use line, tonal values and color to represent architectural space and the ability to use drawing to represent architectural proposals at various levels of abstraction Coursework includes free-hand and constructed perspective, shade and shadow projection, chiarroscurro drawing in colored pencil and color drawing in pastel. Work is submitted in three portfolio submissions of two weeks duration each. Coursework is built around exercises in the required course text: Drawing and Perceiving, John Wiley and Sons.

48-175 Descriptive Geometry
Spring: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. This is a manual construction course for solving problems in three-dimensional geometry through working with two-dimensional planes using basic mechanical drawing tools. The course covers basic concepts of descriptive geometry; solving problems involving lines and planes in space and their spatial relationships; rotations in three dimensions; locating points and tangents on solids and surfaces; intersection of solids; shades and shadows; perspectives; and development of surfaces.

48-200 Architecture Design Studio: Elaboration I
Fall: 18 units
This studio is an introduction to architectural design stressing concept generation and the development of a rich design process to create evocative spatial experiences through architecture. Building on the explorations of form and space in the 1st year, we investigate in greater depth the role that program, context, and the physical "elements of architecture" play in creating meaningful architecture. We seek to understand design principles underlying the buildings of the past and present, from the broadly theoretical and conceptual, to the real implications of tectonics and sustainability, and apply these ideas with intent and significance. We will focus on developing challenging architectural ideas, profound building details, and effective ways of communicating them in order to explore architecture's potential for creating poetic expressions, appropriate shelter, or exalted experiences, as well as its ability to embody ideas and impart meaning to the world around us.
Prerequisites: 62-123 and 62-126 and 62-106 and 48-025 and 48-100 and 62-122 and 62-125 and 48-105 Min. grade C

48-205 Architecture Design Studio: Elaboration II
Spring: 18 units
Building on the fall studio, the spring semester is concerned with more in-depth understanding and development of designs for small-scale buildings, now informed by greater knowledge related to materials, fabrication, and the act of construction. Following the "New Materiality" evident in architecture today, and acknowledging the importance of materials and assembly techniques for sustainable design, we seek to explore the aesthetic and experiential meaning of materials (WHY?), and the technical knowledge related to the use of materials and the processes of construction (HOW?). The creative opportunities and design implications of using varied materials, structural systems, fabrication and assembly techniques—both analogue and digital—are elaborated, especially as they determine the artistic, conceptual, poetic, creative, spatial, and experiential aspects of architecture. The studio projects, lectures, and the required building study will focus on the application and integration of knowledge acquired in a parallel "Materials & Assembly" course 48-215.
Prerequisite: 48-200

48-215 Materials & Assembly
Spring: 9 units
48-215/ 48-647 introduces and examines the fundamentals between design intent and construction materials, the science of materials (performance) and their assemblies. Learning how materials and techniques inform spatial and form making decisions will be a central theme for the semester. Lectures and discussions will focus on the meaning, aesthetics and techniques related to the use of materials and the process of construction.
Prerequisite: 48-100

48-217 Structures
Spring: 9 units
Structures is a required course taught in the second year. It is a successor course to Statics, complementing that previous course by emphasizing structural member design in wood, steel, and reinforced concrete; spatial synthesis of hierarchical one-way systems for gravity load; structural types for lateral load including braced frames, shear walls, and rigid frames; introduction to geometric structures such as cable nets, domes, shells, and air-supported structures.

48-240 Historical Survey of World Architecture and Urbanism I
Fall: 9 units
This course cuts a broad swath through time, geography and cultures, surveying critical episodes in the built environment of Europe, the Middle East, Asia, and the Americas from antiquity through the 19th century. Reflecting the inseparable relation between building and human needs, this course is not only a history of architecture, but also a history through architecture. It examines architectural and urban design as a form of cultural expression unique to its time and place. The design, use, meaning and legacy of a building is conditioned not only by the architect's will or the patron's desire, but also by a web of technological, religious, social, cultural, economic, and political factors of the time. This foundation course is the first in the architectural history sequence, and introduces students to the subject and skills of world architectural history. It is a prerequisite for all subsequent architectural history courses. Student work will include several exams and a final.

48-241 Modern Architecture
Fall: 9 units
This survey of modern architectural history lecture course picks up where the historical survey 48-240 leaves off. It focuses attention on the 20th-century, and investigates the web of interwoven ideas and issues that characterize the modern age and ?modernism.? We begin with a look at the "crisis of modernity" that plagued most of western civilization in the late 19th-century, and then survey the major movements of the avant-garde and other responses to modernity, and end with what came to be known as ?Post-Modernism.? We will look more closely at the increasing divide between the ?disciplinary? edge of architecture, and architecture?s increasing ?professionalization? in the last century, focusing on how architecture has influenced culture through experimentation and provocative thinking, even when the primary intent was functional, technological, social, political, etc. Emphasis will be placed on the relationship of buildings to the more general cultural, intellectual, and historical circumstances in which they were created. Special attention will be devoted to the important manifestoes, theoretical, and critical writings that so determined the project of modern architecture.

48-250 Case Studies in Architecture and Cities
Fall: 9 units
To be determined by the department

48-300 Architecture Design Studio: Integration I
Fall: 18 units
Design Studio III: Building and Site is a required course taught in the third year. The subjects of the Third Year Fall Semester are the reciprocal orders of buildings and landscapes and the development of the building site. The work builds on knowledge gained in prerequisite and co-requisite courses including 48-312 Site Engineering. This course asks students to continue their investigations into the formal and spatial composition and enquiries of previous semesters with a focus on the following concepts: Occupancy: Social and cultural phenomena, dimension/measurement and cycles of time relating to human and non-human occupancy Site assessment: site inventory at many scales Grading and surface manipulation: compatibility of grading with related technical considerations for water management, ground structures, surfacing, plants, and maintenance Road alignment: design of roads and parking to support construction, service and the anticipated occupancies, design of roads to connect to other roads with appropriate sight lines, stack spaces, and turning requirements, layout and sizing of parking spaces for vehicles Stormwater: volume and direction of runoff water on both the undisturbed and developed areas, storm water surface system, Plants: selection of plants and plant communities with consideration for regional, local, and site-specific factors
Prerequisites: 62-275 and 48-200 Min. grade C and 48-205 Min. grade C and 48-116 and 48-215 and 48-324 and 62-225

48-305 Architecture Design Studio: Integration II
Spring: 18 units
The basis for the CMU studio course sequence is the expectation that the student retains and applies knowledge gained each semester to the current studio. The spring semester of the third year of architectural studies at Carnegie Mellon University is concerned with the detailed development and refinement of an architectural design as informed by the technical knowledge of structural systems, enclosure systems and the process of construction. The student is expected to articulate concepts and develop designs with more precision and in greater detail than done in previous studios and courses. In addition to criteria related to the development of design skills appropriate to one's sixth semester of the studio sequence, the following criteria are an explicit part of the evaluation of the student work: Aesthetics: The degree to which the design responds to formal issues as articulated in prior design studios. Structural System: The degree to which the proposed building is presented as a statically stable structure which defines the spatial order and satisfies the architectural intentions made explicit in the project. Enclosure System: The degree to which the proposed enclosure system satisfies the design requirements and responds to the physical phenomena of the environment into which it is placed. Material Selection: The degree to which the selected building materials and their implementation are appropriate to the occupancy, articulate the architectural order, and satisfy the physical design requirements. Constructability: The degree to which the proposed building is developed in response to an understanding of the processes of construction. Presentation: The clarity, craft and completeness of the presentation.
Prerequisite: 48-300

48-315 Environment I: Climate & Energy in Architecture
Fall: 9 units
This course introduces architectural design responses for energy conservation, human comfort, and the site-specific dynamics of climate. Students will be expected to combine an understanding of the basic laws of comfort and heat flow with the variables of local climate to create energy design guidelines for their own work. The state of the art in building energy conservation and passive heating and cooling technologies will be presented, with take-home readings and assignments. To stress the significance of architectural design decision-making on energy consumption and comfort, full design specifications and calculations will be completed for a residential-scale building. Students will compile a professional energy consultant's report, designing the most viable energy conservation retrofit measures for their client from siting, massing, organization, enclosure detailing, opening control, to passive system integration and management. An overview of world energy consumption in buildings and energy design standards will be challenged by lectures on building energy conservation successes, and emerging demands for a broader definition of sustainability. The course will end with a focus on the design integration of natural conditioning systems and the potentially dynamic interface of mechanical systems in small- and large-scale buildings.

48-324 Structures/Statics
Fall: 9 units
To be provided by department

48-332 Teaching and Learning
Intermittent: 6 units
In this course, students will learn about effective strategies for teaching architecture and the built environment. Topics include the cognitive differences between novices and experts, instructional techniques, and goal alignment. As part of the coursework, each student will implement these teaching strategies to design and teach a lesson. Elements of developmental psychology, learning theories, and classroom practices will inform the architectural education lesson. Teaching and learning techniques can be generalized for communication with clients, practice, and the community.

48-338 European Cities in the XIX Century: Planning, Architecture, Preservation
All Semesters: 9 units
The history of the main cities of Europe during the XIX century is a history of change and transformation. The physical environment and the political, financial and administrative structures adapt to the needs of new masses of population and to the challenges of metropolitan life. In some cases, cities even acquire new representative functions, as they become a national capital. This course traditionally offers an overview of the urban culture of XIX century Europe, reconstructing aspects of the broader historical context and then focusing on reading the effects of the XIX century transformations on the physical appearance, structures and image of present-day European cities, such as Paris, London, Berlin, Barcelona, Vienna and Rome. This semester we will add to this analysis, acquired by learning and applying a set of essential questions about XIX century urban transformations, a second look at the image of the city - the issue of how the city is represented and described in the various moments of its Nineteenth century transformation (from historical maps, to paintings, from postcards to literary descriptions). We will try to consider its changing visual representation and the different perception of its character and peculiarities over time, finally discussing how the Nineteenth century image of each city still affects how it is viewed today. We will rely, along with the usual reading materials (articles, book excerpts) also on visual documentation, such as photography and film. The course is based on lectures and discussions and requires personal elaboration, as well as a fair amount of reading and writing.
Prerequisite: 48-240

48-339 IDeATe: Making Things Interactive
Spring: 12 units
In this hands-on design-build class you will learn the skills to embed sensors and actuators (light, sound, touch, motion, etc.) into everyday things (and places etc.) and to program their interactive behavior using a microcontroller. You'll also dive into the fields of VR/AR/MR and experiment with combining these disciplines with physical computing. Through weekly exercises and a term project the class will introduce basic analog electronics, microcontroller programming, projection mapping and virtual reality; as well as exploration into using kinetics and materials to make the things you design perform. Emphasis will be on creating innovative experiences. The graduate edition of this course will require additional work including a paper that can be submitted to a peer-reviewed interaction design conference such as CHI, UIST, or TEI. Students from all disciplines are welcome: but please note that the class demands that you master technical material. Experience in at least one of: programming, electronics, or physical fabrication is strongly recommended.(Participants will provide their own supplies and materials.)
Prerequisites: 16-223 or 60-223

48-340 Modern Architecture and Theory 1900-1945
Intermittent: 9 units
This architectural history lecture course surveys the modern buildings and literature of the first half of the twentieth century, focusing primarily on Europe but extending also to non-western countries. We begin with a look at the "crisis of modernity" that plagued most of western civilization in the late 19th-century, and then focus on the major movements of both the avant-garde and other responses to modernity from 1900-1945. The course includes lectures, readings, and discussions about a broad range of issues, including 1) Formal tendencies; 2) Theoretical issues; 3) National traditions; 4) Biographical sketches; 5) Significant technologies and materials; 6) Political motivations; 7) Social & cultural influences. Emphasis will be placed on the relationship of buildings to the more general cultural, intellectual, and historical circumstances in which they were created, especially the important manifestoes, theoretical and critical writings that so determined the project of modern architecture. Work for the course involves extensive reading and a major research paper.
Prerequisite: 48-240

48-341 Expression in Architecture
Intermittent: 9 units
This architectural history seminar will explore expression in architecture in its many forms, particularly in written works of architectural theory through the ages. We start with the premise that architecture is not merely pragmatic, technical, or functional: it can express or communicate like a language, it can represent and inspire like many of the arts, it can shape behavior and emote, it can trigger memories, emotions, or meanings. As Isozaki put it: ?Architecture is a machine for the production of meaning.? We?ll investigate many ways that architects have theorized the design process, as well as the forms, materials, and contexts of architecture, to express a myriad of ideas and sensibilities. We?ll also look at the ways that buildings can communicate and have meaning, often beyond the intent of the architect, and usually changing over time. Some of the topics to be explored include the classical orders, gothic geometry and mystical light, the theatrical space of the Baroque, architecture parlante, character, and style in the Enlightenment, tectonics as structural expression, political architecture and morality, the aesthetics of functionalism, Expressionism, key terms such as ornament, representation, linguistics, and semiotics, as well as more recent theoretical constructs such as embodiment, materiality, atmosphere, and affect. The work of the seminar will include intensive weekly readings, especially of primary sources by the architects seeking to express ideas, weekly presentations and discussions about the sources, and a term paper on an important theory of expression in architecture of your choice.
Prerequisite: 48-240

48-347 ImPrint. Writing for Creatives
Spring: 9 units
Experience the impact of writing and publishing on your design process. In this hands-on workshop for a small group, the raw material is your completed and in-progress studio work. See your design thinking evolve and develop under the lens of a thoughtful, design-oriented writing practice. Learn to use writing and editing to clarify and refine your thought process and decision-making. Explore how text, images and layout come together to help you meaningfully adjust your communication strategy. The weekly three-hour session is a dedicated time to reflect on your studio work, do hands-on writing, share and discuss. You will create effective, evocative, intriguing presentations, respond to feedback from a panel of guest readers and finally see your work published in a SoA sponsored book at the end of the term.

48-348 Architectural History of Mexico & Guatemala
Intermittent: 9 units
Despite the leveling forces of mass culture and globalization, the geographic and social diversity of the U.S. has created distinctive regional mosaics of landscape and architecture. Say New England and images of English Pilgrims, town greens with white framed churches, and industrial mill villages may come to mind. The Southwest conjures different images, perhaps of adobe pueblos, Spanish friars, arid ranches, and the color turquoise. The built environment of the Midwest, the California coast, the Mississippi Delta, and many places in between reflect particular regional identities that have been both unconsciously and consciously created over time. This course examines the historical development of regional patterns in the American built environment. It investigates how and why a regions architectural identity evolved in the ways that it did. To what degree is place something to respond to, to interact with, and to what degree is place something that is created? Our focus will be primarily pre-20th century when the forces of vernacular traditions were stronger, we will also examine more recent trends of regionalism as an aesthetic choice and a theoretical stance.
Prerequisite: 48-240

48-350 Postwar Modern Architecture and Theory
Intermittent: 9 units
This architectural history lecture course surveys the modern buildings and architectural theory of the post-World War II period. It begins with the cataclysm of WWII and the fundamental shifts it caused on the conception of modernism, technology, cities, and geo-politics. It proceeds to investigate themes such as rebuilding and reconstruction, grand modern masters such as Mies, Kahn, and Le Corbusier, the fascination with technology, megastructures and utopian thought, the need for monumentality, meaning, and regional identity, and the dissemination of modernism from corporate America to the third world. It ends with the rupture in modernism associated with the social revolutions and the rise of a post-modern architecture in the late 1960s and early 1970s. The course includes lectures, readings, and discussions to define the unique character of the postwar period, as modernism both reigned supreme, and began to be questioned. Emphasis will be placed on the relationship of buildings to the more general cultural, intellectual, and historical circumstances in which they were created. Special attention will be devoted throughout the course to the important manifestoes, theoretical and critical writings that so determined the project of modern architecture. Work for the course involves extensive reading, preparing for class discussions, and a major research paper.
Prerequisites: 48-240 or 48-241

48-351 Human Factors in Architecture
Intermittent: 9 units
Required course Human Factors is an investigation of what makes buildings tick for people: the internal spaces, transitional spaces, transactional spaces, defensible space, owned space, shared space, public space, and most importantly, occupied space. We move up in scale from the individual and group to the community to consider our designers' biases in how we analyze the human needs, how we judge the quality of space and subsequently, how we apply this knowledge to our own design work. Students develop a research question and test it in field research using observation, interviews and surveys. They draw conclusions about the quality of a space and place and how to improve it. Students should leave this class with the ability to discern a problem, experience in applying their understanding of behavioral settings and the human condition to specific research foci, and the ability to use their knowledge and skills deftly in practice, where time and resources are limited. Assignments will be a mix of individual and group work, with emphasis on the latter. There will be an emphasis on reading relevant literature, field investigations and understanding research methods and collaboration for applications in practice.

48-355 Perspective
Intermittent: 9 units
Course addresses perspective on the basis of three distinct understandings of perceptual psychology: 1) A Kinesthetic Basis for Perspective, which is built on the drawing pedagogy of Kimon Nicholaides. It aligns with the transactionalist understanding of perception and considers perspective as partly invented and partly discovered truth. 2)The Order of Appearance, which is built on the early work of the perceptual psychologist, J.J. Gibson, and aligns with the ecological position of Gibson and his followers It considers perspective as an absolute truth of the visual field. 3)Perspective Imposed, which aligns implicitly with the position of Gestalt psychology. It treats perspective as an imposed schema. Along the way some use is made of on-going design work for subject material. Work is submitted in 3 portfolio submissions of 3-4 weeks duration each.
Prerequisite: 48-105

48-356 Color Drawing
Intermittent: 9 units
Color Drawing builds knowledge and provides practice in the use of color in depicting architectural surroundings. Media used are pastels on gray backgrounds, colored pencil on white backgrounds and water color. In the interest of speed the principal technique used in watercolor is a moderate dry brush technique. Coursework assumes knowledge of linear perspective and basic use of color. Work consists of in-class exercises and weekend assignments built on these. Students can expect to spend up to 6 hours of work per weekend.
Prerequisites: (48-126 and 48-121) or (48-135 and 48-130) or (62-125 and 62-126) or (48-120 and 48-125)

48-368 Rediscovering Antiquity: Travelers, Archeologists & Architects in Mediterranean
Spring: 9 units
The course proposes a journey in the Mediterranean, with special focus on Greece and Turkey, but also travel through time. In fact ancient cities and archeological sites, from the hills of Troy to the archeological sites of Pergamon and Ephesus, to the cities of Athens and Costantinople/Istambul, will be studied not so much as signs of the important Greek and Roman past of the region, but as the object of late Eighteenth and Nineteenth century rediscovery. The rich vestiges of the mythical past of this region were then brought to the light, in the frame of complex and adventurous missions. The eyes of scholars, travelers and artists filtered and transformed the reality of the ancient objects and places, adding to their fascination and vitality and changing the way we perceive this legacy today. At the same time though, a new political agenda, new biases and new aims were connected with the rediscovery. These in turn influenced not only the way the past of the region was explored and the way the finds were studied and exposed, but also the cultural debate in the rest of Europe, with important effects on the architecture of the main European cities.
Prerequisite: 48-205

48-371 American House and Housing, 1850-1975
Intermittent: 9 units
This architectural history course examines the development of American house and housing choices during the period 1850-1975. A recurring picture of the "American Dream" has typically included the image of a single-family, detached dwelling set within its own green yard in the suburbs. However powerful and durable that image is, the history of house and home in America is actually a far more complex story with many different twists and turns. In the course we will look at both urban and suburban housing choices and cultures, ranging from single family detached dwellings to multi-unit housing, and across a social spectrum income, class, race, and gender. Through the use of occasional field trips, we will use Pittsburgh as a touchstone for understanding broader national trends in the history of American urban and suburban housing. The course is organized as a lecture course supplemented with field trips and discussions based on field trips and primary source readings. The additional time slot on Thursday afternoons will be used only when field trips are scheduled. Student work will include a research paper and several shorter written assignments throughout the semester.
Prerequisite: 48-240

48-374 History of Architecture in the Islamic World- A Primer
Fall: 9 units
This course serves as an introduction to the architecture that developed in the Islamic lands over the centuries. The aim of the course is to provide a basic understanding of major epochs and regional variations, examining the social and historical context within which Islamic art and architecture developed. Through lectures, discussion and guided research activities, the students will learn the function and meaning of the most important building types, examine how these types changed over time to adapt to the needs of changing societies, and consider influences and exchanges with other traditions. While the main geographical focus of the course will be on the Mediterranean area, from Moorish Spain to the modern Middle East, the students will have the opportunity to develop independent research projects on other areas of the Islamic world.
Prerequisite: 48-240

48-380 Real Estate Design and Development
Spring: 6 units
This course will provide an overview of the real estate development process and explore the interdependence of real estate development and design. The course will introduce real estate development team members, processes, and phases, including feasibility, predevelopment, construction, and marketing. The course will include a substantial financial component that will introduce students to the basic techniques of property valuation, project budgeting, pro forma analysis, sourcing of financing, and investment analysis. Students will study how market demand, tenant requirements, site constraints, zoning restrictions, and available capital affect design solutions. Course work includes classroom learning, independent reading and exercises, guest lectures, and examination of case studies. The semester?s effort culminates in the execution of a team development project based on a current Pittsburgh development project. Teams will complete a basic market analysis, program evaluation, schematic design creation, project cost estimation, pro forma analysis, and evaluation of financial feasibility. Development practitioners will provide a critique of each team?s project to offer ?real world? guidance on student schematic designs and feasibility analysis prior to the final completion of the project.

48-381 Ethics and Practice
Spring: 12 units
An examination of moral concepts, reasoning, and methodologies that influence the built and natural environments through action/applied ethics. The course utilizes principles of business practice as a foundational lens through which to understand central and contingent dimensions of contemporary professional practice in, and related to, architecture. Lecture content and assignments emphasize establishing a critical awareness and broad understanding of the mediating factors that inform the intelligent resolution of architecture and construction through multiple forms of advocacy. Theory, case studies, analytical exercises, representational investigation, and production are utilized as a means of developing knowledge in the contractual, legal, fiscal and representational contexts requisite for the fulfillment of the architect's social contract.

48-383 Ethics and Decision Making in Architecture
Intermittent: 6 units
Course description coming soon.

48-390 Physical Computing Studio
Spring: 10 units
This collaborative studio course will allow interdisciplinary teams to develop wearables with a focus on assistive technology. The ubiquitous nature of mobile devices coupled with low-cost and easily integrated sensors and actuators make this a good time to approach real problems for a range of users from the physically disabled to athletes. Teams will learn skills in hardware, software, fabrication, and design communication in order to effectively develop and share their ideas.
Prerequisites: 16-223 Min. grade C or 60-223 Min. grade C

Course Website: http://ideate.cmu.edu/

48-400 Advanced Synthesis Options Studio I
Fall: 18 units
Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities.The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.
Prerequisite: 48-305 Min. grade C

48-405 Advanced Synthesis Options Studio II
Spring: 18 units
Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities.The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.
Prerequisites: 48-400 and 48-412

48-410 Advanced Synthesis Options Studio II
Spring: 18 units
Course Description coming soon.
Prerequisite: 48-305 Min. grade C

48-432 Environment II: Design Integration of Active Building Systems
Fall: 9 units
High performance buildings are achieved with designs that effectively integrate passive and active systems. Having been introduced to passive systems in prior semesters, students in 48¿432/48¿655 will focus on the active systems typically included in commercial buildings and strategies for their successful integration with passive components. The goal of the Design Integration of Active Building Systems course is to familiarize students with active building systems and integrative design strategies that should result in high levels of occupant comfort in commercial buildings that, in the US, are moving toward net zero energy and net zero carbon emissions Active systems introduced in this class include: Electric lighting Mechanical ventilation Active heating and cooling Water systems for interior and exterior use and water heating, including solar Onsite electricity generation with renewable energy Building transportation systems Active fire protection & smoke control Because of the breadth of this subject area, the course will be future¿focused, concentrating on design approaches and technologies that appear to be well¿suited to a net zero energy and net zero carbon future.

48-440 American Regions & Regionalism: An Architectural History of Place, Time, and Cul
Intermittent: 9 units
Despite the leveling forces of mass culture and globalization, the geographic and social diversity of the U.S. has created distinctive regional mosaics of landscape and architecture. Say New England and images of English Pilgrims, town greens with white framed churches, and industrial mill villages may come to mind. The Southwest conjures different images, perhaps of adobe pueblos, Spanish friars, arid ranches, and the color turquoise. The built environment of the Midwest, the California coast, the Mississippi Delta, and many places in between reflect particular regional identities that have been both unconsciously and consciously created over time. This course examines the historical development of regional patterns in the American built environment. It investigates how and why a regions architectural identity evolved in the ways that it did. To what degree is place something to respond to, to interact with, and to what degree is place something that is created? Our focus will be primarily pre-20th century when the forces of vernacular traditions were stronger, we will also examine more recent trends of regionalism as an aesthetic choice and a theoretical stance.
Prerequisite: 48-240

48-448 History of Sustainable Architecture
Intermittent: 9 units
The History of Sustainable Architecture investigates themes of nature, ecology, pollution and conservation in the built environment and visual arts. The term ?sustainable architecture? is a comparatively recent one, arising in reaction to the destructive and toxic nature of the industrial era and its strident ambassador, Modern architecture. Yet, an esthetic and philosophical view of harmony with nature accompanies many forms of historical human activity in the built environment. Similarly, issues of waste removal, mechanical systems and natural materials that characterize current concerns have illustrative historical roots in numerous civilizations going back centuries and even millennia in pre-Industrial or non-industrial cultures. This course will engage texts and examples relating not simply architecture, landscape and urban history, but also art, philosophy and popular culture as a means to understand the many precedents for today?s interest in sustainable architecture and planning. The course will examine texts and works by figures including Vitruvius, Pliny, Leon Battista Alberti, Thomas Cole, Frederic Law Olmsted, Buckminster Fuller, Reyner Banham, Ebenezer Howard, Hassan Fathy, Bernard Rudofsky, Norman Foster, Robert Smithson, Andy Goldsworthy and more. Students will be encouraged to apply principles from the class to understanding and execution of work in their own discipline.

48-452 Real Estate Design and Development
Fall: 6 units
This course will introduce the Real Estate development process and explore the interdependence of development drivers and the design process. Classroom learning, exercises and guest-lectures will introduce students to the concepts of market and financial analysis, as well as the basic techniques of budgeting, proforma development, and valuation. Parallel to this investigation, students will evaluate real world developments and interface with the development professionals that executed them to learn how development drivers shaped the development process and decision making. Students will study how market demand, tenant requirements, site constraints, and available capital affect feasibility, and through this the ultimate design solution. The semester's effort culminates in the execution of a mini-development project. Students will work in teams to complete a basic market analysis, program evaluation, schematic design, construction and development cost estimate, proforma analysis, and a determination of financial feasibility. Development practitioners will interface with student teams during this mini-project to offer "real world" guidance on student schematic designs and feasibility analysis.
Prerequisite: 48-305

48-453 Urban Design Methods
Fall: 6 units
This undergraduate lecture course introduces urban design history, theory and methods. It is a required supporting course for the Urban Laboratory design studio, and similarly examines urban design at multiple scales: city form and networks, neighborhoods and block structures, streets, public spaces, and urban building typologies. Key issues introduced include the emergence and evolution of urban design as a discipline, economic, social and political factors affecting the contemporary city, and environmental sustainability at the urban scale. A wide variety of cities, projects, proposals and methodologies are examined. Assignments include readings from seminal texts, quizzes, and a final examination.
Prerequisite: 48-305

48-454 Futures of the City/Cities of the Future
Intermittent: 9 units
If all design can be read as attempts to predict and to shape the future, then no one looks further into the future than the urban designer and the urban planner. The work in which they are involved often does not materialize in their lifetimes; in fact, the duration of the projects are so long twenty, thirty, fifty and hundred year timeframes, it is more than likely that he or she will pass on before the project reaches fruition. The trouble with predicting the future is that it is so uncertain, so undecided, so unknowable. A brief look backwards reveals that we are not the first generation to consider the future. History is replete with predictions, some of which were actualized, the vast majority of which were not. Today's forecasts for tomorrow vary wildly. A handful of optimists view the future through rose colored glasses, whereby humanity is delivered to salvation via technological wonders and the widespread adoption of common social values. A larger group predicts the end of the world as we now know it, but even they cannot agree on the cause of our demise, with those arguing that climate change will kill us clashing with those convinced that we will be destroyed when robots achieve technological singularity. Shy of total extinction, however, any vision of the future requires designers, and will likely occur in urban (or formerly urban) locations. As of this decade, for the first time in history, more than half of the world's population, almost three and a half billion people, live in towns and cities. Estimates suggest that by 2030 this number will swell to almost five billion.
Prerequisite: 48-205

48-470 Exploring Pattern Through Lamination
Fall: 9 units
Lamination is the process of gluing wood together along the edge or face of a plank. There is unlimited variety in the ways to do this and to generate pattern in the process. This course will prescribe a few basic ways to laminate following standard rules of wood working and then introduce the possibilities of pattern generation. Generally lamination is unidirectional, however, in this class we will introduce ways to achieve cross directional patterning and the use of inlay to elaborate on the idea of patterning. Projects will be visual and sculptural statements. Their function will be limited and will not be furniture. Each exercise will present a series of basic wood working operations, which, when repeated and recombined will become products of compelling visual character. As visual idea statements you will be asked to experiment, invent and explore and take these standard operations in new directions. As visual idea statements the greatest clarity of vision will be achieved through careful construction.

48-473 Hand and Machine Joinery, New Directions
Fall: 9 units
In the Fall 2017 and Spring 2018 there will be some changes to the shop electives offered. First the Spring Furniture Design and Construction course # 48564 will no longer be offered because that content is incorporated within the Furniture Studio in the fall. Next, the two shop mini courses previously offered in the fall will each be expanded to become full electives, one in the fall and one in the spring. The prerequisite for both of these classes is documentable experience with the band saw, table saw (ripping and crosscut), drill press and the belt and disk sander. The Hand and Machine Joinery, New Directions, is scheduled Tuesday and Thursday mornings 10:30 am to 11:50 in the spring 2018, and will be a 9 unit elective running the entire semester. The elective will focus on building a free standing (or hung) cabinet with doors. If enrolled students have taken the Exploring Pattern course in the fall the doors made in that class will be mounted on the cabinet. If students have not taken that course then a pair of simple doors will be made instead. The primary goal of this course will be to learn the steps of making a simple cabinet using hand and machine joinery. Quality of craft will be of great importance. Uniqueness of design will not be emphasized, however individuation of the cabinet will still be possible throughout the construction, starting with choices between a wall mounted or free standing (with legs) cabinet, the selection of hardwoods, the specific size of parts, and the selection of particular detail options. The construction process will be carefully staged with demonstrations continuing throughout the semester. The cabinet will be perpendicular and rectangular. Students will use standard mortise and tenons of various sizes, bridal joints, floating tenons, tongue and groove, spline and dovetail joints.

48-478 Digital Tooling
All Semesters: 6 units
This course serves as an immersive analysis of the available technologies located in the Digital Fabrication Lab at Carnegie Mellon and beyond. Students begin to understand equipment limits/boundaries, purposes and concepts; and the possibilities that arise from thoroughly comprehending how these tools work. During your Digital Experience, students begin to understand more systematically how to use these tools to their advantage. A better understanding of the equipment proves very useful towards a SoArch Student's 3rd, 4th and 5th years at Carnegie Mellon; but more importantly provides a fundamental understanding of a leading edge technology that will certainly prove itself as an integral tool for any Designer throughout their professional career. It is based on the idea that pushing the limits of design fabrication; comes from knowing the limits of your tools. The course operates by discovering tooling extremes; thus indicating limits, and then incorporating these boundaries (and/or breaking them) with Digital Fabrication methods and tooling; ultimately providing a platform in which students begin to understand and incorporate project efficiency. Prerequisites: Imagination, Laser Cutting, Milling and 3D-Modeling Experience required. (Rhinoceros 3D Preferred)
Prerequisite: 48-205

48-493 Representing Activism
Intermittent: 9 units
Efforts to promote social, political, economic and environmental change range in form from written word to direct action. Sources of injustice that those efforts address are multi-dimensional and complex. Effective forms of activism are fueled by creativity that synthesize and distill complex constellations of information and foster understanding. REPRESENTING ACTIVISM explores the role of multi-media graphic representation as a lens through which change and social justice can be fostered. Exploration of efficacy in application will span four dimensions, 1) Social Media, 2) Film, 3) Poster/Graphic Design, and 4) Publication - all aspiring to achieve the status of art. Art and Activism are predicated on exposing the truth. Art has the unique power to convey messages across linguistic and cultural barriers that often divide. Part of the Activist's challenge is to grip and inspire people to action. With the avalanche of information and media modern society absorbs every day, this is increasingly hard to do. Sometimes it is too much to ask people to stop and think: sometimes it's too much just to ask them to stop. Successful art compels this, penetrating apathy and imploring the viewer to look deeper and explore the narrative that is embedded in what elicited a visceral response. This seminar aspires to compel action in the public interest through artful representation.

48-494 Beyond Patronage
Intermittent: 9 units
TBD

48-497 Thesis Prep
Spring: 3 units
The primary goal of this mini is to help students formulate a robust proposal for the 5th year Thesis, but it could be used to create a proposal for any grant, scholarship or academic research project. A series of weekly workshops, readings, discussions, and guest lectures will help students move from wide-open initial ideas about issues they are curious about and seek to explore, to the development of a rigorous research process that builds on existing knowledge and attempts to develop new ideas and advances the discipline. The class will explore the difference between design and research in architecture, how different research methods and modes of representation can be leveraged, and how concepts of disciplinarity and "project" can focus a topic. Students will begin to identify precedents, key readings and a research bibliography, an overview of the general topic they will research in depth, a detailed plan for a years worth of independent thesis work, and a well-defined end-product, likely a design proposal. An important task will be to identify advisors who can support, guide, and critique your work, who can act as intellectual collaborators as much as evaluators. This course (or an equivalent approved by the Thesis coordinator) is a pre-requisite for doing a year-long Thesis or semester-long Independent Project in 5th year studio.

48-500 Advanced Synthesis Options Studio III
Fall: 18 units
Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities.The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.
Prerequisite: 48-410

48-505 Advanced Synthesis Options Studio III
Spring: 18 units
Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities.The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.
Prerequisite: 48-105

48-509 Architecture Design Studio: Thesis I/ Independent Project
Spring: 18 units
Thesis is a year-long, independently defined research and design project that takes the place of upper level option studios. Thesis is an opportunity to develop skills, thoughts, and habits essential for future success, including mental discipline; independence of mind and judgment; working with advisors; the capacity to focus and pursue a subject in depth and over an extended time; the ability to design and execute a complex project; the skills of analysis, synthesis, and clear writing; and the self-confidence that grows from mastering a difficult challenge. Thesis topics and research agendas are generated by the student, but must be determined in collaboration with an advising team, and approved by a Thesis Coordinator. The School seeks to encourage an expansive range of rigorous and provocative inquiry as a culminating experience for the B.Arch education, including work that speculates, invents, or improves on existing ideas, practices, or systems through research and design; work that challenges the boundaries of the discipline and the profession, and moves beyond mere practice or solution-based work; worj that engages with open-ended and generalizable ideas, as much as with specific situations; work that projects or imagines a better future and an improved world; work that leads to the new knowledge, ideas, understanding, or paradigms. Acceptance into Thesis is dependent on passing the 48-497 ?Thesis Prep? course or its pre-approved equivalent, and submitting a rigorous thesis proposal to the Thesis Coordinator in late August, before the begin of classes. Approval for the 2nd semester is contingent upon successful completion of the 1st.

48-510 Advanced Synthesis Options Studio IV
Spring: 18 units
Course description coming soon.
Prerequisites: 48-400 Min. grade C or 48-410 Min. grade C

48-519 Architecture Design Studio: Thesis II/ Independent Project
Spring: 18 units
Thesis is a year-long, independently defined research and design project that takes the place of upper level option studios. Thesis is an opportunity to develop skills, thoughts, and habits essential for future success, including mental discipline; independence of mind and judgment; working with advisors; the capacity to focus and pursue a subject in depth and over an extended time; the ability to design and execute a complex project; the skills of analysis, synthesis, and clear writing; and the self-confidence that grows from mastering a difficult challenge. Thesis topics and research agendas are generated by the student, but must be determined in collaboration with an advising team, and approved by a Thesis Coordinator. The School seeks to encourage an expansive range of rigorous and provocative inquiry as a culminating experience for the B.Arch education, including work that speculates, invents, or improves on existing ideas, practices, or systems through research and design; work that challenges the boundaries of the discipline and the profession, and moves beyond mere practice or solution-based work; worj that engages with open-ended and generalizable ideas, as much as with specific situations; work that projects or imagines a better future and an improved world; work that leads to the new knowledge, ideas, understanding, or paradigms. Acceptance into Thesis is dependent on passing the 48-497 ?Thesis Prep? course or its pre-approved equivalent, and submitting a rigorous thesis proposal to the Thesis Coordinator in late August, before the begin of classes.

48-527 5th-Year/Senior Seminar
Intermittent: 3 units
Seminar for students graduating from the Bachelor of Architecture and Bachelor of Arts in Architecture programs.

Course Website: http://soa.cmu.edu

48-530 Human-Machine Virtuosity
Spring: 12 units
Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

48-531 Fabricating Customization: Prototype
Intermittent: 9 units
Students in this advanced digital fabrication course will leverage the full range of fabrication techniques (digital and analog) in the school of architecture to develop an architectural building component of a previous studio project with high fidelity. The course challenges students to situate their work within a context of materially sensitive built work, while seeking to explore the theme of digital materiality. The course is divided into two modules, the first of which studies significant recently completed built work related to proposed student building components. The second module operates as a laboratory / workshop in which students develop component prototypes through digital and analog methods of fabrication.
Prerequisite: 48-305

48-545 Digital Fabrication
Spring: 9 units
Using project-driven learning as its method, Making Intelligence will provide an immersive (re)introduction to the fundamentals of design fabrication by providing an applied overview of various methods of synthesizing ?traditional? and digital modes of making. Intended primarily as a portal course for graduate students that plan to use the School of Architecture?s digital fabrication lab, this course will give students the opportunity to learn how digital equipment works by discovering machine limitations and possibilities through design fabrication while also expanding on their understanding of the design development process. Students will apply their new knowledge by using the 3-axis router, 3D printing, laser cutters, and the vacuum former for the development of two highly-refined projects.

48-550 Issues of Practice
Fall: 9 units
Issues of Practice is a required course taught in the fifth year. It consists of three modules: Personal Promotion, Emerging Professional's Companion, and Excursions. The Personal Promotion module provides the students with a framework to create a resume, cover letter, and portfolio. The EPC (Emerging Professional's Companion) provides concentrated study in different aspects of professional practice. The Excursions require students to see how architecture relates to the wider world with architecturally related events that can include volunteer opportunities, lectures, mentorship, or teaching.
Prerequisite: 48-305

48-551 Ethics and Decision Making in Architecture
Spring: 9 units
Ethical Decision Making in Architecture is a required course in the fifth year of the Bachelor of Architecture Degree. It is part of a sequence dealing with professional aspects of the field of architecture, alongside courses like Human Factors, Real Estate Design and Development, and Issues of Practice. It builds on an understanding of the issues of occupancy, economics and practice in design decision making. The course covers basic frameworks of decision making and ethical adjudication through several case studies including Fallingwater, Sydney Opera House, Citicorp Tower, Pruitt-Igoe housing development, Crystal Palace and Kansas City Hyatt. The text for the course is a manuscript by the instructor entitled "Ethical Decision Making in Architecture".
Prerequisite: 48-205

48-555 Introduction to Architectural Robotics
Spring: 6 units
Introduction to Architectural Robotics is an entry-level course that exposes students to various aspects of industrial robots and automated fabrication including hands-on programming, workflow simulation, sensors, fixtures, and the tactics needed for designing flexible automation. This course will empower the student with the fundamental software and hardware knowledge necessary to do advanced fabrication in subsequent courses. Structured, competency-building exercises within the lab environment will be the method used to develop tacit knowledge of the equipment.

48-558 Reality Computing
Fall: 12 units
Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented reality / virtual reality, 3d printing, robotics). This semester the studio will focus on utilizing these technologies to capture places and objects to digitally recreate them for archives, artifacts, and interactive experiences. We will explore and analyze how to optimize these creations for real-time rendering and analyze how these platforms bridge the divide between "virtual" and "real."

48-564 Furniture Design & Construction
Spring: 9 units
This course is for students who already have a basic knowledge of hand tools and machines, and standard fabrication methods. Wood is the primary material, although other supplemental materials are permitted. One functional project will be built during the semester. Because all the equipment in the shop is traditional analog, the fabrication will remain analog. All operations will be done with hand tools or machines operated and controlled by hand. The emphasis of the design phases will also be non-digital. However recognizing the versatility of CAD, students will be permitted to advance and refine their ideas using their computer. One full scale orthographic drawing by hand will still be required, including plan, elevations, sections, and dimensions on 1/8" ply or mdf.
Prerequisites: 48-105 and (48-473 or 48-470)

48-568 Advanced CAD, BIM, and 3D Visualization
Fall: 9 units
This course is designed to introduce a student to 3D software tools, including AutoCAD 3D, Revit Architecture, and 3D Studio MAX. Building information and parametric modeling, materials, lighting, rendering, and animation concepts allow students to create integrated CAD/BIM projects, 3D video animations, and realistic renderings. At the conclusion of this course, students will have projects and animations created and architectural CAD/BIM standards outlined. Students should have some familiarity with basic AutoCAD 2D commands. Those who don't have AutoCAD 2D knowledge can contact the professor to arrange for on-line tutorials that need to be completed before classes begin.
Prerequisite: 48-305

48-569 GIS/CAFM
Spring: 9 units
A Geographic Information System (GIS) integrates displays, edits, analyzes, and shares spatial data for informing decision making. Industries benefiting from GIS include architecture, business, city planning, defense and intelligence, education, government, health and human services, natural resources, public safety, transportation, utilities and communications, and urban planning/design. GIS topics include map design and outputs, geodatabases, downloading and importing spatial and attribute data, digitizing, geocoding, and advanced spatial, 3D, and network analysis. Other topics such as raster-vector integration and web-based GIS will also be covered. Facilities management is the practice of coordinating the physical workplace with the people and work of the organization. Computer Aided Facilities Management (CAFM) integrates software tools to streamline operations, boost productivity and develop strategic planning goals for an organization. CAFM topics include space management, asset management, building operations, emergency preparedness, environmental health and safety, telecommunications, and real property and lease management. This course prepares students to understand, maintain, and manipulate spatial and organizational data using world leading software applications. By the end of the course, students will have sufficient background to identify spatial characteristics of diverse application areas enabling them to integrate spatial thinking and analysis into their academic research and careers.
Prerequisite: 48-205

48-576 Mapping Urbanism
Intermittent: 9 units
This seminar provides the critical tools necessary to examine the city as both a representation and a reality in flux. Through an interdisciplinary framework, students study urban history, theory, visual thinking and spatial mapping. Contemporary urban issues are introduced through weekly lectures, readings, and class discussions. Parallel to these urban explorations, students learn to employ a diverse set of representational techniques to create inventive mappings. Upper-level (300 and 400 level) undergraduate students and graduate students are encouraged to register.

48-587 Architecture Lighting Design
Intermittent: 9 units
Through hands-on exploration in the light lab, lecture and discussion, students will develop a design process for lighting people and architecture. Topics will include: Role of the architectural lighting designer in the collaboration process; Establishing design goals and a point of view; Communicating design ideas; Lighting interiors (retail, restaurants, offices, museums, hotels); Lighting exteriors (landscape, buildings, bridges); Technical tools (luminaires, lamps, control and dimming) A large part of class time will be devoted to hands-on experimentation of light. Students will also spend time in the light lab outside of class preparing realized lighting designs. The final design project will include full-scale lighting mock-ups.
Prerequisite: 48-105

48-596 LEED Buildings and Green Design
Spring: 6 units
Green building and sustainable design have been rapidly gaining acceptance in all sectors of the building market. Global issues of energy use, emissions, resource depletion, and land use are forcing building professionals to re-evaluate standard design and construction processes, and look to more environmentally friendly practices. The U.S.Green Building Council (USGBC) developed green building rating systems entitled Leadership in Energy and Environmental Design (LEEDTM) in order to define "green building" by establishing a common standard of measurement. LEED considers green building methods and technologies in several categories including site, water, energy, materials, and indoor air quality, and awards points towards an overall green building rating of certified, silver, gold or platinum. Currently, LEED registered projects make up 3% of the current U.S. commercial building market, and Pennsylvania is the third leading state with LEED registered projects. There is now a demand for design professionals with knowledge and experience not only in sustainable design but specifically with the LEED rating system as well. This course will provide students with background knowledge of the USGBC, the LEED system, as well as referenced standards related to specific topics. The course will benefit greatly from the large number of LEED projects in the Pittsburgh region, which will serve as case studies. Upon completion of the course, students will be prepared to take the LEED Professional Accreditation Exam, which is quickly becoming the standard of recognition for green building professionals.
Prerequisite: 48-315

48-630 M.Arch Studio: Integration I
Fall: 18 units
TBA

Course Website: https://soa.cmu.edu/march

48-631 Fabricating Customization
Fall
to be created by the department
Prerequisite: 48-205

48-634 Architectural Theory
Fall: 9 units
This graduate history and theory seminar starts with the conviction that Architecture is not only space, materials, technology, structure, form, program, site... but also culturally constructed discourse, meaning, communication, concept, and debate: or theory. Architects must draw from other disciplines, distinguish multiple positions on any issue, take a stance, act on, and be able to discuss, debate, and defend their ideas. The course will begin with the fundamental questions: What is theory in architecture? How has our understanding of architecture and theory evolved historically to get to this point? How will it continue to transform into the 21st century? Where is architecture going? Students will discover how architectural ideas and theories evolve and reoccur, and even the oldest theories have contemporary relevance. The topics covered will vary from year to year to acknowledge the dynamic nature of the program, profession, environment, and global context. The work of the seminar will focus on readings, weekly presentations and discussions about the sources, and a research paper on a theoretical aspect of architecture that might lead to a thesis or grant proposal. Thanks for syllabi. For NAAB clarity, but also for optics, I will ask all my colleagues teaching required courses for the M.Arch to issue a separate syllabus with the correct course number, and if they want, slightly different language about expectations, attendance, etc. I will also ask all faculty teaching required courses to list in their syllabus the SPC that are being demanded in the course... so students and faculty are clear.

Course Website: https://soa.cmu.edu/march

48-635 Environment I: Climate & Energy
Fall: 9 units
This course introduces architectural design responses for energy conservation, human comfort, and the site-specific dynamics of climate. Students will be expected to combine an understanding of the basic laws of comfort and heat flow with the variables of local climate to create energy design guidelines for their own work. The state of the art in building energy conservation and passive heating and cooling technologies will be presented, with take-home readings and assignments. To stress the significance of architectural design decision-making on energy consumption and comfort, full design specifications and calculations will be completed for a residential-scale building. Students will compile a professional energy consultant's report, designing the most viable energy conservation retrofit measures for their client from siting, massing, organization, enclosure detailing, opening control, to passive system integration and management. An overview of world energy consumption in buildings and energy design standards will be challenged by lectures on building energy conservation successes, and emerging demands for a broader definition of sustainability. The course will end with a focus on the design integration of natural conditioning systems and the potentially dynamic interface of mechanical systems in small- and large-scale buildings.

Course Website: https://soa.cmu.edu/march

48-711 Paradigms of Research in Architecture
Fall
This course is both an introduction to important models and methods of academic research particularly as they are related to building design issues and a forum for intellectual curiosity. During the initial ten weeks of the semester, the course presents an overview of the field and covers several models of research as they relate to the building design. These will include models of natural sciences, social sciences, sciences of the artificial, engineering and aesthetics in building design. During the final five weeks of the semester faculty both CFA and CIT will be invited to make presentations about their areas of research and the methods they use. These presentations correspond in many respect to those covered in lectures.

48-721 Building Controls and Diagnostics
Intermittent: 12 units
This course introduces the concepts and methods of building diagnostics. It focuses on the empirical evaluation of the built environment (building components and systems, interactions between building, occupants and environmental conditions) in view of multiple performance criteria (thermal, visual and acoustic performance). Field measurement and assessment techniques will be introduced. The empirical methods of building analysis are commonly used to: describe/specify building components; study the real-time behavior of buildings; detect the causes of building failures; and gather data for model validation. The course will address these issues, both theoretically and practically, through the application of: field measurement techniques; physical modeling methods; and computer-aided building modeling. Computer-aided data processing techniques will be applied for the analysis and interpretation of the results of model and field studies. The role of building performance simulation in the area of building diagnostics will be investigated

48-722 Building Performance Modeling
Fall: 12 units
This course introduces fundamentals and computational methods in building performance modeling. Topics include: modeling and design, overview of thermal, visual, and acoustical domain knowledge, integration of performance simulation in computer-aided design, introduction to the application of advanced computational building simulation tools, case studies and design assignments on the application of simulation in the evaluation and improvement of building performance.

48-723 Performance of Advanced Building Systems
Spring
Advanced Building Systems Integration This is a graduate level course that focuses on commercial building performance achieved through systems integration. In lectures, class discussion, and student projects, we will explore the topic of building performance, the design and technical strategies that support sustainable high performance; the design, construction and operation processes that are likely to produce sustainable high(er) performance buildings; and the current state of theory versus practice. The course assumes a basic understanding of buildings' impact on the environment, of building design and materials performance, and the calculation of building heating and cooling loads. On that foundation, we will examine the concept of systems integration and how this approach can sustain the occupants and the environment far better than conventional design, construction and operation. Although US climate, building conventions and codes will be our reference point, we will broaden our discussion by using examples and data from many other countries. An essential aspect of our exploration will be identifying successful built projects and examining the factors that may have allowed those projects to succeed. If this course meets its objectives, students who successfully complete the material will understand and be able to discuss sustainable building performance characteristics, will understand the systems integration approach and how it differs from conventional approaches to building design, and will know how to positively affect architectural and engineering decisions to support the design, construction and operation of sustainable high performance buildings.

48-724 Scripting and Parametric Design
Intermittent: 6 units
This is an introductory course to parametric modeling, which can be taken either as a half-semester assignment-based course, or as a full semester course with a parametric design project component. The course will introduce i) fundamental concepts of geometric modeling including such topics as: spatial coordinates, projections, Boolean operations, formal transformations, freeform surface creation, development and deformations; ii) parametric techniques and tools to model designs parametrically, to construct geometrical relationships among complex shapes, and to deal with constraints and their propagation. The lectures will be on computational geometry that can be applied to architectural design. In addition, the lectures will focus on hands-on techniques that can be applied to the design process, to extend the efficiency and productivity of work during the process. For practical reasons, the course will use Rhinoceros, Grasshopper, Rhinoscript, and .NET framework.

48-725 Real Estate Design and Development
Fall
This course will provide an overview of the real estate development process and explore the interdependence of real estate development and design. The primary objective of this course is for you, the student, to understand how real estate development, public policy, and finance will affect your professional life when you enter the workforce. The course will introduce real estate development context, team members, processes, and phases. Students will study how market demand, tenant requirements, site constraints, zoning restrictions, and available capital affect development projects. The course will include a financial component that will introduce students to the basic techniques of property valuation, project budgeting, pro forma analysis, sourcing of financing, and investment analysis. We will also touch on societal issues including social equity and international real estate topics. The semester's effort will culminate in the execution of a team development project. The project client will be a nonprofit or government entity. The project will be a real project/site in the city of Pittsburgh. The project components may include a basic market analysis, program evaluation, schematic design, project cost estimates, pro forma analysis, and evaluation of financial feasibility. You will make a final presentation to the class and the client.

48-729 Productivity, Health and the Quality of Buildings
Intermittent
Given the growing demand for green buildings by federal and private sector clients, professional practices are ?tooling up? all over the world to deliver high performance, environmentally responsive, ?green? buildings and communities. However, investments in green, high performance building solutions and technologies are still limited by first cost decision-making, and life cycle tools are still largely inaccessible to professionals. A building investment decision support tool ? BIDS? - continues to be developed by the Center for Building Performance and Diagnostics at Carnegie Mellon University, with the support of the Advanced Building Systems Integration Consortium. This cost-benefit decision support tool presents the substantial cost-benefits of a range of advanced and innovative building systems designed to deliver ? privacy and interaction, air quality, ergonomics, lighting control, thermal control, network flexibility, and access to the natural environment - from field case studies, laboratory studies, simulation studies, and other research efforts. This course will explore the relationship of quality buildings, building systems, and land-use to productivity, health, well-being and the environment. The course will engage students in the literature that relates building design decisions to ten cost/performance impacts: energy, facilities management, organizational change, technological change, attraction/retention (quality of life) of employees, individual productivity, organizational productivity, salvage/ waste, tax/ insurance/ litigation, and health.

48-738 Special Topics: Ecological Footprints
Fall: 6 units
The Ecological Footprint is a measure of the demand that human activity puts on the biosphere. More precisely, it measures the amount of biologically productive land and water area required to produce all the resources an individual, population, or activity consumes, and to absorb the waste they generate, given prevailing technology and resource management practices (Global Footprint Network 2010). This course will engage students in the metrics and impacts of our collective consumption and waste of: -Energy -Materials (Cradle to Cradle) -Food -Water -Transportation -The Integration of Systems towards Quality of Life Starting at the global context, this course will address challenges/opportunities to advance regenerative practices, improving our relationship to nature. Learning from international best practices, we will continue to explore ecological footprints at the global, national, regional, city, neighborhood, building and individual scale. The course will be based on lectures and readings, with assignments and student presentations to fully explore each of the footprint characteristics. Experts on water, energy, materials, food and other resources have been invited to lecture. By mid semester, an application project will be selected for ecological footprint analysis and the development of design, engineering, and operational guidelines towards reducing that footprint. The potential application projects include: the CMU campus footprint and Donner House retrofit; the Energy Innovation Center and education of the trades in reducing our regions footprint; or a new Net Zero building for Carnegie Mellon University. This will be a collaborative effort.
Prerequisite: 48-305

48-739 Making Things Interactive (Graduate)
Fall: 12 units
In this hands-on design-build class you will learn the skills to embed sensors and actuators (light, sound, touch, motion, etc.) into everyday things (and places etc.) and to program their interactive behavior using a microcontroller. You'll also dive into the fields of VR/AR/MR and experiment with combining these disciplines with physical computing. Through weekly exercises and a term project the class will introduce basic analog electronics, microcontroller programming, projection mapping and virtual reality; as well as exploration into using kinetics and materials to make the things you design perform. Emphasis will be on creating innovative experiences. The graduate edition of this course will require additional work including a paper that can be submitted to a peer-reviewed interaction design conference such as CHI, UIST, or TEI. Students from all disciplines are welcome: but please note that the class demands that you master technical material. Experience in at least one of: programming, electronics, or physical fabrication is strongly recommended.(Participants will provide their own supplies and materials.)

48-749 Special Topics in CD: Critical Perspectives and Technologies
Intermittent: 6 units
A graduate reading and discussion seminar addressing topics in design, computation, data, and algorithms in society and the built environment.

48-752 Zero Energy Housing
Fall: 9 units
Net zero energy construction has gone from concept to policy in just a few years, but built examples are still rare. What does it take, technically, to achieve net zero and what else, beyond technical requirements, advances or impedes a net zero future? 48-752 is a graduate level class that explores net zero energy design and construction in the residential sector. Through case studies and applied projects, we will explore what it takes to achieve quantitative net zero in residential buildings while maintaining occupant comfort and satisfaction. In locations where net zero is now required, we will examine the results of those requirements. At the outset, we will discuss specific definitions of a net-zero building and the implications of each definition. Through case studies, lectures, field trips, outside reading and assignments, we will examine how a net-zero building is achieved, including the use of renewable energy to achieve the net-zero balance. We will apply lessons learned from metered examples to real sites and to new design or renovation projects in Pittsburgh and will use simulation software to test and quantify the impact of our design/renovation strategies. We will also compare our strategies to requirements in US codes and rating systems such as IECC-2012 and LEED for Homes to evaluate their impact in moving the US residential sector toward much higher performance buildings. Although our focus is residential, many of the concepts and strategies we cover have parallels in the commercial sector. Students who enroll in the class must know how to calculate without software heat loss and heat gain for a small building. You are also expected to have a fundamental understanding of residential design and construction, plan reading and mechanical systems; US residential materials and construction methods for net zero will be covered in class.

48-753 Intro to Urban Design Media
Fall: 6 units
This course introduces urban design history, theory and methods of analysis and representation. Urban design is examined at multiple scales: city form and networks, neighborhood and block structures, streets, public spaces, and urban building typologies. A wide variety of cities, projects, proposals and methodologies are examined with a special focus on urban sustainability in the contemporary city. Assignments include readings from seminal texts, presentations and discussions, graphic assignments and a final project. A required course for Master of Urban Design students, it is also open to fourth and fifth-year architecture undergraduates as well as graduate students in related programs.

48-779 Processes of Digital Design Fabrication
Intermittent: 3 units
Digital Fabrication techniques are well established and widely used across all stages of design to production. Contemporary pre-occupations with materiality, ornament, digital craft, and surface topology are tethered to the affordances of these workflows and their direct connection to digital design methods. The impact of these processes reverberates across scales and around the globe, its presence undeniable. Off-site, prefabrication techniques are increasingly reliant upon computational methods to achieve greater control and precision, while recasting traditional design to production workflows. The architect¿s traditional conveyor of design intent, the working drawing, and its conventions of plan and section are increasingly supplemented with machine and robot code. Meanwhile the jobsite and field construction of buildings remains a largely human endeavor, reliant upon the skill of local labor to assemble the many components that constitute a building to produce the one-off piece of architecture. This tension between the promise of the factory floor and the messy reality of the job site reflects the evolving nature of construction and its regimes of labor. Building construction is an industry in flux rooted in traditions that pre-date the emergence of computation, yet also in the midst of digital disruption as seen in advancements in onsite architectural robotic fabrication. Lest they succumb to greater marginalization, architects must engage these transformations and leverage their design affordances. Practitioners should be versed in the basic principles of digital fabrication and understand its affordances and potential influence upon the design process. Translations from drawing and model to building increasingly rely upon these modes of production. Emerging practitioners must be capable of engaging these modes of communication and leveraging these techniques in the realization of their design intent.

48-783 Generative Modeling (GRAD)
Fall and Spring: 9 units
This course introduces students to the fundamentals of generative modeling using computer aided design as practiced in the field of architecture. Core competencies will be developed through modeling projects and software intensive labs, while a broader critical framework for conceiving of contemporary and historical parametric practices will be encouraged through periodic lectures. Emphasis will be placed on careful consideration of digital mediums and developing a sense of craft related to digital modeling in the hope that students will become conscientious makers and consumers of digital content. Students will be encourage to understand and apply algorithmic problem solving to the many design constraints encountered in architecture. The course will explore the relationship of parametric workflows to design thinking and will situate contemporary trends in a broader framework of computational design. The course will also forefront complex form-making as a response to bio-mimicry, systems thinking, and mass-customization. Rather than positioning parametric modeling as a disruption of historical architectural design process, the course will encourage students to consider how new tools might augment the discipline's historical commitments to orthographic projection, perspectival drawing, and physical modeling.

48-795 LEED, Green Design and Building Rating in Global Context
Spring: 6 units
48795, LEED, Green Design and Building Rating in Global Context is a graduate level mini-course that examines building rating system content, strategies, goals and outcomes. The course is organized within the framework of the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Rating Systems, which contains rating system prerequisites and credits in the following categories: location & transportation, site, water, energy, materials, and the interior environmental quality. Within that framework, we explore strategies promoted within LEED (and the new WELL standard) and compare/contrast them with strategies in the rating systems of other countries. We also consider the design of the rating system itself, its implementation, and the national context in which the system was created. The course is designed to develop your understanding of, and hone your critical thought about, sustainable building design and operation. Class lectures address the concepts and environmental issues underlying rating system requirements and credits; present multiple strategies for improved building performance; and to the extent possible, address the impact of specific rating systems and strategies. Students are then challenged to apply this information to specific locations & issues, based on the environmental/energy issues associated with the rating system categories listed above. Although the course provides a foundation for taking USGBC's LEED Green Associate and/or LEED Accredited Professional exam, it is not an exam prep course. Students who successfully complete the course will understand a range of impacts that buildings may have on the environment and on building occupants, will have insights into contextual aspects of sustainability, and will be familiar with a range of strategies that may be used to encourage development of better buildings and communities.
Prerequisite: 48-315

48-801 Office Visits
Fall: 6 units
Each candidate will arrange with their home office a virtual 'visit' for members of the degree program and organize presentations of the projects, methodological challenges, recurring problems, best and worst practices within the context of their office experience. Asynchronous Course Delivery (Fall 2014) -> September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-802 Principles of Research I
Fall: 6 units
Candidate's current knowledge of problems, methods and outcomes based on their professional work. Overview of the eight knowledge areas as existing disciplines and their potential place in them. Asynchronous Course Delivery (Fall 2014) -> September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-803 Areas of Practice
Fall: 6 units
Candidate presentations of area(s) of expertise summarizing the methods and problems that are prevalent; using case studies to establish a situated approach to research. Asynchronous Course Delivery (Fall 2014) -> September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-804 International Exchange I
Fall: 12 units
Conduct workshops for collaborative research and information exchange meetings with EU cohorts visiting from the Université Toulouse III - Paul Sabatier, Doctoral Programs in Architecture. Asynchronous Course Delivery (Fall 2014) -> September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-805 Directed Study I
Fall: 6 units
Prepare the first publishable article under the supervision of the advisor, based on the current professional practice record of the candidate. Submitted to a committee of faculty for approval. Asynchronous Course Delivery (Fall 2014) -> September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-809 International Exchange II
Spring: 12 units
Visit Université Toulouse III - Paul Sabatier, Doctoral Programs in Architecture and participate in collaborative research and information exchange meetings with EU cohorts, based on the cohorts current knowledge base culled from their practice experience. Asynchronous Course Delivery (Spring 2015) - January 18, through May 13, 2015— Online Synchronous Course Conclusion (Spring 2015) - May 14 through 17, 2015

48-810 Comparative Analysis of US and EU Practices
Spring: 6 units
Practices in the building sector vary considerably in the US versus the EU. The instructor will provide a rich collection of national and international initiatives in the AEC domains and include a stimulating series of site visits to important installations in the area. Asynchronous Course Delivery (Spring 2015) - January 18, through May 13, 2015— Online Synchronous Course Conclusion (Spring 2015) - May 14 through 17, 2015

School of Art

Charlie White, Head
Location: College of Fine Arts 300
www.art.cmu.edu/

The School of Art's undergraduate program bridges traditional studio practice with the experimental practices of new and unconventional media. The School offers two tracks for undergraduates—the Bachelor of Fine Arts (BFA) degree and the three interdisciplinary degrees collectively known as the BXA Intercollegiate Degree Program—along with a minor in art.

The program provides focused foundational instruction over the first two years that builds toward a broad range of individualized study in the second two years. As underclassmen, students experience a wide array of intensive medium-specific and thematic concept studio courses, developing both technical skill and critical thinking. As upperclassmen, students direct their study across four primary concentrations with the freedom to pursue either in-depth study, hybrid study across concentrations, or specialized practices. The four primary concentrations are:

I. Drawing, Painting, Print Media, and Photography

II. Sculpture, Installation, and Site Work

III. Electronic and Time-Based Work

IV. Contextual Practice

Studio courses comprise over sixty percent of the course of study and academic courses comprise the remainder.

The School of Art occupies over 50,000 square feet of fabrication facilities, multi-purpose classrooms, media-specific studios and workshops, student and faculty studios, presentation rooms, and exhibition spaces, offering students access to both traditional and state-of-the-art tools. All juniors and seniors have dedicated, independent, 24-hour studio space.

The School's distinguished faculty includes pioneers in computer animation and new media; artists and scholars exploring the complexity of queer thought and culture; and emerging practitioners confronting some of society's most pressing issues. Throughout the program, these professors provide one-on-one support and feedback, helping to foster an individualized artistic practice for each student.

The program emphasizes an interdisciplinary approach to learning and art making, and students are encouraged to take advantage of the many resources of the College of Fine Arts and of the University. These include: the IDeATe network, the STUDIO for Creative Inquiry, the Miller Institute for Contemporary Art, and the Center for Arts in Society, among many others.

Graduates from the School of Art pursue diverse careers paths including traditional studio practice, animation, game design, positions with leading technology companies, and founding their own start-ups.

Using five categories of courses, the curriculum presents art-making in a unique manner which respects tradition and encourages innovation. The course categories are:

I . Concept Studios
II. Media Studios
III. Advanced Studios
IV. Critical Studies Courses
V. University Academic Courses

I. Concept Studios

The Concept Studios are the core of the art curriculum. Students are required to complete five concept studios. Experiences gained in the other four components of the program are integrated into Concept Studios. Themes and topics addressed in Concept Studios include: the self and the human being, space/time, systems/processes, contextual practice, and senior studio.

First-year and sophomore Concept Studios are organized around structured assignments designed to assist the student in developing a personal, non-medium-specific approach to generating art as well as in learning transferable conceptual skills. The progression from semester to semester leads toward increasing complexity and independence. Contextual Practice Studios embrace the context or social conditions in which an artwork exists, covering a range of methods to making art in the public including street art, interactive social media, environmental art, hacktivism, participatory art, guerilla performance, project-based community art, and urban interventions. In the senior year, the Concept Studios, titled Senior Studio, are devoted to a single student-generated body of work.

II. Media Studios

The Media Studios can be viewed as the foundation courses for the program. Students take a total of seven Media Studios within the first year and sophomore year. These studios ensure that all students have an exploratory experience with all of the media resources of the school. They also serve as preparation for advanced studio work.

Two-Dimensional Media Studios introduce drawing and imaging during the first year, and painting or print media during the sophomore year. Electronic Media Studios introduce the moving image through video and animation during the first year, and interactivity in the sophomore year. Three-Dimensional Media Studios introduce media such as ceramics, welding, wood, metals, art and arduino, multiples and mold making, and digital fabrication during the first year.

III. Advanced Studios

Students take a total of twelve Advanced Studio elective courses over the course of the second semester of the sophomore year and the junior and senior years. These courses address specialized studio work in one of the four artistic concentration areas in the school, which are:

- Drawing, Painting, Print Media, and Photography (DP3)
- Sculpture, Installation, and Site Work (SIS)
- Electronic and Time-Based Work (ETB)
- Contextual Practice (CP)

A minimum of four courses must be taken in one of these concentration areas. One of the twelve Advanced Studio courses must be a College of Fine Arts interdisciplinary course or in one of the Schools outside of Art: Architecture, Design, Drama, Music.

IV. Critical Studies Courses

Students complete a sequence of four courses in Critical Theory in Art in their first and sophomore years:

First Year (fall):	**Critical Theory in Art I**
First Year (spring):	**Critical Theory in Art II**
Sophomore Year (fall):	**Critical Theory in Art III**
Sophomore Year (spring):	**Critical Theory in Art IV**

After the sophomore year, students must take two elective critical studies courses.

V. University Academic Courses

Ten academic courses outside of Art and Computing @ Carnegie Mellon are required.

First Year

The student is required to take the following three courses:

Computing @ Carnegie Mellon (99-101), Global Histories (79-104), and one of the First-Year Writing options, either one of the two full-semester courses, (Interpretation and Argument (76-101) or Advanced First Year Writing: Special Topics (76-102)), or two of the three half-semester writing courses (Writing about Literature, Art and Culture (76-106), Writing about Data (76-107), or Writing about Public Problems (76-108)).

After First Year

The student must take one course in each of the following academic areas or "options":

- Humanities and Languages or "Culture Option"
- Math, Science, Computer Science and Engineering or "Technical Option"
- History, Psychology, Economics or "Social Science Option"

The student must then take at least three additional courses from one of the academic areas/options listed above.

Finally, the student must take two additional, but unspecified, academic electives.

In selecting courses for the university academic component of the curriculum, students are encouraged to complete a cluster of courses that appeals to and develops their interests as emerging artists. In the process of taking their university electives, students can often simultaneously earn a minor.

Bachelor of Fine Arts (B.F.A.) Curriculum

Minimum units required for B.F.A. in Art 387

Below is the recommended distribution of courses in the four-year B.F.A curriculum. After the freshman year, students may begin to choose university electives. After the first semester of the sophomore year, students have more options regarding the sequencing and selection of their coursework.

First Year

Fall		Units
60-101	Concept Studio: The Self and the Human Being	10
60-131	3D Media Studio I	5
60-132	3D Media Studio I Students must select different topics for 60-131 and 60-132.	5
60-150	2D Media Studio: Drawing	10
60-105	Critical Theory in Art I	9
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
		51

Spring		Units
60-110	Electronic Media Studio: Introduction to the Moving Image	10
60-133	3D Media Studio II	5
60-134	3D Media Studio II Students must select different topics for 60-133 and 60-134.	5
60-160	2D Media Studio: Imaging	10
60-106	Critical Theory in Art II	9
79-104	Global Histories	9
		48

Second Year

Fall		Units
60-201	Concept Studio: Space and Time	10
or 60-202	Concept Studio: Systems and Processes	
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-250	2D Media Studio: Painting	10
or 60-251	2D Media Studio: Print Media	
60-205	Critical Theory in Art III	9
xx-xxx	Academic Elective	9
		48

Spring		Units
60-280	Introduction to Contextual Practice	10
60-4xx	Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
60-206	Critical Theory in Art IV	9
xx-xxx	Academic Elective	9
		48

Third Year

Fall		Units
60-4xx	Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
60-3xx	Academic Art Elective	9
xx-xxx	Academic Elective	9
		48

Spring		Units
60-4xx	Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
60-3xx	Academic Art Elective	9
xx-xxx	Academic Elective	9
		48

Fourth Year

Fall		Units
60-401	Senior Studio	10
60-403	Senior Critique Seminar or 60-4xx Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
xx-xxx	Academic Elective	9
xx-xxx	Academic Elective	9
		48

Spring		Units
60-402	Senior Studio	10
60-403	Senior Critique Seminar or 60-4xx Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
xx-xxx	Academic Elective	9
xx-xxx	Academic Elective	9
		48

Sophomore and Senior Year Reviews

Students give an overview of their work twice in their four-year course of study. At the end of the sophomore year, students undergo a faculty review of their work to date in the program. A successful review is required for advancement to the junior year.

The senior review affords students in the fall of their final year the opportunity to review, analyze and summarize their work and to engage a faculty committee in discussion about issues that face someone preparing to enter a career in art.

Art Majors Minoring or Double Majoring in Another Department

About a third of current B.F.A. Art students pursue a minor or a second major. If students are contemplating this option, they must discuss their plans with academic advisors from the minor or second major department as well as with the School of Art academic advisor.

Study Abroad

Art students are encouraged to spend either a semester of their junior year, or a summer before or after their junior year, in one of many available international programs. These programs include university sponsored and exchange programs in which a student's financial aid package remains in effect, and programs sponsored by other institutions.

Programs with other Pittsburgh Institutions

Art students are eligible to take courses at the nearby University of Pittsburgh's History of Art and Architecture Department, and at the Pittsburgh Glass Center. Established agreements with these institutions and other Pittsburgh colleges, universities or centers offer cross-registration opportunities at no additional expense to the student.

BXA Intercollege Degree Programs

BACHELOR OF HUMANITIES AND ARTS (BHA)

BACHELOR OF SCIENCE AND ARTS (BSA)

BACHELOR OF COMPUTER SCIENCE AND ARTS (BCSA)

Carnegie Mellon University offers a degree program that combines an Art Focus (11 courses) with a focus in the Dietrich College of Humanities and Social Sciences, the Mellon College of Science, or the School of Computer Science. The Assistant Head of Academic Affairs in the School of Art advises BXA majors in selecting courses in the Art Focus. A description of these three programs, and a list of requirements and electives, can be found in the in the BXA Intercollege Degrees Program section (p.) of this catalog.

Art Minors

Students from other colleges and departments are eligible to pursue a minor in art. A minor requires six courses in the School of Art, selected from a list of requirements and electives as described in the Minors Offered by the College of Fine Arts section (p. 183) of this catalog.

Master of Fine Arts (M.F.A.) Degree

The School of Art offers a three-year program leading to a Master of Fine Arts in Art. This is a unique program designed to connect art-making to the university at large, and to Pittsburgh communities and organizations. Information about this program is available at the School of Art website (http://www.art.cmu.edu).

Master of Arts Management (M.A.M.) Degree

The College of Fine Arts and the Heinz College School of Public Policy and Management co-sponsor a Master of Arts Management degree. Students admitted to the M.A.M. degree program in their junior year may complete both a Bachelor of Fine Arts degree and a Master of Arts Management degree in five years. Students interested in this graduate degree should consult with advisors early in their undergraduate program.

Pre-College Program

The School of Art offers a Summer Pre-College Program, with both three- and six-week options.This program is designed to prepare the college-bound high school student for college level work in art. Information is available at the Summer Pre-College site (https://admission.enrollment.cmu.edu/pages/pre-college-art).

Full-Time Tenure Track Faculty

KIM BECK, Associate Professor of Art – M.F.A., Rhode Island School of Design; Carnegie Mellon, 2004–

BOB BINGHAM, Professor of Art – M.F.A., University of California, Davis; Carnegie Mellon, 1993–

JOHN CARSON, Professor of Art – M.F.A., California Institute of the Arts; Carnegie Mellon, 2006–

JOHANNES DEYOUNG, Assistant Professor of Art – M.F.A., Cranbrook Academy of Art; Carnegie Mellon, 2018–

JAMES DUESING, Professor of Art – M.F.A., University of Cincinnati; Carnegie Mellon, 1997–

ISLA HANSEN, Assistant Professor of Art – M.F.A., Carnegie Mellon University; Carnegie Mellon, 2019–

KATHERINE HUBBARD, Assistant Professor of Art – M.F.A., Bard College; Carnegie Mellon, 2019–

ANDREW JOHNSON, Associate Professor of Art – M.F.A., Carnegie Mellon University; Carnegie Mellon, 2004–

JONGWOO JEREMY KIM, Associate Professor of Art History and Theory – Ph.D., Institute of Fine Arts at New York University; Carnegie Mellon, 2018–

CAROL KUMATA, Professor of Art – M.F.A., University of Wisconsin, Madison; Carnegie Mellon, 1979–

GOLAN LEVIN, Professor of Art – M.S., Massachusetts Institute of Technology; Carnegie Mellon, 2004–

JOSEPH MANNINO, Professor of Art – M.F.A., University of Southern Illinois; Carnegie Mellon, 1986–

CLAYTON MERRELL, Dorothy L. Stubnitz Professor of Art – M.F.A., Yale University; Carnegie Mellon, 1998–

PAOLO PEDERCINI, Associate Professor of Art – M.F.A., Rensselaer Polytechnic Institute; Carnegie Mellon, 2009–

RICHARD PELL, Associate Professor of Art – M.F.A., Rensselaer Polytechnic Institute; Carnegie Mellon, 2008–

MELISSA RAGONA, Associate Professor of Visual Culture and Critical Theory – Ph.D., State University of New York at Buffalo; Carnegie Mellon, 2003–

JON RUBIN, Associate Professor of Art – M.F.A., California College of Arts and Crafts; Carnegie Mellon, 2006–

DEVAN SHIMOYAMA, Cooper-Siegel Assistant Professor of Art – M.F.A., Yale University; Carnegie Mellon, 2014–

SUZIE SILVER, Professor of Art – M.F.A., The School of the Art Institute of Chicago; Carnegie Mellon, 1999–

SUSANNE SLAVICK, Andrew W. Mellon Professor of Art – M.F.A., Tyler School of Art; Carnegie Mellon, 1984–

ANGELA WASHKO, Assistant Professor of Art – M.F.A., University of California, San Diego; Carnegie Mellon, 2015–

CHARLIE WHITE, Regina & Marlin Miller Head, Professor of Art – M.F.A., Art Center College of Design; Carnegie Mellon, 2016–

IMIN YEH, Assistant Professor of Art – M.F.A., California College of the Arts; Carnegie Mellon, 2016–

Full-time Joint Appointments

CHARLEE BRODSKY, Associate Professor of Art and Photography – M.F.A., Yale University; Carnegie Mellon, 1978–

ELIZABETH CHODOS, Director, Miller Institute for Contemporary Art – M.A., School of the Art Institute of Chicago; Carnegie Mellon, 2017–

ROGER DANNENBERG, Senior Research Computer Scientist and Artist – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1982–

JAMIE GRUZSKA, Special Faculty and CFA Photography Administrator – M.F.A., University of Buffalo;

DYLAN VITONE, Associate Professor, School of Design – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2006–

Visiting Faculty

EVEREST PIPKIN, Visiting Assistant Professor of Art – M.F.A., Carnegie Mellon University; Carnegie Mellon, 2019–

MARIA ELENA VERSARI, Visiting Professor of Art History and Theory – Ph.D., Scuola Normale Superiore;

ALISHA WORMLEY, Presidential Postdoctoral Fellow – M.F.A., Bard College; Carnegie Mellon, 2018–

School of Art Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

60-101 Concept Studio: The Self and the Human Being
Fall: 10 units
Concept Studio: The Self and the Human Being is first of a sequence of five studio courses designed to develop a personal approach to generating art and to learning transferable conceptual skills. The topics of the first three Concept Studios are addressed through a sequence of structured, media-independent projects. Open to first-year students admitted to the School of Art, or by instructor permission.

60-105 Critical Theory in Art I
Spring: 9 units
Critical Studies 1 is the first part of a year-long course intended to introduce CMU's students to key readings in the history of artistic theory, studied in relation with the concurrent development of Western art. It is devoted to the period ranging from the 1500s to the end of the 1800s and covers major artwork and theories spanning from the Renaissance to Symbolism and Primitivism. The course is structured as a seminar discussion of theoretical texts, integrated with lectures. Readings will introduce students to the historical and critical background of the themes discussed in class and familiarize them with the varied methodologies and argumentative styles proper to art criticism, critical theory and philosophy. Open to first-year students in the School of Art, or by permission of the instructor.

60-106 Critical Theory in Art II
Spring: 9 units
This is the second part of a year-long course intended to introduce CMU's students to key readings in the history of artistic theory, studied in relation with the concurrent development of Western art. It is devoted to the period ranging from 1900 to 1960 and covers major artwork and theories spanning from Cubism and the historical avant-garde to totalitarian art and 1950s artistic research worldwide. The course is structured as a seminar discussion of theoretical texts, integrated with lectures. Readings will introduce students to the historical and critical background of the themes discussed in class and familiarize them with the varied methodologies and argumentative styles proper to art criticism, critical theory and philosophy. Open to first-year students in in the School of Art, or by permission of the instructor.
Prerequisite: 60-105

60-110 Electronic Media Studio: Introduction to the Moving Image
Spring: 10 units
Electronic Media Studio: Introduction to the Moving Image is an introduction to the computer as a dynamic tool for time-based media production. In this course students develop skills in digital video and audio production through the exploration of narrative, experimental, performance, documentary and animation themes and forms. Historical and contemporary works are presented and discussed to provide a context for studio projects. Open to first-year students in the School of Art, or by instructor permission.

60-125 IDeATe: Introduction to 3D Animation
Spring: 12 units
This class will explore computer animation as it pertains to a professional animation production pipeline. The course is designed to give students exposure to key job descriptions that align to the animation industry. Topics covered include: character design, world building, storyboarding, digital sculpture, look development, rigging, layout, animation, cinematography, lighting, and rendering. These topics are taught in 2-4 week sprints that allow a student to learn the fundamentals of each craft. In a mixture of class lectures, critiques, and training workshops, students will become acquainted with the necessary skills needed to create their own characters and animations. By completion of the course, students will be familiar with industry-standard best practices and ready to take advanced courses related to animation, vfx, and video game related pipelines. This course specifically offers insight on how the craft of animation is always evolving at top studios such as Walt Disney Animation Studios, Pixar, and Industrial Light and Magic.

Course Website: http://cmuanimation.weebly.com/

60-126 Introduction to Performance Capture and Rendering
Intermittent: 6 units
[IDeATe course] This mini is designed for those interested in the growing world of performance capture and visual effects. Utilizing the advanced motion capture facilities at Carnegie Mellon and the Kinect, students will learn how to capture motion from performance and apply it to CG characters and objects. While this technique is found in many video games and vfx movies, it has the ability to create endless possibilities within the realm of computer graphics and experimental animation/art. Students will also become more familiar with the process of rendering to create the necessary polish for their animations/visualizations. CG Lighting, camera work, and material shading are just a few of the many topics covered in this course.
Prerequisites: 62-150 Min. grade C or 15-104 Min. grade C

60-128 IDeATe: Real-Time Animation
Fall: 10 units
An introductory course that explores improvisational strategies for making animation within real-time computer graphics frameworks. Advancements in motion capture technologies, real-time 3D computer graphics engines, and visual programming tools for AV synthesis provide open frameworks for the exploration of animation in spatial and interactive contexts. Studio work will explore real-time animation in a variety of contexts, including screen-based interaction, site-specific installation, and spatial immersion. Conceptual frameworks drawn from the histories of video art, animation, and immersive media design will inform collaborative group work and class discussion. Students without the prerequisite may register by instructor permission.

60-131 3D Media Studio I
Fall: 5 units
An introduction to three-dimensional form. Various materials and methods are explored through projects covering a broad range of sculptural concerns. Art majors must complete one topic of 60-131 and a different topic of 60-132 to satisfy the 3DI requirement. Students are required to select two of the following four sections: Digital Fabrication; Small Metals; Art and Arduino: learn the basics of electrical circuits and coding to create work that senses its environment and interacts with the viewer, the space, or even the world; and a fourth TBA topic. Materials fee may be required. Open to freshmen in the School of Art, or by instructor permission.

60-132 3D Media Studio I
Fall: 5 units
An introduction to three-dimensional form. Various materials and methods are explored through projects covering a broad range of sculptural concerns. Art majors must complete one Mini-1 course and one Mini-2 course to satisfy the 3DI requirement. Students are required to select two of the following four sections: Digital Fabrication; Small Metals; Assembly and Armature; and Art and Arduino. Materials fee may be required. Open to first-year students in the School of Art, or by instructor permission.

60-133 3D Media Studio II
Spring: 5 units
Four unique mini classes offer an introduction to basic language and approaches of sculptural practice - Multiples, Mold Making, and Casting: focus on the use of repeated objects; Mixed Media/Mini-Installation: emphasis on mixed media to create a composition with a relationship of objects in space; Surfacing, and 3D Printing and Lasers. Art majors complete one 60-133 section and one 60-134 section to satisfy the 3D Media II requirement. Materials fee may be required. Open to School of Art first-year students or by instructor permission.

60-134 3D Media Studio II
Spring: 5 units
Four unique mini classes offer an introduction to basic language and approaches of sculptural practice - Multiples, Mold Making, and Casting: focus on the use of repeated objects; Mixed Media/Mini-Installation: emphasis on mixed media to create a composition with a relationship of objects in space; Surfacing, and 3D Printing and Lasers. Art majors complete one 60-133 section and one 60-134 section to satisfy the 3D Media II requirement. Materials fee may be required. Open to School of Art first-year students or by instructor permission.

60-141 Black and White Photography I
Fall and Spring: 10 units
This course will teach you the basic craft of photography from exposure of the negative through darkroom developing and printing to print finishing and presentation. Content includes student presentations, class discussions, shooting assignments, darkroom sessions and class critiques. We will concentrate not only on the technical aspects of photography, but also the aesthetics of seeing with a camera. The course concentrates on photography as a fine art — what is unique to it and the concerns that are shared with other visual arts, such as composition, tonal values, etc. and aims to equip students with an understanding of the formal issues and the expressive potentials of the medium. Lab fee and 35mm manual camera required. Each student is responsible for the cost of paper and film.

60-142 Digital Photography I
Fall and Spring: 10 units
This course explores digital photography and digital printing methods. By semester's end students will have knowledge of contemporary trends in photography, construction (and deconstruction) of photographic meaning, aesthetic choices, and the use of color. Students will learn how digital cameras work, proper digital workflow, RAW file handling, color management and Adobe Photoshop. Through the combination of the practical and theoretical, students will better define their individual voices as photographers. No prerequisites. Digital camera required.

60-150 2D Media Studio: Drawing
Fall: 10 units
This course focuses on the language, materials and concepts of drawing as foundation for all the visual arts. Initial emphasis on the development of perceptual, analytical, and structural drawing skills with increasing attention to idea development. Exposure to methods of creating pictorial and illusionistic space; recording the external world of light and form; and making visible the internal world of the heart, the mind, the soul. Experience with line, texture, tone, shape and mass; in a variety of wet and dry drawing media. Open to first-year students in the School of Art, or by instructor permission.

60-160 2D Media Studio: Imaging
Spring: 10 units
A continuation of Two-Dimensional Media Studio: Drawing. Includes an expansion of drawing to include multimedia approaches, painterly issues, digital input/output and work with digital image processing tools. Open to first-year students in the School of Art, or by instructor permission.
Prerequisites: 60-157 or 60-150

60-200 Sophomore Review
Fall and Spring
Students present their work and their ideas about their work to a faculty committee. A successful review is required for advancement to the junior year. Although this is a non-credit course, it is required of all Art (BFA, BHA, BSA, and BCSA) sophomores.

60-201 Concept Studio: Space and Time
Fall: 10 units
Concept Studio: Space and Time is a continuation of Concept Studio: The Self and the Human Being with a focus on space and time through projects of increasing complexity. Such topics as biological time, historical time, psychological time, celestial time, clock time, and public space, private space, mathematical space, and virtual space are addressed through projects. Open to sophomores in the School of Art, or by instructor permission.
Prerequisite: 60-101

60-202 Concept Studio: Systems and Processes
Fall: 10 units
Concept Studio: Systems and Processes focuses on the utility, discovery, and the generation of systems and processes through projects. Open to sophomores in the School of Art, or by permission of instructor.

60-205 Critical Theory in Art III
Fall: 9 units
The Duchampian attack on traditional aesthetic categories has been the engine behind the distinctive shifts in postwar art. Photography, performance, conceptual proposals, installation art, film, video, and appropriations from mass culture play an equal part in contemporary visual culture. Duchamp's attack on art as an institution set the tone for other anti-modernist projects to follow which did not accept the "white cube of the gallery" as their sole exhibition space (or measured worth as an artist). His notions of "indifference," (critique of aesthetic judgment), reproducibility, simulation, performativity, artist-as-curator, and interactivity between the spectator and the work of art set the stage for a host of innovative explorations by artists ranging from the Combines of Robert Rauschenberg to the Mod-Spaceships of Mariko Mori. This seminar examines a tumultuous period in contemporary art and culture from 1960 to the mid-eighties, with special excursions into the aesthetics of commodification, phenomenology, materialism, conceptualism, semiotics, abjection, and technology. The impact of social movements and American foreign policies (i.e. Vietnam, Civil Rights, The Women's Movement, Globalism, the Aids Crisis) on the production and reception of contemporary art will also be examined. Open to sophomores in the School of Art, or by instructor permission.

60-206 Critical Theory in Art IV
Spring: 9 units
This course traces the shifts in art from late Modernism until our After Post era. It will examine the diversity of art produced, as well as the critical ideas that arose over a span of 60 years. The rise of a pluralist / conceptual art will be discussed within the context of social change, technology and globalization. Open to sophomores in the School of Art, or by instructor permission.
Prerequisite: 60-205

60-208 Alternative Photography: Contemporary Antiquarian Printmaking
Intermittent: 5 units
This focused, making-based course explores antique, handmade printmaking/photography methods through contemporary techniques. Students will learn how to make light-sensitive papers, while creating their own negatives digitally, combining both processes in a traditional darkroom. Students will use the Van Dyke, Cyanotype, and Platinum printing methods from start to finish, creating handmade, unique images that are distinct from those made with digital processes alone.

60-210 Electronic Media Studio: Introduction to Interactivity
Fall: 10 units
Electronic Media Studio: Introduction to Interactivity is an introduction to software programming and physical computing within the context of the arts. In this course students develop the skills and confidence to produce interactive artworks using audiovisual, networked and tangible media.

60-212 Electronic Media Studio: Interactivity and Computation for Creative Practice
Intermittent: 12 units
This is an intermediate level course in "creative coding", interactive new-media art, and computational design. Ideal as a second course for students who have already had one semester of elementary programming (in any language), this course is for you if you'd like to use code to make art, design, architecture, and/or games — AND you're already familiar with the basics of programming, such as for() loops, if() statements, and arrays. This course satisfies the EMS-2 (60-210: Interactivity) requirement for BFA and BXA-Art majors. As with EMS-2, students in this course will develop an understanding of the contexts, tools, and idioms of software programming in the arts. Unlike EMS-2, this course additionally satisfies the computing portal requirement for CFA and Dietrich students pursuing IDeATe minors and concentrations. (Students with no prior programming experience should register instead for 15-104, 15-110, or 15-112.) This is a "studio art course in computer science," in which the objective is art and design, but the medium is student-written software. The course develops skills and understanding of text-based, imperative programming techniques in a variety of popular open-source arts-engineering toolkits, including p5.js (JavaScript), Processing (Java), and openFrameworks (C++), with the aim of applying such skills to interactive art and design, information visualization, generative media, and other creative cultural practices. Rigorous programming exercises will develop the basic vocabulary of constructs that govern static, dynamic, and interactive form. Topics include the computational manipulation of: point, line and shape; texture, value and color; time, change and motion; reactivity, connectivity and feedback; interactive graphics, sound, and simulation; and the incorporation of various modes of input (sensors, cameras) and multimedia output.
Prerequisites: 15-112 Min. grade C or 15-104 Min. grade B or 15-110 Min. grade C

60-214 Photography and the Narrative of Place
Intermittent: 5 units
This half-semester course will use photography to develop understandings of our surrounding environments. Students will choose a single location to work in, photographing and researching its function in the community, its history, and its relationship to broader concepts and similar spaces. Weekly assignments will require students to work with a variety of photographic methods to construct a narrative that derives meaning from the complex connections between people, objects and the spaces they inhabit. Throughout the course, students will strengthen their understanding of the ways in which these tangible and abstract elements of our environments work together through in-class exercises, weekly discussions and critiques. The course work will culminate in a portfolio of the completed project. The class will study work and books by notable and emerging figures in the medium, including Robert Adams, Carolyn Drake, Roy DeCarava, Rinko Kawauchi, Alec Soth, Carrie Mae Weems, Zoe Strauss, Gregory Halpern, and Susan Lipper. Required readings will include essays and short stories by Wendell Berry, Rebecca Solnit, Teju Cole, Joan Didion, and Georges Perec.

60-218 IDeATe Portal: Real-Time Animation
Fall: 10 units
An introductory course that explores improvisational strategies for making animation within real-time computer graphics frameworks. Advancements in motion capture technologies, real-time 3D computer graphics engines, and visual programming tools for AV synthesis provide open frameworks for the exploration of animation in spatial and interactive contexts. Studio work will explore real-time animation in a variety of contexts, including screen-based interaction, site-specific installation, and spatial immersion. Conceptual frameworks drawn from the histories of video art, animation, and immersive media design will inform collaborative group work and class discussion. Students without the prerequisite may register by instructor permission.

60-220 IDeATe Technical Character Animation
Fall: 10 units
Technical Character Animation is a deep dive into the fundamental concepts of character animation and "The Illusion of Life." This course will focus on building a foundation of body mechanics that demonstrate weight, balance, and authenticity. Through a series of strategically designed modules, students will gain a command of the 12 principles of animation, beginning with a ball bounce to more advanced block, spline, and polish workflows. This course is designed to give students exposure to the art of movement as it is done by animators in the fx, film, and game industries.

Course Website: http://tcacmu.weebly.com/

60-223 IDeATe: Introduction to Physical Computing
Fall and Spring: 10 units
[IDeATe portal course] Physical computing refers to the design and construction of physical systems that use a mix of software and hardware in order to sense and respond to the surrounding world. Such systems include digital+physical toys and gadgets, kinetic sculpture, functional sensing and assessment tools, mobile instruments, interactive wearables, etc. This is a project-based course that deals with all aspects of conceiving, designing and developing projects with physical computing: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who collaboratively synthesize and implement several systems in a short period of time. The course is organized around a large set of essential skills that students must gain in order to effectively tackle physical computing problems. It is then deployed through a series of quick group projects that utilize the essential skills and challenge students to not only consider HOW to make things, but also for WHOM we design, WHEN the time is ripe, and WHY the making is worthwhile/necessary. Upon completion of this course the students will be able to: work in a mixed physical-digital environment and laboratory, make effective use of standard hardware and software tools for physical computing, approach complex physical computing problems with a systematic overview that integrates iterative research and design steps, generate systems specifications from a perceived need, partition functionality between hardware and software, produce interface specifications for a system composed of numerous subsystems, use computer-aided development tools for design, fabrication and testing and debugging, evaluate the system in the context of an end user application or experience. Students are encouraged to also take the micro course 99-353 IDeATe CAD and Laser Cutting.

Course Website: https://courses.ideate.cmu.edu/60-223

60-240 Unfolding Environments: The Intersection of Person and Place
Intermittent: 10 units
This course will use photography to explore our surrounding environments. Assignments will focus on editing and image sequencing, combining the practices of portraiture, landscape, still life and observational photography to create narrative work that explores the complex connections between people, objects and the spaces they inhabit. Throughout the course, students will strengthen their understanding of the ways in which these tangible and abstract elements of our environments work together, while also developing their technical abilities by working with color and black and white images and varied light sources. Students will also learn approaches to project development and digital workflow. Discussions, readings, gallery visits and critiques will provide an outline for completing assignments. The class will study work and books by notable and emerging figures in the medium, including Robert Adams, Rineke Dijkstra, Carolyn Drake, Roy DeCarava, Milton Rogovin, Judith Joy Ross, Rinko Kawauchi, Alec Soth, Larry Sultan, Carrie Mae Weems and Susan Worsham. Required readings will include essays and short stories by Wendell Berry, Rebecca Solnit, Robert Walser and Albert Camus.

60-241 Black and White Photography II
Fall and Spring: 10 units
This course allows you to gain experience with medium and large format film cameras while emphasizing aesthetic development and personal artistic growth. As an advanced student, you have access to an unusual assortment of panoramic and pinhole cameras that will change the way you make photographs, revealing unknown perspectives. Additional topics include digital process though negative scanning and inkjet printing, advanced monotone printing methods, and a focus on exhibition and folio presentation. Cameras will be supplied for this course.
Prerequisites: 62-141 or 60-141

60-242 Digital Photography II
Intermittent: 10 units
Digital Photography II combines digital and analog processes in both color and black & white. Students will gain experience with digital workflow, analog to digital conversion, virtual drum scanning and large format digital printing. Topics include trends in contemporary photography, professional practices, project development, narrative and serial work, and portfolio presentation. Students will be expected to develop their own self-directed projects throughout the semester culminating in a cohesive portfolio of their work. Readings, assignments, artist visits, critiques and discussions will give context to the practical work and help develop a wide ranging familiarity with the subjects. Prereq: 62-141 or 62-142 or equivalent or consent of instructor
Prerequisites: 62-141 or 62-142 or 60-141 or 60-142

60-244 Contemporary Photo Theory
Intermittent: 9 units
Because, you know, the photographs are more a question than a reply. (Sebastiao Salgado) A photograph is a moral decision taken in one eighth of a second, or one sixteenth, or one one-hundred-and-twenty-eighth. (Salman Rushdie) This seminar investigates current topics in photography and the image; our goals are twofold: identification of photo theory as it applies to current practice from both the viewpoint of maker and consumer. The course is designed to address philosophical issues for photographers working now and will favor conversation over written work; students are expected to fully participate in critical analysis and discussions. Readings include works by Roland Barthes, Stephen Shore, Susan Sontag, Hollis Frampton, John Szarkowski, Robert Adams, Italo Calvino, Berenice Abbott, John Berger and James Elkins. No pre-requisites.

60-245 Portrait Photography
Intermittent: 10 units
Portrait Photography explores the emotional and visual process of collaboration between subject and photographer that creates a photograph. We use cameras of all formats and levels of sophistication to create portraits in the studio and on location. Each photographer is challenged to find and exploit available light, and create artificial light to complete his or her vision. The class will explore a wide range of digital and darkroom strategies to support and add richness to their final prints. Through film and video photographers will meet some of the masters of this form like Arbus, Newman, Avedon, and Penn. Together we will take advantage of any opportunities to visit exhibitions and photographer's studios. Lab fee required. Prerequisites: As listed or consent of instructor.

60-250 2D Media Studio: Painting
Fall: 10 units
This course serves as an introduction to technical, conceptual and historical practices of painting. Through a variety of painting experiences and presentations using oil/acrylic media, students progress from observational exercises and exposure to materials and techniques to developing personal processes, imagery and ideas. Class sessions include technical demonstrations, illustrated lectures, personal and group critiques.
Prerequisite: 60-160

60-251 2D Media Studio: Print Media
Fall: 10 units
Printmaking is a process-based medium that produces multiples of original artworks. Students will create four works on paper using the following printmaking approaches: Relief (carved), Intaglio (engraved), Lithography (planographic), and Screen Printing (stencil). Each technique's unique set of materials, processes and aesthetics will be explored. This course focuses on traditional tools and practice, but will include utilization of digital images and sources through a critical lens. While primarily focused on the learning of fundamental approaches, the class will also expose students to ways that Print Media can be a tool (physically and conceptually) in contemporary practice.
Prerequisite: 60-160

60-280 Introduction to Contextual Practice
Spring: 10 units
For some time now art has moved out of gallery and museum spaces and into all facets of public life, where complex social situations and diverse audiences have become important parts of the work. In the past this might have been called Public Art, but today new strategies are being used that challenge public art's tradition of static sculptures and embrace more dynamic forms of public engagement. As its name implies, Contextual Practice embraces the context or social conditions in which an artwork exists as part of the material of that work. Evolving out of the history of site-specific, conceptual, and performance art practices, Contextual Practice covers a range of exciting new methods to making art in the public including street art, interactive social media, environmental art, hacktivism, participatory art, guerilla performance, project-based community art, and urban interventions. Students in this field-based class will create projects that work with the social dynamics of a variety of on and off-campus and online public contexts. We will research new trends in public engagement through art, architecture, and design, as well as politics, ecology, sociology, and economics. Fundamentally, this class asks students to experiment with how their art practice can intersect directly with the real world (outside of the traditional art venues) and how they can proactively create new sites and audiences for their work.

60-333 IDeATe: Character Rigging for Production
Fall: 10 units
Character Rigging for Production explores processes for building digital skeletons and control systems to drive computer animated forms. This course investigates vital techniques and concepts to create expressive, fully articulated characters for computer animation, film, and game production. Beginning with rigging fundamentals, coursework will advance through various systems and methods that are needed to convey motivated movement and expression in a variety of character forms. Certain key topics include kinematics, joint orientations, driven keys, direct connections, space switching, corrective blend-shapes, custom attributes and graphic user interfaces (GUIs), skinning and deformation. Additionally, coursework provides an introduction to scripting methods for rig creation, including expressions, Python, and MEL. Students will be provided a valuable range of tools that meet production standards for animated film and game creation, as well as a necessary conceptual framework to enable complex problem solving at all levels of rig creation. Anyone interested in the artistic and technical sides of computer animation are encouraged to enroll. Previous experience with Autodesk Maya/3D animation is preferred.

60-350 Professional Development for Creative Practices
Fall and Spring: 9 units
This course is intended to expose students studying in creative fields to the basic principles, skills and functions of business used every day in creative practices and industries. Supporting a creative practice - whether an individual studio practice, a temporary collaboration or commission, or an incorporated business or non-profit - all require a foundational knowledge of basic organizational, legal, and financial structures and practices. Throughout this seminar-style course, students can expect to develop a starting knowledge of basic business concepts; learn a foundational understanding of ethics and best practices in business; develop problem-solving skillsets and methodologies for managing creative projects and programs; and practice applying these learnings to their own creative practices. Topics covered will include, but are not limited to: basic business structures; intellectual property; Contracts and employment; methods for generating income and fundraising; financial management and taxes; marketing and communications; negotiation and compromise; and elements of business strategy development. This course assumes no prior background in business education or administration experience.

60-352 NOISE: Toward a Critical Theory of Sound and Hearing
Intermittent: 9 units
This seminar will explore audio art in its widest sense: sound sculpture and installations, radio art, the soundtrack, just about anything audible but not conceived as music. Special focus on the production (and reception) of sound by artists, amplifying those creative efforts that, in having explored acoustics, soundscapes, and listening, might also serve to inspire students to incorporate sound in their own work. Contemporary critical theory, by and large, is still glaringly silent on aurality and auditory phenomena; it seriously fails to consider sound as an object of study, instead focusing quite exclusively on visual culture (film, TV, video, computer screens, which are, of course, technologies of vision and sound). This seminar will address this roaring silence by examining some suggestive but disparate theoretical work related to sound and by engaging with a range of artistic practices that explore the production and reception of sound itself.

60-353 Critical Studies: Media Performance - History, Theory, and Contemporary Practice
Intermittent: 9 units
During the last decade of the twentieth century, new technologies have transformed the way we think about live performance. By examining the use of media (analog and digital) across the areas of sound/music, dance, theater, performance art, gaming, and installation, this course will traverse multiple theories and practices of performance history. With an eye to how changing theories of performativity have influenced how artists think about what it means to "perform," this seminar, in a sense, will be engaged in both philosophical and aesthetic research about how technology has changed the conventions of performative artistic practice. What was the role of technology in the dematerialization of the object of art? How have ideas about virtual, parallel worlds changed the way artists think about the "performing body?" If technology once acted as a prosthetic device, increasing an artist's sensual and perceptual world, what happens to the role and impact of an artist's work in the seemingly inert realms of programming or the increasingly autonomous areas of Robotic Intelligence? What does art look like in a post-internet age?

60-362 Art Writer
Intermittent: 9 units
ART WRITER will strive to bring together the intersecting discourses of artists use of writing as an object, art criticism, as well as experiments by both artists and critics to use theory as invention. The idea of experiment implied here emphasizes the urgency that art writing move beyond its own history, beyond the received understanding of its proper practices in order to propose new modes of critical reflection. The form and material force of language will be explored through the conceptual and critical work of Dan Graham, Lawrence Wiener, Donald Judd, Lee Lozano, Joseph Kosuth, Vito Acconci, Mel Bochner, Eleanor Antin, the international projects of Art and Language, Fluxus, as well as more recent iterations. This is a writing intensive seminar with experimentation at its core. Members will workshop their writing: revise, rethink, perform, and publish.

60-366 Culture in the Public Realm
Intermittent: 9 units
The seminar offers a discerning critical overview of key concepts about culture, public space & the public sphere. We will introduce & critically explore the historical, theoretical & practical production & use of 'public space', & art/culture beyond the museum or gallery. We will consider the historical evolution of the city as both an actual & theoretical entity. The class will explore urban environments in terms of economics, demographics,political, cultural production & psychology & the city of Pittsburgh will function as our site laboratory. We will inquire about the function of public art?what happens when space is required for the public realm for a means of cultural production that aims to yield some form of transformative effect for the ?public? or citizens at large. Moreover the term "public" is an important topic to be investigated: Who is the public? Who is the audience? This interdisciplinary course will consider & examine the interplay of artists & their public & how certain belief systems of a society at a specific time are able to influence a culture's perception of art. What is the role of the artist, critic, curator & urban planner in relation to the public & what is at stake in utilizing public space as a platform for art & other forms of cultural production? We will reflect on why have we become in recent times so preoccupied with public space as a platform for cultural production. Changing attitudes among artists & in museums have played a role in this cultural shift & theory. We will query a range of cultural mediums in order gain insights into the construction of public culture. The means to inspect the varied issues will go beyond assigned readings: it will include class discussions, personal reflections, writings, videos & guest speakers from the field of architecture, public policy, art, & public art. A conjoint class student project will take place to further probe this subject.

60-371 Breathless: International New Wave Cinemas
Intermittent: 9 units
What does Jean-Luc Godard's "Breathless [A'bout de souffle] (1959) have in common with Wong Kar-Wai's "In the Mood for Love" [Fa yeung nin wa] (2000)? What does Satyajit Ray's "Pather Panchali" (1955) share with Mark LaPore's "The Glass System" (2000)? By examining an array of films from the classic days of International New Wave Cinemas, beginning with French Nouvelle Vague, Indian "Parallel Cinema," as well as German, Italian and Japanese innovations and moving to contemporary (and experimental) film movements in Iran, Korea, Hong Kong, Eastern Europe, and the US, we will explore the ways a handful of young directors found novel ways to fund and shoot their movies in direct defiance of commercial, narrative, and cultural norms. By focusing on mise-en-scene over thematics, on-site locations over studios, lesser-known actors over box-office idols, and small production teams over professional crews, these directors were able to turn lo-fi aesthetics and financial shortcomings into a radical new filmic style. Especially central here will be how forms of cinematic experimentation translated internationally—and how these approaches continue to challenge hegemonic forms of media culture.

60-376 Large Format Photography: The Antiquarian Avant-Garde
Intermittent: 10 units
This course takes part in the anti-digital movement by exploring the roots of photography. Students will shoot with an array of large format cameras and use 19th and 20th century processes to create "one-of-a-kind" photographic images. Course topics include non-silver printing processes, pinhole photography, and contemporary tin-types. Prerequisites: 60-141/62-141/ equivalent or consent of instructor.
Prerequisites: 60-141 or 62-141

60-380 Color Photography and Digital Output
Fall and Spring: 10 units
This is a course using digital photography with digital printing methods. Students will gain an understanding of color theory and aesthetics, while better defining their individual voices. By semester's end, students will have a finely printed body of work using Mac OS, RAW file handling, color management and Adobe PhotoShop.
Prerequisites: 60-141 or 62-141 or 51-265

60-397 Critical Studies: Art, Conflict, and Technology in Northern Ireland
Intermittent: 12 units
Art, Conflict and Technology in Northern Ireland is a 12-unit course cross-listed in the School of Art, the Robotics Institute, and the Department of English.The class consists of a weekly seminar (Wednesdays) and a required 3-unit recitation in the Robotics Institute (Fridays). Throughout the term students will be introduced to a history of social strife in the North of Ireland from the 1960s to the present, and efforts to reconcile differences in the contemporary period. We will consider the influence of advancing technology on how narratives are shared within a community and worldwide. If you have ever considered how artists explore societal strife through their writing or visual arts practice, if you are interested in the social and political influences of evolving technology, or if you are a practicing artist who uses advancing technology as a tool for individual expression, this integrative course is for you. Throughout the semester we will examine the practice of a range of visual artists that include Rita Duffy, John Kindness and Willie Doherty and writers and dramatists like Dermot Healy, Patrick McCabe and Christina Reid. Students will learn how to use CREATE Lab's technologies as platforms for exploring the content presented in class and for the development of final projects. We will travel to Belfast for spring break 2018, to meet a variety of writers and artists whose work we will study, and stakeholders in reconciliation efforts throughout the region.

60-398 Critical Studies: Social History of Animation
Intermittent: 9 units
Social History of Animation will investigate the history of animation from early experiments with trick film through the development of major studios, to independent animation, web based work and emerging forms. Animation will be analyzed and discussed in relation to the social movements and technological innovations that effected animators and their work. This class will read related texts and view examples from around the world to explore animation as a means for personal expression and as a reflection of the context in which they were made.

60-399 Critical Studies Independent Study
Fall and Spring: 9 units
A tutorial course in which an Art student works individually on a self-generated project under the supervision of a School of Art faculty member. Prior to enrolling in Independent Study, the student must complete an "Independent Study Proposal" form (available in the bins on the 3rd floor of CFA) which is signed by the faculty member and the Assistant Head of the School of Art. Prerequisite: Art junior or senior status, or by instructor permission.

60-400 Senior Review
Spring
Students present their work and their ideas about their work to a faculty committee. This review affords graduating students the opportunity to analyze and summarize their work, and to engage a faculty committee in discussion about issues that face an artist preparing to enter a career in art. Although this is a non-credit course, it is required of all Art (BFA, BHA, BSA and BCSA) seniors.

60-401 Senior Studio
Fall: 10 units
Students initiate a comprehensive two-semester project in the first semester to be continued and completed in the second semester of their senior year (60-402). Each student pursues an ambitious and cohesive body of work with guidance by a team of School of Art faculty. Multimedia, multidisciplinary, and collaborative work is encouraged. Studio work is supplemented by group critiques, workshops on writing, professional presentation skills, career preparation, and technical instruction as needed. Attendance at all 6:30pm School of Art Lecture Series events is required for this class. Open to seniors in the School of Art, or by instructor permission.

60-402 Senior Studio
Spring: 10 units
Students continue a comprehensive two-semester capstone project. Each student pursues an ambitious and cohesive body of work with guidance by a team of School of Art faculty. Multimedia, multidisciplinary, and collaborative work is encouraged. Studio work is supplemented by group critiques, workshops on writing, professional presentation skills, career preparation, and technical instruction as needed. Attendance at all 6:30pm School of Art Lecture Series events is required for this class. Open to seniors in the School of Art, or by instructor permission.

60-403 Senior Critique Seminar
Fall and Spring: 10 units
Senior Critique Seminar comprised of group discussions that analyze the conceptual and aesthetic frameworks that surround each student's individual studio practice. The course supports independent inquiry, mature studio practice and both an in-depth critical reading of visual art and an increased comfort in the articulation of ideas and processes. Each student can expect two hour-long critiques throughout the semester, paired with ample time for individual studio work. These course discussions will also be informed by the Visiting Artist Lecture series and concepts and concerns carried from studio and academic seminar classes.

60-406 Advanced ETB: Internet Resistance
Intermittent: 10 units
Through booms and crashes, colonizations and disruptions, IPOs and LOLZ, Internet has been a spectacular laboratory of social conflict. But what can artists do on the net beside tweaking their pitiful portfolios and sinking into social media malaise? What is the function of the network in the age of pervasive surveillance, fake news, and filter bubbles? How to Internet under the First Troll President of the United States? Internet Resistance is both a schizo-seminar about critical issues in cyberculture and a trans-media studio to develop terrible ideas for the networked society. http://internetresistance.molleindustria.org/
Prerequisites: 60-210 or 60-110

60-407 IDeATe: Experimental Sound Synthesis
Spring: 9 units
[IDeATe course] In this course we will explore a variety of experimental approaches to music, sound design, and sonic artwork. Topics will include: composing and mixing in multichannel sound formats, building analog smart-synthesizers, electroacoustic music performance, 3D sound recording, reactive sound environments, sound installation and beyond. In this course students from a variety of disciplines will work together to design, prototype, and execute a series of ambitious projects. This course is part of the new Integrative Design, Arts, and Technology (IDeATe) program at Carnegie Mellon University and makes use of the new IDEATE@Hunt Media Lab, an adaptable multimedia black box located in the lower level of Hunt Library. Students are expected to be proficient in one or more of the following areas: · Real-time graphical programming environments (Max or PD), · Physical computing platforms (Arduino, Raspberry Pi) · Experimental music composition/performance · Instrument design · Interactive art

Course Website: https://courses.ideate.cmu.edu/57-344

60-408 Advanced ETB: Digital Storytelling and Resistance
Intermittent: 10 units
Digital Storytelling & Resistance is a class through which students will explore the varied ways artists use contemporary technology to create complex alternative stories to dominant media narratives as well as the ways in which video, film, performance and media artists have historically used hybrid documentary storytelling practices and appropriation as a way to resist, respond to, and deconstruct one-dimensional news media and pop cultural stories. In this course students will create video essays, remix and appropriation-based works, hyperlinked interactive stories, modded games, written pieces and interactive moving-image based narrative works through new multimedia publishing platforms.
Prerequisite: 60-110

60-409 Advanced ETB: Video & Performance
Intermittent: 10 units
This studio course will concentrate primarily on the historical and ongoing relationship between video and performance. That said, this course will be flexible enough to allow students to create video, performance and video/performance projects. For structured projects, all students will be expected to participate in performance. Class time will be spent considering the history of performance and video/performance, viewings of primarily video/performance works to provide background and inspiration, presenting and critiquing student projects and studio time to work on projects. Technical instruction in video editing, compositing and effects, audio recording/editing and midi applications will be offered on an as needed basis.
Prerequisite: 60-110

60-410 Advanced ETB: Moving Image Magic: Visual Effects and Motion Graphics
Intermittent: 10 units
Fly like Harry Potter, fall into Alice?s looking glass, create new worlds, or take a head-trip into the inner reaches of your subconscious. It?s all possible in Moving Image Magic! This course serves as an introduction to the creation of extraordinary cinematic visions using a variety of analog and digital tools and techniques. These include: digital compositing, miniatures, motion tracking, rotoscoping, matte painting, puppets and motion graphics. Primary software tools are After Effects and Photoshop with forays into, Motion, Resolve, Logic and Smoke. Prerequisites: Electronic Media Studio: Introduction to the Moving Image or instructor permission.
Prerequisite: 60-110

60-412 Interactive Art and Computational Design
Intermittent: 12 units
This is an advanced studio course in arts-engineering and new media practice, with a special emphasis for Spring 2016 on mapping and information visualization using geographic data. Topics surveyed in the course will be tailored to student interests, and may include: experimental interface design, locative and mobile media, data-driven activism, image processing and computer vision-based interactions, and other topics. Through a small number of exploratory assignments and a public capstone project, students will bolster interdisciplinary problem-solving abilities and explore computation as a medium for curiosity-driven experimentation. Enrolling students are expected to have demonstrable programming skills, without exception, beyond the level of an introductory class such as 15-112. Although the course will provide technical overviews of major visualization toolkits (including D3, Processing, and openFrameworks), assignments may be executed in the student's preferred programming environment. Graduate students should register for section 51-882, 60-712, or 62-726, which meets with the undergraduate sections 60-412 and 51-482.
Prerequisites: 60-112 or 15-110 or 15-112

60-414 Advanced ETB: Animation Art and Technology
Spring: 12 units
Animation Art and Technology is an interdisciplinary course cross-listed between Art and Computer Science. Faculty and teaching assistants from computer science and art teach the class as a team. It is a project-based course in which four to five interdisciplinary teams of students produce animations. Most of the animations have a substantive technical component and the students are challenged to consider innovation with content to be equal with the technical. The class includes basic tutorials for work in Maya leading toward more advanced applications and extensions of the software such as motion capture and algorithms for animating cloth, hair, particles, and grouping behaviors. The first class will meet in CFA room 303.
Prerequisite: 60-110

60-415 Advanced ETB: Animation Studio
Fall: 10 units
Chance Protocols is an intermediate level animation studio course that explores procedural animation techniques as experimental design frameworks. This course draws upon historical art, music, and literary traditions of chance operations as guiding structures for experimental computer animation, non-linear narrative, and experience design. Through this lens, students investigate procedural animation frameworks for improvisation in Maya, Unity 3D, and Processing. A theoretical framework establishes parallels between contemporary animation practice and the pioneering works of historical avant-garde artists. A series of open-ended prompts draws meaningful theoretical resonance with the works of Tristan Tzara, Hannah Höch, Oskar Fischinger, John Cage, William Burroughs, Norman McLaren, Mary Ellen Bute, and Robert Breer. Class discussions, screenings, and tutorials explore the intersections of critical inquiry and creative production. Practically, students will develop skills and methodologies for incorporating procedural animation techniques into traditional keyframe animation practice, cultivating contextual and theoretical awareness, and artistic agency. Through exposure to a variety of trends and techniques in contemporary animation practice, this class encourages discovery, innovation, and creative counterpoint to popular normative animation paradigms.
Prerequisites: 60-220 or 60-333 or 60-110 or 60-125

60-416 Advanced ETB: Documentary Storytelling
Intermittent: 10 units
In this class students will develop projects which use a variety of narrative concepts to convey stories in new ways. We will begin with a core practice around video, audio, and expand into internet media, performance, physical media and installation. Emphasis will be placed on story structure and strategies for choosing a media most appropriate to the narrative as well as the desired audience. Works by Janet Cardiff, Errol Morris, Spalding Gray, Werner Herzog, Laurie Anderson, This American Life and others will be mined for inspiration. With permission of instructor. We will also examine and discuss a range of historical and contemporary strategies employed by art makers who have used forums from on-line and virtual spaces to physical and site specific venues to expand and explore the relationship between the art object and the audience.
Prerequisite: 60-110

60-417 Advanced ETB: Video
Intermittent: 10 units
This course offers an in depth exploration of video as a tool for creative expression. Topics for investigation and discussion will include:
histories of experimental media, contemporary trends in the field, technological developments, performativity, and theories of perception and representation. Additionally this course will provide instruction in advanced digital video production and post-production techniques, including lighting, editing, visual effects, 2D animation, motion graphics and sound design. If you have not taken 60-110 but have basic proficiency in Adobe Premiere and After Effects please contact Professor Suzie Silver suziesilver@cmu.edu.
Prerequisite: 60-110

60-419 Advanced ETB: Experimental Game Design
Intermittent: 10 units
Experimental Game Design: Storyspaces - A hands-on game design course focused on innovative and expressive forms of gameplay. In this installment of Experimental Game Design the emphasis is placed on the complex relationship between stories and games. Topics include: environmental storytelling, world building, branching narratives, Virtual Reality, visual novels, AI-driven narratives and more. The class consists in one long session per week that allows for extended prototyping exercises (mini-jams), technical tutorials, as well as frontal lectures and in-depth playtesting sessions. Projects are team-based. Coding experience is recommended but not required.
Prerequisites: 15-112 or 15-110 or 60-212 or 15-104

60-422 Advanced ETB: Experimental Animation
Spring: 12 units
[IDeATe course] This class will examine animation production from the student's perspective. Animations that explore both form and content will be developed and discussed. Topics will include; non-linear narrative, visual music, puppetting, non-traditional materials, manipulation of motion and performance capture data and immersive environments.
Prerequisites: 60-220 or 60-333 or 60-110

60-428 Advanced ETB: Art of Robotic Special Effects
Intermittent: 10 units
Inspired by the early "trick" films of George Melies this project-oriented course brings together robotics and film production technique to create innovative physical effects and infuse cinema with the wonder of live magic. Students will learn the basics of film production using animatronics, camera motion control, and live compositing, then apply them to create short films all the way from concept to post-production. The course emphasizes real-time physical effects to explore the immediacy and interactivity of improvisation and rehearsal. The course includes a brief overview on the history of special effects and robotics to set the work in context.

60-429 Advanced CP/ETB: Digital Worlds: Making and Performing in Digital Contexts
Intermittent: 10 units
In this class students will look at digital spaces including social media, chatrooms, online galleries, phone applications, YouTube, 3D renderings, massively multi player online games, and more to produce works that respond to the specificity of these terrains. There is a rich history of site specificity and contextual practice in the physical world; this class will consider parallels in computer-based environments. In addition to theory and research components, students will develop a variety of technological skills in video production, webcasting, audio editing, gif animation, 3D modeling, and more in this course.
Prerequisite: 60-110

60-430 Advanced SIS: Open Sculpture
Intermittent: 10 units
Sculpture is perhaps the broadest field among the contemporary visual arts. Through its privileged relationship to the physical world and the viewer's body, sculpture is the glue that connects the intermedia practices of object, installation, interactive art and performance. In this class we build on skills and concepts learned in 3D media 1 and 2 to develop students' individual approach. Students define independent responses to topics proposed through discussion of contemporary sculptors. Emphasis is placed on individual development. Students are encouraged to explore interdisciplinary approaches.

60-431 Advanced SIS: Installation
Intermittent: 10 units
This course explores a broad range of sculptural issues concerning the practice of Installation Art. Studio focus on relatively large scale works which often involve an ensemble of objects or phenomena in a particular space. Both temporary and permanent works are addressed. Emphasis on research about "place" and the proposal process for a specific context. Various strategies, methods and materials investigated through projects, readings, presentations, discussions and field trips. Exercises and projects assigned initially, but students expected to establish their own projects later in the semester.

60-433 Advanced SIS: Why Not Mud - Clay Sculpture
Intermittent: 10 units
Clay is a primary building block of sculpture. This supple, responsive and versatile material is being incorporated into the work of many contemporary artists today. This class will ask students to create projects that explore the use of clay as a medium in the context of their own work. It is intended for students who would like to specialize in clay sculpture, as well as students who work primarily in other mediums. Projects will originate from self-generated ideas. Class critiques will stress group participation to broaden viewpoints and sharpen critical abilities. The majority of class time will be for studio projects. The use of mixed media is allowed. A materials fee is required.

60-435 SIS: Metals
Intermittent: 10 units
Studio focus on fabrication using light metalworking techniques including forming, joining, and finishing. Metalsmithing and jewelry techniques will be explored in the context of sculptural issues. Metal stretching, forging, brazing, texturing, small scale casting and coloring are also presented. Slides looking at small scale metalwork, as well contemporary sculpture using metal techniques will be presented periodically. Metals provided include copper ,brass, and bronze sheet and wire. Materials fee will also cover silver solder and other expendables. This is a repeatable class that will add to the tools and techniques acquired in earlier metals classes while expanding individual growth within the concept and context of sculpture.

60-437 Advanced CP/SIS: Environmental Sculpture
Intermittent: 10 units
Studio focus on sculpting with the environment. Includes object making, installations and site work with an emphasis on ecological materials, growing systems, environmental impact and related issues. Students required to explore and develop proposal-making skills in order to acquire permission for sites in which to implement projects. Both individual and collaborative projects are possible.

60-438 Advanced SIS: Intimate Objects
Intermittent: 10 units
The intimate object - exploring the issues of small scale sculpture. This class will deal with the creation of objects that require a one on one interaction with the viewer. Unlike much heroically scaled sculpture, there is a distinctly personal and intimate connection that these objects engender. The class will look at historical examples, as well as 20th century works starting with the dada and surrealists. Problems of small scale sculpture will include topics such as the miniature versus actual size, the nature of materials, the issues of craftsmanship, the problem of preciousness. This class is open to advanced sculpture students working in any media.

60-446 Advanced SIS: Expanded Theater Fusion Studio
Intermittent: 10 units
[IDeATe collaborative course] As the boundaries between theater, art, entertainment and everyday life continue to expand through engagement with new technologies, it is critical that emerging artists and technologists be provided with the tools, language, and vision to thrive in the new millennium. Expanded Theater will reanimate classical modes of performance with media, networks, robotics, locative applications, and mobile systems. Considering theater as an ancient technology of mass participation and social cohesion, this fusion studio explores how emerging technologies can expand upon the basic theatrical relationships in new and culturally relevant ways. Collaboration and integration of design, media and storytelling is critical to this approach. Experimentation with new forms can reanimate the basic values of theater; the essential nature of a live event, the possibility of visionary spectacle, and the creation of meaning in dialogue with an audience. Expanded Theater is an opportunity to explore avenues outside of traditional theatrical production modes and beyond each student's individual discipline. The curriculum combines resources from Carnegie Mellon's Schools of Art and Drama, Integrative Design, Arts, and Technology (IDeATe), the Emerging Media Masters (EM2), Computer Science, the Robotics Institute, and their collaborators across the university in a new configuration. Expanded Theater will explore domains ranging from site specific and networked-based performance and interventionist practices, to pervasive social media technologies and their influence on interpersonal communication. The goal is to investigate contemporary languages that allow authors, actors and technologists to collaborate in ways that push beyond our present understanding of theatrical production and reception. This course alternates between two modes of research and design.

60-450 Advanced DP3: Drawing
Intermittent: 10 units
Uncontrollable emotions? PASSION drawing embraces you. Dionysian daydreams? PRIVATE drawing releases you. Anger worth sharing? PARTISAN drawing supports you. By example and creating our own, this course promotes unapologetic drawing: too wild to be contained; too raw to be seen; too declarative to be denied. Through presentations, excursions, critiques, readings, discussions, exercises and atmosphere, we will develop independent methods and work beyond our current assessment of the permissible. Through three overlapping lenses - of abandon, the anti-repressed and the advocatory - we will focus and expand our work. Expect campfires, candles and torches.
Prerequisites: 60-160 and 60-150

60-451 Advanced DP3: Concepts of Figuration
Intermittent: 10 units
This course encourages creative exploration of the human image beyond observational figure drawing. We will be thinking of the figure as a symbol to explore narrative, anthropological, cultural, sociopolitical, gender, and dream-life imaging. Through these lenses the figure becomes primary to the understanding of personal or group identity, place, sexuality and gender identification. Figure drawing is open to the use of traditional and extreme image making methods including observational and fictional representations or other conceptual premises relevant to the successful presentation of privately held concerns. Emphasis will be on experimentation with both material and image. The class will consist of studio time, critique, readings, and discussion.

60-452 Advanced DP3: Color
Intermittent: 10 units
In this advanced course, students will learn to employ a wide range of color theories and color systems through hands-on exercises and studies. Studies will be done primarily in paint, with some use of collage and digital media. These exercises will be aimed at mastering a variety of color approaches that will be applicable to each student's own artistic practice. Students will develop, based on their own interests, a cohesive body of work in which to practice and expand on the skills learned through the directed exercises. Studio work will be augmented by lectures, demonstrations, critiques, readings and critical discussion of writings about color.

Course Website: https://sites.google.com/view/color-spring-2018/home

60-453 Advanced DP3: Painting
Fall and Spring: 10 units
This course is designed to help promote a painter's development, both conceptually and technically. It encourages students to expand their ideas through a diverse set of projects. Through research and studio experimentation, students will explore issues of scale, surface, materiality, process and performativity in painting. They will also consider notions of the "picturesque" and how non-artistic disciplines can inform painting. Lectures and assignments are designed to enrich the painter's conceptual and technical base and to promote creative growth.
Prerequisite: 60-250

60-458 Advanced DP3: Serigraphy
Intermittent: 10 units
Advanced PDP: Serigraphy. Studio focus on processes and artmaking issues related to water-based/acrylic serigraphy. Emphasis on individual conceptual/artistic development. Material fee required.

60-460 Advanced DP3: Paint/Print
Intermittent: 10 units
Paint/Print encourages creative exploration of the boundaries between print media and painting through material investigation, thereby eliminating any assumed hierarchy between the two modes of working. Painting and printmaking are open to the use of traditional and extreme image making methods including observational and fictional representations, abstraction, collage, installation, digital drawing/painting or other conceptual premises relevant to the successful presentation of privately held concerns in image-making. Emphasis will be on experimentation with both material and image. The class will consist of studio time, critique, readings, and discussion.
Prerequisites: 60-251 and 60-250

60-463 Advanced DP3: Print/Draw
Intermittent: 10 units
This course will focus on the development of technical and conceptual strategies in drawing AND/OR print media. With students working in either or both areas, the class the function as a studio workshop in which students set personal goals and strive to produce a significant body of work. Students will be expected to experiment and to create their own problems/limitations, while investigating a range of materials and considering the relationship between form and content. Individual and group critiques will help guide students; presentations on artists, readings, and field trips will contextualize the group's work.

60-464 Advanced DP3: Expanding the Graphic Novel
Intermittent: 10 units
In this course, students will critically and creatively engage with the medium of comics to learn how to better communicate their ideas in this format as well as challenge its boundaries. A substantial portion of the course will focus on familiarizing students with the basics of storytelling in a sequential narrative format and creating opportunities for students to discover, hone and explore their own voice and style. In addition to creating new work, students will also explore the history of comics and the origins of the "modern" graphic novel. Students will also be exposed to both graphic and non-graphic artists whose works have challenged and redefined the genre. We will explore these artists in order to understand how our own work borrows from and draws upon a rich lineage. Students will also be expected to think beyond the commonly accepted notions of comics and to question the relevancy of their work in this medium. Finally, each student will produce a new body of work that will culminate in the production of a 4-5 "page" "sequential" narrative.

60-468 Advanced DP3: Print Media - Out of Print
Intermittent: 10 units
This fast-paced Advanced Print Media class begins with collecting out-of-print ephemera as the source inspiration for creating new images using any technical process or conceptual strategy from the Print Media tool box. This is a high output, low stakes class that emphasises Making and Doing as the key foundation for a generative creative practice. This class will include visits to used bookstores and library special collections for source images and hands-on workshops at local print studios and letterpress shops. Students will have access to Screenprint, relief, intaglio, lithography, scanners, large format digital printing on both paper and textile, xerox, risograph, laser/cnc aided print matrixes etc. Students will explore alternative distribution methods (portfolio exchanges, zines, artist books, gifs, instagram, tumblr) of the graphic image to recirculate images and texts that were out-of-print.
Prerequisite: 60-251

60-472 Advanced DP3: Mutable Landscape
Intermittent: 10 units
With camera in hand, students will explore, document and invent a sense of place in Pittsburgh. Informed by photographic history and landscape studies, students will develop their own portfolios of digital prints. As a CFA Interdisciplinary photography course, students will be encouraged to consider their photographs in the medium of their home department, and in some cases as a starting point for projects in other materials. No prerequisites.

60-475 Advanced DP3: Open Print
Intermittent: 10 units
This advanced Print Media course focuses on student-driven development of a studio practice focused on contemporary print, multiples and distributed art. In this class, individuals will continue to build on technical skills and concepts, and the interdisciplinary applications of both, through self-directed, individual approaches. The course includes written assignments, weekly critiques and discussion, field trips to local print studios, and visiting artists. This course is for advanced students of art, ready to focus on larger-scaled, conceptually and formally ambitious projects that are formed from long-term investigations.
Prerequisites: 60-251 and (60-474 or 60-475 or 60-468)

60-476 Advanced Print: Print Media: Relief Printmaking
Intermittent: 10 units
This courses is an comprehensive and intensive study of relief printmaking. The course introduces students to various materials (linoleum, wood, movable type), various hand-carved techniques (single color, multiblock, reductive, letterpress) and also the introduction of various, new technologies (laser etched, engraved plates, digitally rendered photopolymer plates). With an over thousand year history, relief printmaking is one of the earliest methods in which humans were able to record, communicate, and distribute their history, stories and ideas for posterity. This powerfully expressive medium has been and continues to be a visual voice for political movements across various cultures. Primarily focused on work on paper, students will also have opportunity to consider the sculptural, participatory, and time-based applications applications of the medium within contemporary practices.

60-486 The Art and Science of Color
Intermittent: 10 units
This interdisciplinary course will consist of a combination of chemistry lecture & labs with studio art & art history. The focus of the course will be on the intersection of painting practice with chemistry, particularly in the study of pigments of mineral & inorganic origin. This is a project course open to majors in chemistry & art. The course & its projects are designed to expand the expertise of students in each discipline, while exposing them to the methods, demands, & aims of the other. Historically, the craft of painting was closely linked to the practice of pigment manufacture, with painters procuring their materials in raw form directly from the chemist/apothecary, & often performing themselves the final purification & grinding of the minerals into pigments. Color has been used by both artists & alchemists as a benchmark for tracking changes while creating new materials based on minerals found in nature. With the advent of mass-produced & marketed art materials in the nineteenth century, the distance between chemist & artist increased until the two worlds have little to do with one another. This class aims to reconnect the two disciplines for a study of their common ground. Students will learn about the origin of the color of minerals with primary focus on colors that originate from electronic transitions & will work collaboratively on hands-on laboratory research projects that involve the synthesis, characterization, & use of inorganic pigments. In the studio, they will make their own egg-tempera paints, & use them in painting projects designed to increase color skills as they learn about the history of pigment use. Students will collaboratively design & carry out final projects which combine research, experimentation & creative work. A series of researchers who work at the boundary between art & chemistry will give guest lectures, & the class will make field trips to local research labs & museums.

60-487 Advanced CP: The Amateur
Intermittent: 10 units
If a contemporary artist can truly do and be anything, how come so much art looks the same? More and more contemporary artists are pushing beyond the conventional media and methods of the art world by strategically operating as "professional" amateurs. The term amateur reflects a voluntary motivation to create as a result of personal passion for a particular activity, regardless of expertise or authority. For the artist, embracing the role of the amateur allows for the use of any profession, institution, or social activity as a possible material within their creative practice. This includes artists who "perform" as amateur preachers, psychologists, geneticists, politicians, and exotic dancers; artists who create amateur institutions like sanitariums, circuses, hair salons, talk shows, and planetariums; and artists who collaborate with professional hypnotists, ornithologists, stunt coordinators, ventriloquists, and diplomats in order to manifest their work. Students in this class will work on self-defined projects that utilize the role of the amateur as a critical method for expanding the breath and reach of their art practice into new forms and venues. With faculty mentorship, each student will be responsible for developing their projects through independent research, apprenticeships, and collaborations with experts in fields relevant to their work. Workshops, lectures, and in class critique of ongoing work will look at contemporary trends related to amateurism in art practice, theory, and the world at large. This class is not about being an amateur artist, but about being a serious artist who uses amateurism as a tool. Thus the class is only open to students with ???

60-499 Studio Independent Study
Fall and Spring
A tutorial studio in which an Art student works individually on a self-generated project under the supervision of a School of Art faculty member. Prior to enrolling in Independent Study, the student must complete an "Independent Study Proposal" form (available in the bins on the 3rd floor of CFA) which is signed by the faculty member and the Assistant Head of the School of Art. Prerequisite: Art Junior/Senior status and by instructor permission.

60-590 Internship
Fall and Spring
Art Internships are open to all BFA, BHA, BSA and BCSA Art students. Internships may take place with appropriate individuals or organizations within or outside of Carnegie Mellon University. The requirements for an internship are in the School of Art Handbook (available at the School of Art website). Prior to being enrolled for an internship, students must complete an Internship Proposal Form, which defines the goals of the internship. This form must be signed by their site supervisor and approved by the Assistant Head of the School of Art. Forms are available in the bins on the 3rd floor of CFA. Junior and Senior Art majors only.

School of Design

Terry Irwin, Head
Location: Margaret Morrison Carnegie Hall 110
design.cmu.edu

Design at Carnegie Mellon

Design is the thoughtful activity that humanizes our environment through visual communication and the shaping of products that help us in our daily lives. Whether in magazines and books, posters and exhibitions, video and film, human-computer interactions, or any of the myriad of everyday products such as furniture, consumer goods, vehicles, or medical equipment, designers play an important role in shaping the form and content of our experience.

Designers are concerned with aesthetics, but they are equally concerned with serving people. This requires more than skill in the fine arts. It also requires knowledge about the needs, desires, expectations, and capabilities of human beings. It requires skills of observation and interpretation that help us understand the people that we want to serve. More than this, however, designers must also understand the technological issues that stand behind effective products. They must understand the materials, tools, and production processes of the modern world. An education in design is an education for the mind as well as the eye and hand.

The undergraduate program enables students to develop specialized skills in the areas of Product (Industrial) Design, Communication (Graphic) Design and Design for Environments (design for physical and digital environments), while providing them with a solid foundation in design studies. Students study systems thinking; the ability to see and solve problems at multiple levels of scale, and situate their work within larger social and environmental contexts.

The over-arching theme of the curricula is *design for interactions*, which acknowledges that 'ecologies' of products and communications often come together within complex physical *and* digital environments. Coursework balances making and theory with the integration of new, emergent technologies. Students are encouraged to explore the scope of design as well as the responsibility and ethics involved in the design of interactions between people, the built world, and the environment.

The curriculum is one that provides students with the ability to customize their degree: they may choose to specialize in one of three areas offered (Products, Communications, Environments), but also have the option of combining any two, to create a unique, interdisciplinary design degree.

The undergraduate curriculum also introduces students to three important areas of design focus: design for service, design for social innovation and transition design. These represent both new and established design approaches to framing and solving problems. In their senior year, students bring their disciplinary specialty (communications, products or environments) to projects that are situated within the areas of design for service and/or design for social innovation.

The School offers a Bachelor of Design with tracks in Communications, Products, or Environments.

Communications

The ability to communicate and shape meaning is one of the most powerful and ubiquitous forms of design in today's world. Students learn to design effective communications across a wide variety of media that *always* exist within complex webs of interactions between people, products, and environments. Areas of study include narrative and storytelling, information design, and a variety of analog and digital visualization techniques. Students develop the ability to identify specific audiences and communicate to them through effective visual, verbal and aural communications that educate, inform and delight.

They study the dynamic and 'emergent' characteristics of communications in a globally networked society where technologies and modes of individual and mass communication are constantly changing. Students learn systems thinking and engage in an iterative, multi-disciplinary and collaborative design process that involves research, observation, prototyping and rigorous evaluation. Students develop the ability to identify and communicate to specific audiences through effective visual and verbal communications that educate, inform, delight and invite participation.

Products

Students learn to design products and their interactions within the context of human needs and they develop a deep understanding of the ways in which products shape behavior. Our curriculum acknowledges that no product exists in isolation—it is *always* part of a larger system comprised of people, communications and environments. Within the context of design for service, products exist as 'touchpoints' in a service ecology. For this reason, students learn systems thinking and engage in an iterative, multi-disciplinary and collaborative design process that involves research, observation, modeling/prototyping and rigorous evaluation.

Students are introduced to current production and manufacturing processes as well as sustainable approaches, such as cradle-to-cradle, lifecycle analysis and the use of new, more environmentally friendly materials. The School has a well-equipped analog and digital prototyping facility where students work with traditional materials such as wood and metal and learn to design and prototype using CAD software and 3D digital printers.

Environments

Students learn to design for complex environments that exist in the digital, physical and multi-modal realms. Most of the products and communications we interact with are situated within complex physical spaces (our homes, classrooms, places of business, shopping malls, even amusement parks). We also interact with complex online environments such as large websites, social networking and virtual reality environments. And increasingly we interact in 'smart' physical spaces with multi-modal communications in a combination of the analog and the digital.

In our curriculum, environments are seen as integrated and dynamic systems that require the design of interactions at multiple levels of scale. Students acquire a diverse set of skills that includes a deep understanding of spatial relationships, designing *with* and *for* emerging, multi-media technologies and an understanding of the cognitive challenges presented by multi-modal spaces.

Students who focus on the design of environments delve deep into systems thinking and systems dynamics and spend time learning to collaborate and lead within multi-disciplinary teams (solving large problems involving complex spaces almost always involves teams of people from different disciplines).

Design Minor Program

The School also offers a minor in Design for well-qualified students. Further information on the minor program is provided here (https://design.cmu.edu/node/122).

The Design Curriculum

Minimum units required for Bachelor of Design	360

The design curriculum is for students who are interested in full-time undergraduate study leading to entry-level professional employment or advanced graduate study in the areas of Communication Design, Product Design, or Design for Environments. The first year is a period of discovery, where students explore studio projects and supporting courses in the ideas and methods of design practice as well as courses in design studies. The second and third years are a period of concentration and development primarily within the student's area(s) of specialization. The fourth year is a period of integration and advanced study, with studio projects involving teams of students from all areas of design. There are studio courses throughout all four years, supported by departmental electives in the ideas and methods of design practice and other courses in the history, theory, and criticism of design. In addition, the School also requires all students to take a substantial number of general education courses offered by other departments throughout the university. General education is an essential part of the education of a professional designer.

Foundation Year

In their freshmen year, students are introduced to all three areas of design specialty: Product (Industrial), Communication (Graphic) and digital and physical Environments. Here, they explore these unique and complementary areas of design and gain a wide range of skill sets such as systems thinking, iterative process, collaboration and visualization, and work in both two and three dimensional materials as well as digital media.

At the end of their freshman year, students are given the opportunity to begin to focus their interests in two of three design areas (products/communications/environments) and will eventually decide upon a single area of focus or a dual path of study.

This is the first-year curriculum for all design students.

First Year

Fall

Studio		Units
51-101	Studio: Survey of Design	10

Ideas and Methods		Units
51-121	Visualizing	10

Design Studies		Units
51-171	Placing	10

General Education		Units
76-101	Interpretation and Argument	9
85-102	Introduction to Psychology	9
or 85-211	Cognitive Psychology	
or 85-241	Social Psychology	
99-101	Computing @ Carnegie Mellon	3

Spring

Studio		Units
51-102	Design Lab	10

Ideas and Methods		Units
51-122	Collaborative Visualizing	10
51-132	Introduction to Photo Design	10

Design Studies		Units
51-172	Systems	9

General Education		Units
79-104	Global Histories	9
or 76-241	Introduction to Gender Studies	

Second Year

Following the first-year program, students select two out of three areas of interest: Products[P], Communications[C], Environments[E]. In the fourth semester students select one of the two areas to study more deeply. Students investigate the relationships people form with designed artifacts and the roles that physical, visual, and digital forms play in our lives. They apply what they learn to the design of products, communications, and environments that facilitate interactions. Students are also required to take general education courses to gain a broad vision of many disciplines and fields of knowledge that are relevant to design.

Second Year

Fall

Studio		Units
51-225	Communications Studio I: Understanding Form & Context (Pick two)	4.5, 4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	

Ideas and Methods		Units
51-227	Prototyping Lab I: Communications (Pick two corresponding labs)	4.5, 4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	
51-221	Color for Communications, Products, Environments	9
or 51-229	Digital Photographic Imaging	
or 51-242	How Things Work: Mechanics and Electronics	

Design Studies		Units
51-271	How People Work	9

General Education		Units
xx-xxx	Academic Elective	9

Spring

Studio		Units
51-228	Communications Studio II: Designing Communications for Interactions	9
or 51-248	Products Studio II: Designing Products for Interactions	
or 51-268	Environments Studio II: Designing Environments for Interaction	

Ideas and Methods		Units
51-208	Research Methods	4.5
51-239	Prototyping Lab II: Communications	9
or 51-249	Prototyping Lab II: Products	
or 51-269	Prototyping Lab II: Environments	

Design Studies		Units
51-272	Cultures	4.5

General Education		Units
xx-xxx	Academic Elective	9

Third Year

In the fifth and sixth semesters, students may choose to continue their fourth semester area of focus, or they may choose to study their second area of study from the third semester. Students study how design functions at various levels of scale and degrees of complexity situated in specific contexts. They design products, communications, and environments that function as cohesive systems that live within the built and social worlds.

Third Year

Fall

Studio		Units
51-323	Communications Studio III: Designing for Complex Communication Systems	9
or 51-343	Products Studio III: Designing for Complex Products Systems	
or 51-363	Environments Studio III: Designing for Complex Environment Systems	

Ideas and Methods (Select one Design Elective)		Units
51-321	Design Center: Photographic Narrative	9
51-231	Calligraphy I	9
51-349	Visual Notation/Journaling	9
51-322	Advanced Digital Imaging	4.5
51-359	Tools for UX Design	9
51-324	Basic 3D Prototyping	4.5
51-355	Experimental Sketching	4.5
51-399	Junior Independent Study	Var.
51-341	How Things are Made	9

Design Studies		Units
51-371	Futures I	4.5
51-373	Futures II	4.5

General Education		Units
xx-xxx	Academic Elective	9
xx-xxx	Free Elective	9

Spring

Studio		Units
51-330	Communications Studio IV: Designing Communications for Social Systems	9
or 51-350	Products Studio IV: Designing Products for Social Systems	
or 51-360	Environments Studio IV: Designing Environments for Social Systems	

Ideas and Methods (Select one Design Elective)		Units
51-322	Advanced Digital Imaging	4.5

51-328	Advanced Web Design	9
51-334	Photography, Community & Change	9
51-344	Advanced Digital Prototyping	6
51-346	Production Prototyping	6
51-376	Semantics & Aesthetics	4.5
51-380	Experiential Media Design	9
51-388	Sharing Economies	9

Design Studies		Units
51-372	Persuasion	9

General Education		Units
xx-xxx	Academic Elective	9
xx-xxx	Free Elective	9

Fourth Year

In the senior year, students work to identify their next steps in professional practice, entrepreneurship, or in academia. They apply their design skills and knowledge to client-based and/or self-defined projects that focus on the design of services or social innovation.

The fall semester features the Design Research Studio, a semester-long project where students work in teams applying skill and knowledge learned in Products, Communications, and/or Environments. In the spring the Capstone Project challenges students to work independently on a semester-long project, deepening their understanding of service or social innovation design principles.

Fourth Year

Fall

Studio		Units
51-481	Design Research Studio	12

Ideas and Methods (Select one Design Elective)		Units
51-441	Foundation of BME Design	6
51-451	Fundamentals of Joinery & Furniture Design (I)	9
51-499	Senior Independent Study	Var.
51-376	Semantics & Aesthetics	4.5
51-385	Design for Service	9
51-382	Design for Social Innovation	9

General Education		Units
xx-xxx	Academic Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9

Spring

Studio		Units
51-480	Design Capstone Project: Service Design & Social Innovation	12
		12

Ideas and Methods (Select one Design Elective)		Units
51-374	Understanding Perception through Design	9
51-427	Advanced Book Arts Workshop	9
51-434	Experimental Form	9
51-442	BME Design Project	9
51-452	Furniture Design II (II)	9
51-478	Speculative Critical Design	9
51-499	Senior Independent Study	Var.

General Education		Units
xx-xxx	Academic Elective	9
xx-xxx	Free Elective	9

Other Requirements

General education courses should be selected from other departments throughout the university. Students are strongly advised to select a balanced set of general education electives-in addition to Interpretation and Argument, Global Histories and Introduction to Psychology - from three broad areas of study: arts and humanities, social and behavioral sciences, and natural sciences and engineering, including mathematics. While free electives may include studio courses in other departments, academic electives are non-studio (lecture) courses in other departments. Specific recommendations (and general requirements) for electives in all of these areas are available from advisors in the School of Design. The School places strong emphasis on the value of general education for personal growth as well as professional development. General education electives allow a student to obtain a minor in another department or program, such as business, human-computer interaction, IDEATE, engineering, professional and technical writing, or architecture.

Students may enroll for no more than 18 units of independent study courses, and no more than one independent study per semester. A minimum 3.0 GPA is required for independent study. Independent study is permitted only in the third and fourth years of the program. Proposals for independent study courses must be developed jointly by the student and a faculty advisor. Guidelines are available from the School.

A minimum GPA of 2.0 is required to maintain Professional Program status. Grades lower than “C” in required Design courses will result in academic probation, suspension, or drop from the School of Design.

Full-time students are required to enroll for a minimum of 36 units per semester, with 45 units required for expected degree progress (typically five courses per semester). The minimum number of units required for graduation in Design is 360.

Academic Standards

The design curriculum adheres closely to the fundamental professional entry-level standards established by the two leading national design organizations: the American Institute of Graphic Arts (AIGA) and the Industrial Designers Society of America (IDSA).

Applications

The School of Design accepts applications from students who are completing secondary education or who wish to transfer from within Carnegie Mellon University. The School also accepts applications from students who wish to transfer from other institutions. Students applying for the program are asked to submit a digital portfolio as evidence of design ability. This is considered in balance with evidence of academic ability, based on secondary school grades, SAT scores, class rank, and letters of recommendation. The School also accepts applications for the design minors program for a limited number of spaces. Details are available on the Design website.

Faculty

ERIC ANDERSON, Associate Professor of Design – M.A., Ohio State University; Carnegie Mellon, 1998–

MARK BASKINGER, Associate Professor of Design – M.F.A., University of Illinois; Carnegie Mellon, 2003–

CHARLEE MAE BRODSKY, Professor of Photography – M.F.A., Yale University; Carnegie Mellon, 1978–

STUART CANDY, Associate Professor – Ph.D, University of Hawaii at Manoa; Carnegie Mellon, 2017–

JONATHAN CHAPMAN, Professor – Ph.D, University of Brighton; Carnegie Mellon, 2017–

WAYNE CHUNG, Associate Professor of Design – MID, University of the Arts; Carnegie Mellon, 2007–

DINA EL-ZANFALY, Assistant Professor – Ph.D, MIT; Carnegie Mellon, 2019–

BRUCE HANINGTON, Associate Professor of Design of Environmental and Industrial Design – Master of Environmental and Industrial Design, University of Calgary; Carnegie Mellon, 1998–

KRISTIN HUGHES, Associate Professor of Design – M.F.A., Virginia Commonwealth University; Carnegie Mellon, 2001–

DAN LOCKTON, Assistant Professor – Ph.D, Brunel University; Carnegie Mellon, 2016–

MARK MENTZER, Professor of Drawing – B.F.A., Carnegie Mellon University; Carnegie Mellon, 1975–

THOMAS L. MERRIMAN, Teaching Professor in Design – B.F.A., Carnegie Mellon University; Carnegie Mellon, 1985–

DAPHNE PETERS, Assistant Teaching Professor – MDes, Elisava, Escola Superior de Disseny; Carnegie Mellon, 2017–

STACIE ROHRBACH, Associate Professor of Design – MGD, North Carolina State University; Carnegie Mellon, 2003–

PETER SCUPELLI, Associate Professor – MDes & Ph.D, Carnegie Mellon; Carnegie Mellon, 2011–

STEPHEN J. STADELMEIER, Associate Professor of Design – M.S., Cornell University; Carnegie Mellon, 1977–

ANDREW TWIGG, Assistant Teaching Professor – B.A., Allegheny College; Carnegie Mellon, 2014–

DYLAN VITONE, Associate Professor – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2004–

BRETT YASKO, Assistant Teaching Professor – B.A., The American University, Washington D.C.; Carnegie Mellon, 2019–

MATT ZYWICA, Assistant Teaching Professor – B.F.A., University of Illinois; Carnegie Mellon, 2014–

Courtesy Appointments

JONATHAN CAGAN, George Tallman Ladd Professor of Mechanical Engineering – Ph.D., University of California Berkeley.;

SUGURU ISHIZAKI, Associate Professor of Rhetoric and Visual Design – Ph.D., Masssachusetts Institute of Technology; Carnegie Mellon, 2005–

DAVID S. KAUFER, Professor of English and Rhetoric – Ph.D., University of Wisconsin; Carnegie Mellon, 1980–

GOLAN LEVIN, Associate Professor of Art – M.S., Massachusetts Institute of Technology; Carnegie Mellon, 2004–

Special Faculty

JOSEPH M. BALLAY, IDSA, Professor of Design, Emeritus – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1970-2002–

DAN BOYARSKI, Professor of Design, Emeritus – M.F.A., Indiana University School for Design, Kunstgewerbeschule, Basel, Switzerland; Carnegie Mellon, 1982–

GIDEON KOSSOFF, Special Faculty – Ph.D, University of Dundee, Scotland; Carnegie Mellon, 2017–

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School of Design Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

51-101 Studio: Survey of Design
Fall: 10 units
Students will conduct activities that will help them notice design in the world, investigate how it works, and describe their thinking about design, through photography, video capture, sketching, note-taking and modeling. They will work through projects in various ways as a means of 'testing-out' and reflecting on command design approaches. This course is for undergraduate design majors only.

51-102 Design Lab
Spring: 10 units
Introduce concepts and methods to familiarize students with a range of analog and digital modes of working across products, communications, and environments. Students will use desktop modeling and comping methods to familiarize them with a range of basic materials to build confidence in using and manipulating material to represent ideas. This course is for freshman Design majors only.
Prerequisite: 51-101

51-103 Design Workshop I
Fall: 3 units
Design Workshop is a special course created for first year design students and serves as a supplement to primary studio and elective courses. In this course, students will explore design activities related to their core studio courses, receive special skills training, engage with guest lecturers, and attend field trips. Each class meets once per week.

51-104 Design Workshop II
Spring: 3 units
A recitation style course that is conducted in service of the primary design courses during the semester to provide further instruction or engage in activities that support themes and issues related to these other courses. May include work days for students to spend in studio with teaching assistants.

51-121 Visualizing
Fall: 10 units
This course introduces basic drawing and sketching techniques including figure-ground translation, 2 pt perspective construction, storyboarding for explanation, diagramming for clarification, field notation for recording through guided exercises, demonstrations, and short projects.

51-122 Collaborative Visualizing
Spring: 10 units
This course introduces frameworks of notational, exploratory and explanatory sketching using collaborative methods and exercises to cooperatively communicate design ideas. This course is for undergraduate design majors only.
Prerequisite: 51-121

51-132 Introduction to Photo Design
Spring: 10 units
Using a digital camera, students learn how to extend their 'seeing' with the camera, both in the world and in a shooting studio. Through shooting assignments student will understand how to: deconstruct image meaning and aesthetical choices, construction of photographic meaning and aesthetics, an understanding of color and how color delivers meaning, how a photographic studio works, proper digital photographic workflow and contemporary trends in photography. Intended for Design Majors, or permission of the instructor.
Prerequisite: 51-101

51-171 Placing
Fall: 10 units
This course will explore the context in which students study design. Using primarily photography, students compare where they are from to the bioregion of the Ohio Valley of Western Pennsylvania and the history of the steel town, Pittsburgh. Students also learn about the modern Western emergence of design as a profession and discipline, and map the edges of current design practice by interacting with local professionals.

51-172 Systems
Spring: 9 units
Explore how to understand complex phenomena by creating models of the interrelations between components. Students learn soft systems diagramming as well as the systems thinking associated with ecologies, integrative science and sociotechnical regimes. Students also learn how to see design as a way of making interventions into a leverage point in a system in order to transform how it functions elsewhere in the system.

51-173 Design Center: Human Experience in Design
Intermittent: 9 units
This course introduces the central themes of design and the design professions, and the human centered focus in all aspects of design thinking and practice. We will begin by exploring the nature of having an experience, followed by the broad philosophy of design in relationship to other areas of human activity, the sciences and the arts. We will explore design through its orders of activity: first in communication and second the creation of physical objects. But design has a far greater reach into the intangible and more complex areas of human activity: interaction, systems, environments, and culture. These are the topics of inquiry for design and, unlike what the patchwork of professions would have you believe, are not fixed by boundaries. Design is enormously broad and something everybody participates in as we create the artificial world in which we live. Those who call themselves designers have greater power in shaping this world and for that reason we will end the course with a discussion of ethics. Non-Design majors are welcome.

51-201 CD Studio I: Communicating with Type
Fall: 9 units
As the first studio course in the communication design program, students explore fundamental principles of typography, where type is regarded as image, serving a range of communication goals. Projects allow students to explore form and meaning, hierarchy, legibility and readability, structure and composition, with and without images, in print and on screen. Learning to design across media, in static and dynamic formats, is critical for communication designers, as well as becoming proficient with software tools. The co-required 51-203 Computer Lab will focus on learning software relevant to projects being worked on in studio. While typography is a focused branch of communication design, this introduction to the subject opens a path for students to study all facets of communication in subsequent courses. Providing context to the subject, the course covers basic typography history, relevant typographers and their work, and technologies that have shaped typography. A guided visit to the Hunt Library's Rare Book Room provides added context. This course is for undergraduate Communication Design majors only, or permission of instructor for non-majors.
Prerequisite: 51-102

51-202 CD Studio II: Organizing Information
Spring: 9 units
In this course students participate in a range of exercises, projects, discussions, and readings that are geared towards deepening their understanding of communication design and improving their skills. Course activities require students to consider and propose ways to inform, convince, question, and engage their audiences by clarifying and organizing information. Students deconstruct existing pieces of communication design, studying how their composition, type and image usage, and hierarchy reflects the content being communicated and the order in which it is read. Working in print and digital media, students study the similarities and differences among mediums and explore methods for effectively communicating information in each area. Students analyze design examples from the perspective of the maker and the receiver(s). This facilitates discussions that focus on the role of the designer in the communication of information (Should a designer's voice be evident?) and the need for user-centered design solutions. This course is for undergraduate Communication Design majors only.
Prerequisite: 51-201

51-203 Communication Design Computer Lab
Fall: 3 units
This sophomore-level Communication Design lab introduces students to various software that designers use when creating communication pieces. Software is introduced in support of project work in 51201 CD Sudio 1, providing students with best practices that help them work efficiently and effectively. Software includes InDesign, Illustrator, and AfterEffects. CD majors only, or permission of the instructor.

51-208 Research Methods
Spring: 4.5 units
Learn how to select, conduct, and develop appropriate research methods for understanding and discovering contextual information and behaviors of human participants.

51-211 Generation of Form: Industrial Design I
Fall: 9 units
Generation of Form is the first studio for students in the industrial design program. Students explore product aesthetics and basic formal issues as they pertain to industrial design. This course integrates the principles of three dimensional design, drawing and prototyping as they apply to the generation of product form. Emphasis is placed on issues that dictate the form of products and their creation. Students develop basic prototyping, conceptual drawing, and presentation skills for the purpose of exploring, analyzing, refining and communicating design concepts. Required of ID students; lab fee. Due to space constraints, this course is only offered to undergraduate Industrial Design majors.
Prerequisite: 51-101

51-212 ID Studio II: Meaning of Form
Spring: 9 units
This studio course introduces students to the functional and expressive meaning of product form through creative exploration and decision-making in design. Functional product attributes include those that guide intuitive, safe, and comfortable use; expressive attributes include aesthetic, cultural, and contextual variables. Students are exposed to various methods of conceptual sketching, prototyping, and documentation to realize and communicate ideas in a process that anticipates human interpretation and response to design. Lab fee applies. This course is restricted to undergraduate Industrial Design majors only.
Prerequisite: 51-211

51-215 Making Short Films
Intermittent: 3 units
The objective of this course is to provide students with a practical, technical and theoretical foundation in video work. Students leaving this class will have gained knowledge of developing a moving picture from start to finish. Students will learn storyboard, plan, production, and post-production video. Equally importantly students will start to develop their own visual aesthetics in the creation of 1 short moving pictures. The primary software for this course is Adobe Photoshop, with which students will explore construction, combination, manipulation, input, and output of video as a means of narrative creation. This Micro course will run between 5-6 weeks. The instructor will fly into Doha for a short period of face-to-face classes, centered around a Saturday. Enrolled students should expect two 90-minute face-to-face classes during the week before or after this Saturday date, as well as four 90-minute evening (6-7:30 pm) video classes over the duration of the Micro course (typically two before the campus visit, and two after, although instructors can change this). Specific dates will be confirmed in the syllabus closer to fall semester.

51-221 Color for Communications, Products, Environments
Fall: 9 units
This course will explore the fundamentals of color through the implementation of various media as they apply to their use in communication and expression in design. While this course does not deal with color theory per se we will spend time on the causes and effects of color interaction, color contrasts, color harmonies and color strategies for the effective use of color in our visual design work. We will use both nature and man made constructs to discuss how color affects what we see and its effect on our visual world. Short exercises and longer- term projects will be the vehicles of our explorations. This course is for Sophomore Design Majors.
Prerequisite: 51-122

51-222 Decoding Place
Spring: 9 units
This course will explore ways to decode, see, think and interpret the visual language of 'place'. Through the intersection of found symbols, signs, images and color we will bring to light the function and purpose of our surroundings, and how they speak to natural and the built environment. During the course we will investigate the following question; How do we design visual systems which are understood by everyone, regardless of their language or culture but also work in harmony with natural systems? Students will work with traditional materials and tools as well as computers to understand the strengths and limitations of each, comparing their similarities and differences in the context of theoretical and applied projects. This course is for Communication Design majors only, or by permission of the instructor.
Prerequisites: 51-201 or 51-211

51-223 Color for Communications & Products
All Semesters: 9 units
This course will explore the fundamentals of color through the implementation of various media as they apply to their use in communication and expression in design. While this course does not deal with color theory per se we will spend time on the causes and effects of color interaction, color contrasts, color harmonies and color strategies for the effective use of color in our design work. We will use both nature and man made constructs to discuss how color affects what we see and its effect on our visual world. Short exercises and longer- term projects will be the vehicles of our explorations. This course is for Sophomore Design Majors.

51-224 CD: Web Design
Spring: 9 units
This class will introduce the basics of designing and building websites, the fundamentals of HTML5 and CSS3, and responsive design approaches to assist students in creating semantically sound web pages that can be viewed across a variety of platforms, devices and browsers. The class will help students understand the constraints and advantages of working with the web as compared to traditional print media. Students will also be exposed to content management systems and topics such as responsive web design, research, and information architecture. Upon completion, students will be capable of designing, creating, launching and managing their own web sites. Your own laptop is required, with the following software installed: Adobe CS 5 or later. This course is for Communication Design Majors only.
Prerequisite: 51-201

51-225 Communications Studio I: Understanding Form & Context
Fall: 4.5 units
Giving form to messages and information using type, color, and images will be the focus of this introductory studio in Communication Design. Understanding the connection between content, intent, and form will be the goal of every project and exercise. Principles of hierarchy, chunking, sequence, clarity, and visual voice will guide work for the screen and the printed page, in dynamic and static forms.
Prerequisite: 51-122

51-227 Prototyping Lab I: Communications
Fall: 4.5 units
Learn the basics of the CS suite, particularly InDesign (style sheets), Illustrator, and Photoshop; learn basics of HTML 5.0; the learning of software ideally will align with the activities conducted in the Communications Studio. This is a requirement for Design sophomores studying Communications.

51-228 Communications Studio II: Designing Communications for Interactions
Spring: 9 units
This design studio focuses on designing communications for interactions. Through projects that vary in scale and complexity, students explore ways of inciting interaction and providing feedback in print and digital mediums to recognize the dynamic attributes of communication design. Communication structuresboth traditional and emergentserve as the backbone of the course, as they provide opportunities for students to seek and discover patterns in communication design conventions and apply what they learn to their own work to illicit specific types of interaction. Course projects specifically emphasize the importance of narrative structures to communication design. They prompt students to sketch, diagram, and visually weave together layers of information as a means of moving audiences through a sequence of dense content. This process helps students investigate narrative structures as frameworks that shape interactions with communications and impact audience experiences. The course concludes with an introduction to systems design, where students explore designing for interactions across a set of communication pieces. Prerequisite course includes Communications Studio I.
Prerequisite: 51-225

51-229 Digital Photographic Imaging
Fall: 9 units
The objective of this course is to provide students with a practical, technical and theoretical foundation in digital imaging. The primary software for this course is Adobe Photoshop, with which students will explore construction, combination, manipulation, input, and output of image as a means of narrative creation. Through project critique and other discussion, we will also consider the aesthetic and political implications of the emergence of this and other new electronic imaging technologies.

51-231 Calligraphy I
All Semesters: 9 units
Working with pure unadorned Roman letterforms, this course introduces students to the theory and practice of hand-generated letters, employing a variety of mark-making tools. This course provides an in-depth understanding of the basic principles and techniques of the art of formal writing. Rhythm, texture and composition are achieved through routine, elementary exercises using geometric forms, demanding concentration and manual discipline with the development of hand-eye coordination. The function, use, and harmonious sequencing of letterforms is taught through weekly projects. Awareness of rhythm, texture and letterform structure is achieved through routine exercises. Drills, demonstrations, discussions, individual and class critiques are on-going. Additional related topics and activities introduced in class include books: binding and design. A brief introduction to the historical development of our Western alphabet is provided through film, slides, demonstrations, with discussion of twentieth-century type designs. Students also gain exposure to letter vocabulary, paleography, monoprints, words and punctuation, classical page design, publication design-past and present, and calligraphy's role in design today. Thinking with hands and eyes, the manual placement and spacing of letters practiced in this course awakens sensitivity and judgment in the designer.

51-232 Calligraphy II
All Semesters: 9 units
This course serves as a continuation and deeper investigation of topics explored in Calligraphy I, where students tackle advanced problems in calligraphy and lettering. The introduction of new hands is to be decided by the student and instructor. Prerequisites: 51231
Prerequisite: 51-231

51-236 Information Design
Fall and Spring: 9 units
This studio course focuses on teaching a basic visual design process from ethnographic research through ideation to finished artifact. Students will work individually and in teams to gain proficiency in applying specific design techniques to information design challenges. Students will attend lectures to gain new perspectives, engage in projects to learn through making, conduct readings to balance theory and practice, participate in critiques to verbalize their views and consider alternate perspectives, join in discussions to develop shared understanding, give presentations to communicate their thinking, and complete tutorials and learn software for additional insight.

51-239 Prototyping Lab II: Communications
Spring: 9 units
Program simple websites as a means of learning basic HTML 5.0 and CSS; prepare documents for digital and print production using Adobe InDesign, Illustrator, Acrobat
Prerequisite: 51-227

51-241 How People Work
Fall: 9 units
51241 How People Work: Human Factors (ID/CD Lab I) This course is a general introduction to the field of human-centered design and applied human factors. It centers on the understanding of physical, cognitive, and emotional human needs and desires, including methods employed to acquire this information and translate it into useful criteria for the design and evaluation of products. Lecture, discussion, lab exercises, and projects are employed. Required of all sophomore design students. Others admitted by permission of instructor only.

51-242 How Things Work: Mechanics and Electronics
Intermittent: 9 units
This course investigates the basic principles of mechanics and electronics. Through the combination of lectures, investigations, and lab experiments, students develop simplified representations of complex systems. The skills of freehand drawing, mechanical drawing and three-dimensional models are employed and developed during the project sequence. Instructor permission required for non-Design majors.

51-243 Prototyping
Fall: 4.5 units
A half-semester laboratory mini-course introducing a range of materials, methods, and workshop techniques by which designers prototype designs in three dimensions. Basic competence in shop techniques is established by bringing to realization a series of simple artifacts. Studio and model shop tools are required; lab fee. This course is for ID majors only.

51-245 Products Studio I: Understanding Form & Context
Fall: 4.5 units
Learn basic design processes for understanding the scope of the project, brainstorming, defining the problem, and how interactions aid in developing solutions in relation to a human and user centered activities.
Prerequisite: 51-102

51-246 Visual Communication Fundamentals
Spring: 4.5 units
Design elements are powerful tools for reaching your audience. The objective of this course is to help you understand how to use the fundamental visual tools of communication in your work, and to learn how to evaluate visual communication pieces you encounter in everyday life. Examples of design elements that we will explore are: type, color, format, images, text, pacing and sequencing. We will learn how to use these together to successfully communicate a portfolio of documented design work. This course is required for all ID sophomores.
Prerequisite: 51-211

51-247 Prototyping Lab I: Products
Fall: 4.5 units
Work in various 2D and 3D mediums to represent ideas and solutions; introduce students to digital fabrication methods and output; utilize Adobe CS suite - Illustrator, Photoshop, InDesign to communicate 2D representations.

51-248 Products Studio II: Designing Products for Interactions
Spring: 9 units
Introduce student to 3D semantics, how form communicates meaning, and how to make meaningful objects through appropriate material choices and mechanical manipulation; utilize a range and combination of analog and digital tools for higher fidelity output.
Prerequisite: 51-245

51-249 Prototyping Lab II: Products
Spring: 9 units
Introduce students to high fidelity modeling techniques through a series of machines, processes, and or methods to simulate desired form, scale, and proportions
Prerequisite: 51-247

51-251 Digital Prototyping
Fall: 4.5 units
A half-semester laboratory mini-course introducing 3D modeling software. Each class meeting consists of an introduction to and demonstration of specific aspects and functions of SolidWorks software. At the end of each class session, work related to the covered topic(s) will be assigned for completion by the next class meeting. This course is a requirement for all ID majors. Instructor permission required for non-ID majors. Corequisites: 51-211

51-257 Introduction to Computing for Creative Practices
Intermittent: 10 units
This course is an introduction to Java programming for designers, architects, artists and other visual thinkers, using the popular "Processing" Java toolkit for interactive graphics. Intended for students with little or no prior programming experience, the course uses interaction and visualization as a gateway for learning the traditional programming constructs and the fundamental algorithms typically found in a first course in programming. Students will become familiar with essential programming concepts (types, variables, control, user input, arrays, files, and objects) through the development of interactive games, information visualizations, and computationally-generated forms. Because of limited space, only Design majors may take this course. Students following an IDEATE concentration or minor should register for 15-104.

51-261 Design Center: Communication Design Fundmntls: IxD for Communications
Fall: 9 units
A one-semester course that introduces non-majors to the field of communication design. Through studio projects, lectures, and demonstrations, students become familiar with the visual and verbal language of communication designers, the design process, and the communicative value of word and image. Macintosh proficiency required. This course is required for HCI double majors and Design minors. Section W - Qatar campus only

51-262 Design Center: CD Fundamentals: Design for Interactions for Communications
Spring: 9 units
A one-semester course that introduces non-majors to the field of communication design. Through studio projects, lectures, and demonstrations, students become familiar with the visual and verbal language of communication designers, the design process, and the communicative value of word and image. Macintosh proficiency required.

51-264 Design Center: Product Design Fundamentals: Design for Interactions for Products
Spring: 9 units
In this one-semester studio-like course non-majors are introduced to product design from the product designer's point of view. Through studio projects, lectures, and discussions, students will learn approaches to defining and visualizing product concepts for mass production. Case histories and the analysis of existing products will supplement hands-on experience in developing product concepts. This course is required for all Design minors.

51-265 Environments Studio I: Understanding Form & Context
Fall: 4.5 units
Learn the basic design processes for experience-driven multi-modal environments, making meaningful physical and virtual experiences through planning, structuring, and explaining/visualizing; utilize a range and combination of analog and digital tools for high fidelity output.
Prerequisite: 51-102

51-267 Prototyping Lab I: Environments
Fall: 4.5 units
Learn methods for designing interactions in environments through experiencing the space, low-fi prototyping, rapid making, 3D CAD software and video sketching. Express multi-modal aspects of integrated physical-digital-hybrid environments.

51-268 Environments Studio II: Designing Environments for Interaction
Spring: 9 units
Introduce students to the concept of resonant environments that provide meaningful physical and virtual experiences; utilize a range and combination of analog and digital tools for high fidelity output.
Prerequisite: 51-265

51-269 Prototyping Lab II: Environments
Spring: 9 units
Explore simple reactive and interactive programming as a means to support virtual and hybrid digital/physical environments.
Prerequisite: 51-267

51-271 How People Work
Fall: 9 units
Introduction to human-centered principles of design, including physical, cognitive, and emotional human factors. Capacities and limitations of people affected by design are learned through the study of known principles and user research. The course is delivered through a series of combined lectures, readings, hands-on lab activities, and a team project applying human-centered field research methods and design.

51-272 Cultures
Spring: 4.5 units
Explore the sociotechnical aspects of the many identity based differences between people. These differences may be not only cultural, but also related to gender, age, class, race etc. The course will survey critical theories that are useful for understanding how difference both constructs, and is constructed, by systems, practices and things. Students will also explore different frameworks and strategies for exploring questions of difference, and to think critically around the ethical and political implications for design interventions.

51-278 Design Center: Product Service Ecologies for Artificial Intelligence
Intermittent: 9 units
While the history of AI research is as old as computing, there is little history of successful AI products entering society through entrepreneurship. The social experience of AI is typically the byproduct of large research investments while new startups struggle to compete with limited budgets or consumer insight. This is in part because AI companies have consistently focused on the technology ¿ the nature of AI as a product, or the integration of that product into society. Yet as a user centered design to AI is also insufficient, given the complexity of AI technologies in future economies, communities, and the work place. To develop new and viable AI technologies that enter society through entrepreneurship, are new business models and design methods needed? How can designers shape organizations, products, and markets through new combinations of AI? To explore these questions, this course explores the history and future of AI through the lens of design and entrepreneurship. In-class projects and assignments will provide the opportunity for students to pioneer new conceptions of AI. Students will additionally gain direct exposure to advanced technology startups though guest lectures and joint ventures.

51-301 CD III: Type, Form, Meaning and Context
Fall: 9 units
This course develops advanced skills in typography and communication design, including the study of type and motion. Students learn to conceptualize and visualize more complex bodies of information for a variety of communicative purposes. Projects encourage students to develop a deeper understanding of the expressive potential of type and image and to develop critical and creative thinking skills with which to assess the effectiveness of their own work and that of their peers. Course objectives are to encourage an active exchange of ideas and information which allow students to develop the ability to clearly articulate their ideas and thought processes in relation to their work. This leads to a more focused method for developing and expressing ideas effectively. Instructor permission required for non-CD majors. Prerequisites: 51202
Prerequisite: 51-202

51-302 CD Studio IV: Designing with Systems
Spring: 9 units
This course is the final studio in a sequence of communication design courses for Design majors. It builds on skills and knowledge acquired in the prior three studios. The course focuses on creating a system of designed pieces using large amounts of content, either self-generated or found, in print and digital platforms, at varying levels of scale. The differences and similarities between existing and emerging platforms of delivery provide students opportunities to investigate the future direction of communication design. Data-driven methods are utilized as a means of research and communication. Projects are situated in social contexts, where student study design systems using type, sound, and images. This course is required of Communication Design majors in the School of Design. Prerequisite courses include Type III, Type II, and Type I.
Prerequisite: 51-301

51-311 Product Design ID III
Fall: 9 units
Students participate in a range of exercises, projects, discussions, and readings that are geared towards deepening their understanding of product design. The activities they engage in will require them to understand and consider the user as the key motivator for new and intelligent concepts that address identified problems/needs. To assist them, systematic processes will be introduced (or built upon) to guide inquiry, ideation, conceptual development, and presentation of products that are useful, usable, desirable, and more feasible than their work to date.
Prerequisite: 51-212

51-312 Products in Systems: ID IV
Spring: 9 units
This course introduces the themes of product planning and the development of products within systems and as systems. The projects are broad in scope and require students to develop products that reflect an understanding of the entire development cycle. Tools and skills for the studio and model shop are required; lab fee. Instructor permission required for non-ID majors.
Prerequisite: 51-311

51-319 Digital Photography in the Real World
Intermittent: 4.5 units
DIGITAL PHOTOGRAPHY IN THE REAL WORLD Photographers are active observers. They look until they see what they want others to see -then they compose and click the shutter. In this course students will walk streets with their cameras. They will learn how to use their cameras to better understand what they believe is important, beautiful, and/or intriguing in the world. They will also learn how to communicate their imagery to others through screen-based and print output. Assignments range from accurately describing reality, to showing aspects of life that should be improved, to making images for purely aesthetic reasons. There are two main goals to this course: learning the fundamentals of operating a digital camera and producing digital output; and, learning to become better 'seers' in the world. Students must own a camera but no prior photographic experience is necessary.

51-321 Design Center: Photographic Narrative
Intermittent: 9 units
Most photographs tell stories. We see photographs in newspapers, magazines, snapshot albums, on the web, in books, and in posters. In these contexts photographs often work with words to convey meaning, whether they are shown with captions, news stories, or just with titles. Photographs can work without words, too, to create purely visual narratives. In this course, students will make a photo narrative and determine how it will be seen. Students may make photo books, for example, or decide that their images will be seen digitally on screen. While students are making photographs, we will explore the rich traditions of photographic story-telling that range from the world-oriented work of photo-journalist W. Eugene Smith to the documentarians such as Walker Evans, Nicholas Nixon, and Alec Soth. We will look at photographers, too, who construct fictional worlds, such as Duane Michals, Cindy Sherman, and Gregory Crewdson. As students make their own narratives, we will look at the interplay between words and photographic images; how images are paced and scaled to create rhythm; how photographs are sequenced to tell stories; and other formal elements involved in creating visual narratives. 12-15 students. Prerequisite-a college level photography course.

51-322 Advanced Digital Imaging
Intermittent: 4.5 units
Building on the technical skills and methods of communicating narrative learned in Digital Imaging Advanced Digital Imaging takes communication to the next level of resolution with particular concern in artifact creation. Students explore historical and groundbreaking means of content delivery.

51-323 Communications Studio III: Designing for Complex Communication Systems
Fall: 9 units
Gain a greater understanding of how to craft communications that resonate with specific people by researching topics/audiences/contexts, by developing/iterating/testing concepts, and by investigating deeply the nuances of typographic form/image/sequencing of interactions; learn how to craft graphic form to express ideas that are not dependent on the reading of words themselves; continue to develop communication systems
Prerequisites: 51-228 and 51-225

51-324 Basic 3D Prototyping
Spring: 4.5 units
A half-semester laboratory mini-course introducing a range of materials, methods, and workshop techniques by which designers prototype designs in three dimensions. Basic competence in shop techniques is established by bringing to realization a series of simple artifacts. Studio and model shop tools are required; lab fee. Instructor permission required for non-Design majors.

51-326 Photography & Family
Intermittent: 9 units
Picturing Families at Sojourner's House In this course we will partner with Sojourner's House to tell photo-based stories of the residents. Sojourner's House (SH), located in East Liberty, is a home for women and families who have faced obstacles of addiction and homelessness. Those at SH have lived through hard times. The women, some of whom are mothers, are now 'clean and sober' but before they came to SH, they were addicts who lived strained lives. As a class we will be working with women and families who now are creating positive change in their lives through Sojourner's House supportive environment. Students, working in pairs, will team with individuals or families. Through weekly sessions, students will explore how the camera can be used to tell a range of different stories, which may range from a traditional photo documentary, to a narrative that is 'directed' by a student with photographs made by Sojourner's House residents. Students may work with children to show their day-to-day life; they may work with an individual woman to tell the story of her dreams; or they may choose to work with staff at Sojourner's House to explore why someone goes into this line of work, to name a range of examples. Students will learn how to sensitively work with people who have experienced extreme difficulty while they are learning about addiction through readings and first hand accounts. While they are getting to know their subjects, students will explore the various ways to create an in-depth photo narrative. Most important, students will learn how the camera can be used to create connections and trust between people. Prerequisite: A college level photography course 12 students - sophomores to grads Familiarity with digital photography

51-327 Design Center: Introduction to Web Design
Fall: 9 units
This class will introduce the basics of designing and building websites, the fundamentals of HTML5 and CSS3, and responsive design approaches to assist students in creating semantically sound web pages that can be viewed across a variety of platforms, devices and browsers. The class will help students understand the constraints and advantages of working with the web, with this course focused on technically pragmatic solutions for making websites. Students will also be exposed to content management systems and topics such as responsive web design, research, and information architecture. Upon completion, students will be capable of designing, creating, launching and managing their own web sites. Your own laptop is required, with the following software installed: Adobe CS6 or later, as well as other open-sourced software. This course is for Design Majors only, or by special permission of the instructor.

51-328 Advanced Web Design
Intermittent: 9 units
Advanced Web Design builds off of the fundamentals of Introduction to Web Design to make students more sophisticated web designers. Focusing on furthering skills beyond basic HTML5 and CSS3 and responsive design approaches, this course will also delve more deeply into web research and strategy; content development; hierarchy; design thinking; search engine optimization; and introduce students to the basics of PHP and javascript. Students will also gain a basic understanding of databases, work with content management systems, and design and develop for divergent platforms such as phones, tablets, and desktop computers. With an interdisciplinary, team-based approach, students will develop advanced websites while mastering HTML5 and CSS3, looking at what is viable for implementation today as well as looking forward at what technology is reasonable in the near future of web design. Your own laptop is required, with the following software installed: Adobe CS6 or later, as well as other open-sourced software. Students are required to be competent with building responsive web pages to take this course.
Prerequisites: 51-327 or 51-239

51-330 Communications Studio IV: Designing Communications for Social Systems
Spring: 9 units
As the final course in a sequence of studio courses for Communication Design majors, this one builds on everything learned previously. Apply skills/knowledge learned in researching, developing, evaluating, refining communications to multi-facetted communication challenges that warrant the design of multiple communication pieces that span diverse mediums (in print and digital platforms) and function as a system; learn how to design for futuring (parts of the system yet to be determined) and for co-design where parts of the system are made for growth through contributions from audiences. This course is required of Communication Design majors in the School of Design.

51-331 Advanced Calligraphy I
All Semesters: 9 units
This course serves a continuation of study in the discipline of calligraphy. (It meets at the same time as Calligraphy I.) Students may take one of two directions in the course. (1) Enlarging their repertoire of scripts, contemporary or traditional, for use in limited areas of work such as book or display work, or (2) Concentrating on more intensive problem solving using a limited repertoire of scripts such as Roman, Italic, Sans Serif. Prerequisites: 51232
Prerequisite: 51-232

51-332 Advanced Calligraphy II
All Semesters: 9 units
This course serves a continuation of study in the discipline of calligraphy. (It meets at the same time as Calligraphy II.) Students are encouraged to tackle advanced problems or work with the instructor to determine new directions of study. Prerequisites: 51331
Prerequisite: 51-331

51-334 Photography, Community & Change
Intermittent: 9 units
In this course we will partner with Sojourner?s House to tell photo-based stories of the residents. Sojourner?s House (SH), located in East Liberty, is a home for women and families who have faced obstacles of addiction and homelessness. Those at SH have lived through hard times. The women, some of whom are mothers, are now ?clean and sober? but before they came to SH, they were addicts who lived strained lives. As a class we will be working with women and families who now are creating positive change in their lives through Sojourner?s House supportive environment. Students, working in pairs, will team with individuals or families. Through weekly sessions with SH residents, students will explore how the camera can be used to tell a range of different stories, which may range from a traditional photo documentary, to a narrative that is ?directed? by a student with photographs made by Sojourner?s House residents. In all cases, the residents at SH are going through significant change in their lives and we will see how the camera can be used to support individuals during a time of growth. Students will learn how to sensitively work with people who have experienced extreme difficulty while they are learning about addiction through readings and first hand accounts. While they are getting to know their subjects, students will explore the various ways to create an in-depth photo narrative. Most important, students will learn how the camera can be used to create connections and trust between people. Prerequisite: A college level photography course 15 students ? sophomores to grads Familiarity with digital photography

51-335 Mapping and Diagraming
Fall: 9 units
This course explores the different ways in which we communicate complex information, through maps and diagrams. Students will design maps and diagrams using subject matter of their choice. Instructor permission required for non-Design majors.

51-336 The Non-Selfie
Intermittent: 9 units
The Non-Selfie: using the camera to record, probe, and understand one's own and another's behavior This course is the opposite of the selfie, but it uses the camera to record human behavior, both your own and another's. Designers need to be good human observers in order to design for human needs. Designers also need empathy. This course aims to deepen sensitivity to others by first better understanding ourselves. Informed by Manfred Max-Neef's classification of fundamental needs and other relevant materials, we will create two in-depth photo-essays, the first being a study of ourselves, the second being a study of someone who is unfamiliar to us. In the first half of this course, while looking at the tradition of self-portraiture in photography and other media, we will be making in-depth photographic stories of ourselves. In addition to photographs, we may make scans of objects, include personal artifacts and anything else that may contribute to building an in-depth self-portrait. In the second part of the semester, we will apply what we learned to a person who we do not know, in hopes of bringing new insights and methods to understanding for another. In addition, we will look at the rich literature that exists in documentary photography about representing "the other." By the end of the semester, each student's work will be made into a hand-made Japanese stab book of two volumes: a volume on oneself, and one on another. The skills learned in this course are immediately relevant to becoming a good designer. Digital camera is necessary, and knowledge of camera operation, Photoshop and InDesign is helpful.

51-337 Letterpress in a Digital World
Intermittent: 9 units
What value does the antiquated process of letterpress printing have in our current digital world? What can we learn from the process that was used as the primary form of reproducing the printed word for nearly 500 years? As designers and artists, we have the opportunity to re-examine an obsolete mode of commercial printing, and explore how these techniques and technologies can add to our experience, expand our repertoire, and invigorate our working process. Our goal in this course is to seek out new opportunities in expression, resulting from the harmonious merger of new and old technologies. Intended for design juniors and seniors

51-338 Documentary Photography
Intermittent: 4.5 units
Documentary Photography: the Social and Built Landscape Documentary photography explores issues, often social, humanistic and/or political, in man-made culture. This course examines the work of nineteenth, twentieth, and twenty-first century documentarians while students photographically investigate their own topics. Among the many ethical areas of a documentarian's concern, the course examines (through looking at the documentary tradition and through the student's own work) the following: the photographer's relationship to the subject; the choices involved in representing the subject; the act of selectivity in framing the subject; the reasons for making documentary photographs; the intended audience for documentary photography; and the appropriate final display of the photographs? Extensive shooting, printing, and library research. Prerequisite: A beginning photography course, or by the permission of the instructor.

51-341 How Things are Made
Fall: 9 units
This course will provide a breadth of knowledge for current manufacturing, materials, and processes encountered in the industrial design field. There will be an emphasis on actual production/manufacture methods and not rapid prototyping methods. The class will consist of various lectures, media, electronic tools, and on-site visits to enable an understanding of how mass production affects design and design decisions. Industrial Design Juniors & Seniors or permission of the instructor.

51-343 Products Studio III: Designing for Complex Products Systems
Fall: 9 units
Provide a framework for understanding core practices of the product design profession by placing it in relation to other disciplines and their influences on mass manufacture of goods; students will use a design process to identify problem/s, map a process in which tangible artifacts are made to learn more about the interaction between object, person, space, and context
Prerequisites: 51-245 and 51-248

51-344 Advanced Digital Prototyping
Spring: 6 units
This course is an advanced course using SolidWorks computer modeling. It is a prerequisite for Production Prototyping.

51-345 Pragmatics of Color for Non-CD Majors
Intermittent: 9 units
Pragmatics of Color for non-CD majors Throughout the course, we will explore the application of color and its' use through many different medium, products and environments. We will use a variety of source materials like pigment, colored paper, and photography. These exercises will help us to explore how the different medium affect color perception. Because color is extremely dynamic and interactive, a good deal of emphasis will be placed on your ability to iterate many variations so that comparison becomes the point of discussion and learning. Equally important, is increasing your sensitivity to the nuances of color through direct observation and experimentation. The class exercises are distinctly different in nature from one to the next; they are organized in order to build upon each other. Prerequisites: you must own a digital camera and have previous experience with Photoshop and Illustrator.

51-346 Production Prototyping
Spring: 6 units
This course is the 2nd half of Advanced Digital Prototyping, using your work in SolidWorks to produce hard models.

51-347 Drawing from Nature
Intermittent: 4.5 units
Drawing From Nature This course is about observing and making images of things growing, crawling, flying, swimming etc. Observations will be made firsthand in the field, supported with relevant research in topic areas with the aim of deepening personal understanding of all things biological. Issue surrounding natural forms such as behavior, locomotion, adaptation, the environment and systems will also be investigated. We will work in tandem on refining our abilities in communicating what we discover through the process of drawing. A variety of visualization methods will be covered i.e. analytical drawing, visual notes, and diagramming to name a few. We will be using a variety of basic drawing and digital media to develop our work as we uncover aspects of form, structure and surface. Guest speakers will present work they have done in areas such as botany, biology, and environmental studies to name a few. A majority of the work will be done in the field and will then be developed in the studio. A final project will be assigned that will challenge you to develop a concept along with a compelling form(s) that communicates what you have uncovered about nature to a variety of audiences. This course builds on your experiences from First Year drawing and introduces several more advanced visualization methods. This course is intended for Junior and Senior Design Majors.

51-349 Visual Notation/Journaling
Intermittent: 9 units
Visual notation is the graphic equivalent of taking written notes. While the camera is a valuable and at times indispensible tool for recording what we see, the camera cannot make visible mental concepts. Nor can it discover and display underlying structures, create hierarchies, explain organizational schema or concepts that are not easily seen or understood. This course is about making visual notes in order to become fluent in your abilities to observe, record and interperate. Through daily entries in a journal you will work in several content areas i.e. mapping, natural and built environments and systems to name a few. A good portion of the work in this class will be conducted in the field using the resources available to us such as the museum, zoo and architectural sites. You will also be challenged to incorporate your notes as tools for communicating design concepts, implementing project development and presentations. The course will rely on the use of a variety of simple drawing tools and electronic media. Several visualization methods will be introduced and the work will build on the drawing experiences from First Year drawing. This course is intended for Junior and Senior Design Majors.

51-350 Products Studio IV: Designing Products for Social Systems
Spring: 9 units
Challenge students to build their own design and research process to identify and frame the scale and scope of a problem/opportunity, and place it in relation to the wider system (environment, social, cultural contexts); projects will require synthesizing a range of inputs to develop proposals for future working and living.

51-352 Cardboard Modeling II: Exploring expressive product behavior
Intermittent: 6 units
State-of-the-art interactive products express themselves through their screens. This behavior is mostly ?digital? in nature. In the human-computer interaction community there are many examples of interaction-styles that offer a more physical/tangible experience. In order to design products that offer such experiences new skills and tools are necessary: not only do we need to explore aspects of expressive form and interaction; we also need to explore expressive (physical) product behavior with an emphasis on sensing and actuating. While there are tools such as arduino, phidgets or gadgeteer available to do this there is little integration with the simultaneous exploration of form. This course aims to offer this integration. This course is open to Industrial Design juniors, seniors and grads ? others by permission of the instructor. Cardboard Modeling I is a prerequisite, unless approved by the instructor. Materials and tools need to be acquired in advance, a list will be provided; LAB FEE

51-355 Experimental Sketching
Intermittent: 4.5 units
Experimental Forms of Sketching fall 2011 Advancing design drawing philosophy and application This 7 week mini course seeks to expand our experiences with interpreting forms of drawing quality within the process of sketching. This approach will explore semantics of rendering with mixed media, sensitivity of representational perspective, form building, and sequence evolution, within drawing developments that stimulate emotional connections with a viewer. Through exploring and testing variables, we will use the nature of drawing behavior processes to expand the interpretive significance of abstract idea forms. These "drawing idea forms" will be represented throughout a range of abstract levels from literal to highly figurative. Interpretations will derive from a variety of themes involving design, life, and nature and expressed on paper as objects, scenes, and story persuasions.

51-357 Stuff That's Optional: People at Play
Intermittent: 9 units
Stuff that's optional: People at play Unlike our necessary work that provides sustenance for self and dependants, our recreation is optional and chosen. Products that support recreation are, likewise, an option. Soccer balls, kayaks, daypacks, fly reels, chess sets, running shoes; for that matter, the entire recreational industry is based on election. Our lives are better off for it; play is good for us. In this studio/ project course we will investigate play as an aspect of human endeavor. There are readings, discussions, and sessions aimed at gaining an understanding of the field. We will then respond by searching out and framing design opportunities, ideate and propose, refine and test. We will make stuff as teams and individuals that help us further define what it means to be humans at play. This course is intended for Junior and Senior Design Majors.

51-359 Tools for UX Design
Intermittent: 9 units
The course intent is to develop appropriate user experience of tools and technology for a projected time frame or context of use. The need to understand people's stories, their lives, and how they want to live determines what interfaces, products, and systems should be developed. Student teams will work together to create appropriate user interactions and experiences which are supported by the design of tools and/or technology. This integrated course will utilize rapid prototyping as the basis for the creation of these proposed tools and products. This course is intended for junior, senior, graduate level students, Non-Disclosure Agreement and other legal agreements may be part of the requirements. Proficiency in one or more of these visualization methods: freehand sketching, computer visualization in 2D graphics, motion graphics and/or 3D solid or surface modeling. By Instructor Approval if NOT in Design. Please forward statement of intent to Instructor.

51-360 Environments Studio IV: Designing Environments for Social Systems
Spring: 9 units
Develop high fidelity proposals and demonstrations of multi-modal hybridized physical-digital environments based on rich information content and principles of user experience design.

51-362 Environmental Typography
Intermittent: 9 units
This course will explore typographic systems in the three-dimensional environment. We will begin by discussing theories, concepts, and strategies related to scale, space, hierarchy and graphics. We will then consider movement, time, materiality, and what we are being told by the type in our environments. Through formal and spatial analytic processes, in both individual and team projects, students will build typographic systems for complex 3D applications.

51-363 Environments Studio III: Designing for Complex Environment Systems
Fall: 9 units
Provide a framework and tools for designing for environments using experience design methods as a means to address the plurality of digital/ physical hybrid environments
Prerequisites: 51-265 and 51-268

51-364 Drawing Spaces
Intermittent: 4.5 units
The natural and built environment will comprise the subjects of inquiry in this course. We will investigate systems of spatial and physical organization as found in the landscape in various forms and structures from forest to farm and from tent to tenement as examples. The intersection of these systems found in accessible locals will be investigated in the field through on site drawings using simple media and sketchbooks. These studies will then form the basis for the iteration of more developed images depicting environments both existing and imagined. Some time will be spent on observing people and various life forms as they populate and interact within these spaces to various ends.

51-365 Information & Space
Intermittent: 9 units
In this course, we will take computational approaches to explore information design in space. Students will consider the interactivity and readability of information when creating data-driven systems. They will learn Javascript programming and use P5.js for their interactive systems. There will be three projects: 1) Speech-responsive Kiosk; 2) Immersive Space using Projection; and 3) Data Visualization using Holo Lens. There is no prerequisite for this course, but basic understanding of typography and information design is expected.

51-366 Designing with Community
Intermittent: 9 units
This course will utilize social innovation principles and practices while striving to bring sustainable solutions to a grassroots community space through a series of integrated strategies. The initiative strives to build new types of services and social enterprises by addressing the unmet basic needs of residents. We aim to do that by focusing on the intersection of food, community health, and education. Students will examine Social Design case studies, with a focus on Problem Reframing processes (Dorst), and Solution Amplification (Manzini), and various design-enabled Theories of Change. For the project students will move the vision for Latham St. Commons forward through social experimentation and listening to the needs of an array of people within the neighborhoods of Garfield and Friendship. This type of active participation with the community will help students see the challenges of the community from an insiders point of view, in order for them to design appropriate responses to some of those challenges.

51-367 Design Center: Computational Design Thinking
Intermittent: 9 units
This course explores computational concepts, methods, and ideas in the context of design. Students will take computational approaches in design process by building their own programmes that generate a variety of solutions. This course encourages exploratory studies of artifacts and playful experiments through self-driven projects. Basic understanding of creative coding and visual communication is expected. Students will use Javascript (p5.js, and Basil.js) for two projects on algorithmic drawing and generative publication. Preference will be given to junior and senior Design students.

51-368 Moving Pictures
Intermittent: 9 units
The objective of this course is to provide students with a practical, technical and theoretical foundation in video work. Students leaving this class will have gained knowledge of developing a moving picture from start to finish. Students will learn how to storyboard/scamp, plan/scout, produce, and post-produce. Equally importantly students will develop their own visual esthetics through the creation of 4 short videos.

51-371 Futures I
Fall: 4.5 units
The Futures 1 course focuses on aligning near term design action with longer time horizons aimed at sustainable futures. We introduce the students to Dexign Futures. Dexign is defined as "an experimental type of design that integrates Futures Thinking with Design Thinking." A distinguishing feature of dexign in our usage is the focus on aligning current action with long-term sustainability goals. The course covers different approaches to interpreting the future: from the extrapolations of trend forecasting, through the risk assessments of scenario planning, to attempts to steering the present through backcasting. Students explore the future through utopian and dystopian fictions that are created by authors, filmmakers and themselves. Students also attempt to evaluate futures in terms of their longer-term consequences.

51-372 Persuasion
Spring: 9 units
Examine written argumentation, oral presentations, artifact exhibitions, but also branding and social media. Students learn how to position their design ideas and connect them to the people and organizations that will increase their perceived value to target audiences. A focus of the course is on argument by precedent, where students build the significance of their innovations by situating them historically.

51-373 Futures II
Intermittent: 4.5 units
Futures II is the second half of a semester-long deep dive into foresight for emerging designers, bringing students to the cutting edge of practice, to develop applied skills in Experiential Futures (including Design Fiction and Speculative/Critical Design). In brief, we will learn about possible future scenarios by making them. Futures II represents a confluence of approaches in worldbuilding, transmedia storytelling, and co-design, an advanced module in the School of Design's foresight thread that provides tools for shaping innovations, exploring strategies, and tackling wicked problems as 21st century creatives, entrepreneurs, and citizens.

51-374 Understanding Perception through Design
Intermittent: 9 units
Understanding Perception Through Design 51-374/51774 This course emphasizes audience expectations, also known as schemas, as a major influence on the artifacts we produce. For example, we read marble Corinthian columns as an entrance to a courthouse rather than to a home. The manner we use to communicate, either following or deviating from expectations, affects the way people perceive and process the information we present. Through lectures, discussions, readings, and projects, we will study the use of schemas in both print and digital mediums. We will also explore the bearing of expectations on the types of interactions and experiences we produce, answering the question: Can information become concrete and experiential versus abstract and readerly? Instructor permission required for non-Design majors.
Prerequisites: 51-301 or 51-311

51-375 Meaning in Images
Intermittent: 4.5 units
Images abound in our culture. This course takes a critical look at many different kinds of photographic images to understand how they operate in our culture to inform, persuade, and entertain various audiences. The content for this course will be generated from looking at, thinking about and discussing issues discovered while studying well-known to lesser-known images that range from photographs used in ad campaigns, to photographs that are used in scientific representation, to snapshots in family photo albums, to photographs that are used to show social injustices, to photographs that exist in museum collections. Readings will be assigned and short writing exercises will be required throughout the semester. In addition, photography assignments will be given. Design majors will have preference. Requirement: a digital camera. 15 students, junior and senior Design Majors.

51-376 Semantics & Aesthetics
Intermittent: 4.5 units
The course will explore the principles of visual composition, proportioning systems and the rules of order as it relates to art, architecture and design. The class will involve extensive reading and discussion of these topics in class. Some project work will also be required but minimal to the reading. A reading list will be provided. Instructor permission required for non-Design majors.

51-377 Design Center: Sensing Environments
Intermittent: 9 units
Whereas UX Design is typically described as shaping the immediate environment between a user and an object/interface, this course will instruct you in techniques, methods, and vocabularies to expand the scale of your design. Course content will give students experience integrating and shaping their current work into 2-3 other levels of scale, such as a single room, building, campus, and neighborhood. Students will walk away with an understanding of environments that will expand their range of capability, fitting for interdisciplinary application within fields such as social innovation, community development, public policy, architecture, and urban design.

51-378 Developing Form with Sketches & Models
Intermittent: 4.5 units
Development of Form with Models & Sketches

51-379 Information+Interaction+Perception
Intermittent: 9 units
As a society, we're inundated with enormous amounts of dense information on a daily basis. In fact, many of us have grown so accustom to the abundance of information in our lives that we expect and need it to be accessible virtually anywhere and anytime. Technological advancements, which seem to develop at lightning speed, continuously provide us with tools that make it easy for us to access information quickly. However, little is being done to aid people's understanding of information that is increasing in complexity. Why? Our addiction to accessible and thorough information has caused many of us to turn a blind eye to the perceptual problems associated with its speedy delivery. In this course we will investigate contemporary visualizations of information and the bearing of their forms on the quality of communication. We will also study how peoples' perception of content, interaction with others, belief systems, and mental and physical well being can be affected by the visual communication of information. Thus, although we CAN represent information various ways we will ask how SHOULD it be designed to aid people's understanding of it. Your explorations will take the form of analyses of existing artifacts; class discussions and exercises; short, relevant readings that originate in various disciplines such as cognitive science, architecture, learning science, and design; and corresponding projects that enable you to illustrate what you're learning.

51-380 Experiential Media Design
Intermittent: 9 units
Experiential Media Design focuses on the theory, methodology and history behind the design, development and interpretation of experiential media systems. The class incorporates a multidisciplinary approach to the study of complex media systems as technological, political, economic, socio-cultural and personal experiences. Topics covered include media and communications theory, cultural studies, qualitative and quantitative methodology, design principles, human-computer-interaction, information visualization and representation, user studies and evaluation. Students will create and critique a variety of integrated media systems demonstrating technical competence, aesthetic knowledge, analytic rigor and theoretical relevance. This class is open to Junior & Senior Design Majors, and others by permission of the instructor.

51-382 Design for Social Innovation
Spring: 9 units
Design for social innovation is a seminar that traces the history and application of design methods to solving social problems. The course will weaver together themes from readings in design, business, public policy, technology, social service, international relations and current events. The course will review examples of successful and failed social innovations from local, regional, national and international contexts. Students will learn the role of governments, technology, funding, infrastructure, mindset, emotion, and cultural factors in addressing problems in the social sector. The course will include a real-world problem-solving component where students (in teams or individually) will write a paper, design an artifact or intervention, propose a project or conduct a short design research study that addresses a real-world problem that impacts a local community.

51-383 Topics: Conceptual Models
Intermittent: 9 units
As design problems become more complex, conceptual modeling becomes critical in design process, especially when designing for the abstract concepts such as interaction, experience, service, and systems. Creating conceptual models are often an important step for making the creative leap from user research findings to design implications, which is one of the core challenges in design process. Conceptual models are also effective tool to bring in shared understanding for different stakeholders in teams with multidisciplinary team members, user-participants, and clients. Moreover, these conceptual models often directly lead to final information products to support users to learn how to use complex systems. Conceptual Models is a full semester course that provides students with the opportunity to explore theories related to conceptual models and to improve skills in using them as a means of design. Being primarily developed for graduate and undergraduate students in Design, this course consists of two parts. The seminar part of the course will provide students with readings, examples, and in-class discussions to help them understand the nature of conceptual models. The project part of the course will provide an opportunity to apply these theories to actual projects. Students will work in individuals and teams to create conceptual models for different needs and goals in design process.

51-384 Design Center: Co-Designing for Social Innovation
Intermittent: 4.5 units
This course is for students considering how their work can contribute to a positive societal shift. Through a mix of lecture, readings, classroom activities and short field assignments, the course covers models of change, and methods, approaches, and skills that support the emergence of new social patterns. Such work necessarily involves diverse stakeholders, the complexity of human relationships and beliefs, and the challenges of power, conflict, exclusion and inequity. For that reason, this course helps students make first steps in preparing to facilitate creative change among diverse stakeholders¿attending to the conditions for generative dialogue, listening to all voices, and hosting the long process of co-creation.

51-385 Design for Service
Intermittent: 9 units
We all have an idea of what a good service is — when everything clicks into place, when you feel a little surprised and delighted because of the thoughtfulness and smoothness. And we know what it's like when a service goes wrong — missed flight connections leading to sleeping on an airport floor, sitting for too long in a doctor's waiting room, a website or app acting tone deaf in a sensitive situation. So what does it take to get a service right? And how can our services best communicate and reflect their interactions with us when they're integrating different streams of data? We will explore the fundamentals of service design in this lecture/studio class. In the first part of the class, we'll begin with a set of modules on tools and practices of service design. Then, you'll put them to use in a group project, in which you design and prototype a service. Our goals (and the objectives of this class) will be to learn service design fundamentals by hypothesizing, experimenting, building, testing our assumptions, sometimes failing, tweaking, and improving. Some great visitors will join us too, in person and virtually, to provide real-world insights about service design.

51-387 Introduction to DeXign Futures
Intermittent: 9 units
As corporations, governmental organizations, and civil associations face accelerating change in uncertain times, increasingly they are looking to designers for new ways of thinking and acting. Designers today are engaged as thought leaders, strategists, activists, and agents of change in complex socio-technical problems throughout private, public, civil and philanthropic sectors worldwide. For designers trained to shape futures defined by uncertainty and change, these exponential times represent unprecedented creative opportunities for innovation. In this course, students learn the basic design skills necessary explore the forces that drive change in the future and learn to align innovation strategically with the trajectories of those forces.

51-388 Sharing Economies
Intermittent: 9 units
This topic course explores the nature and practice of sharing. The course is s a survey of cultural theories about why and how we do and don't share and the difference design can make to systems of sharing. It explores philosophies and anthropologies of sharing, distinguishing sharing from giving, lending and exchanging. It interrogates psychologies and histories of ownership, and notions of privacy. The course also explores the range of new systems that promote sharing in the contexts of the new sociality enabled by the social media and cosmopolitan urban living. It investigates the role of politics, such as concerns about ecological sustainability, and the role of perceived autonomy and convenience. By the end of the course, you will have a more comprehensive understanding of what facilitates and constrains sharing, and so be in a better position to design systems that promote increased resource productivity. Open to Sophomore - Graduate from across the university - no prior design capacities necessary, though they will help.

51-390 Social Interaction Design in Community
Intermittent: 9 units
The course looks at Design for Social Innovation principles and practices, Documentary Photography, and Design Research while walking the streets, talking to residents, and working with organizations in a Pittsburgh neighborhood to understand its challenges. Students will examine Social Design case studies, with a focus on Problem Reframing processes (Dorst), and Solution Amplification (Manzini), and various design-enabled Theories of Change. They will also explore histories and theories of Documentary Photography. For the project/ethnographic portion of the class, students will work in teams of two within a neighborhood, and partner with residents and organizations. These collaborations will help students see the challenges of the community from an insiders point of view, in order for them to design appropriate responses to some of those challenges.

51-392 Images and Communication
Intermittent: 4.5 units
No one doubts the value of photography as a means of recording life. Even if we don't think of ourselves as photographers, digital cameras make it easy to photograph our families, our trips, and aspects of our life that we want to remember. But beyond snapshots, can photography also teach us how to see? And how do they teach us about the world? And, what are the qualities inherent in photographs that make them effective as artifacts of communication? Does looking through the camera's viewfinder sensitize us to world and help us see more? Or, as some writers suggest, does the camera interfere with experiencing the world fully. This course explores seeing with the camera and the many issues that arise when one snaps the shutter. We will be looking at a range of different kinds of photographic images, understanding their contexts, and how to read them. Designers and other visual people use photographs extensively in their work. This course endeavors to make students more aware of their decisions and actions when making photographs as well as how to judge a photograph's effectiveness. The issues that we discuss using photographs, relate to other kinds of visual images, as well. We will be making photographs as we are discussing critical issues in photography that come out of readings. Students must own a digital camera but no prior photographic experience is necessary.

51-393 Object Lessons: Design History at the Museum
Intermittent: 4.5 units
This course will use Carnegie Museum of Art's collection to explore the history of three-dimensional design from ca. 1850 to the present (with an emphasis on major designs and designers of the 20th century). In small workshops and gallery sessions with the museum's curator of decorative arts and design, students will engage in close looking, formal analysis, and interpretation of iconic objects. Students will also learn about curatorial practice including cataloguing and acquiring objects and exhibition planning.

51-396 Design Center: Design Ethos & Action
Intermittent: 9 units
Increasingly, designers have the potential to operate as agents of change in a broad range of areas including corporate, government, non-profit, social innovation start-ups, and sustainability projects. With so much choice on the horizon, some designers may wonder, What value do I bring to the world through design? Values often are implicit and may vary across contexts (e.g., profit, efficiency, effectiveness, fairness, social impact, environmental impact). This course focuses on exploring and identifying the potential for positive and negative impact that design can have in the world around us. For example, how might a designer embed values related to sustainability, gender equality, or race relations into his or her design projects and design practice?

51-399 Junior Independent Study
All Semesters
Guidelines for independent study in the Design office. Proposals must be approved by faculty before registration.

51-400 Transition Design
All Semesters: 9 units
Transition Design: Designing for Systems-Level Change. This course will provide an overview of the emerging field of Transition Design, which proposes societal transitions toward more sustainable futures. The idea of intentional (designed) societal transitions has become a global meme and involves an understanding of the complex dynamics of whole systems which form the context for many of todays wicked problems (climate change, loss of biodiversity, pollution, growing gap between rich/poor, etc.).Through a mix of lecture, readings, classroom activities and projects, students will be introduced to the emerging Transition Design process which focuses on framing problems in large, spatio-temporal contexts, resolving conflict among stakeholder groups and facilitating the co-creation of desirable, long-term futures. This course will prepare students for work in transdisciplinary teams to address large, societal problems that require a deep understanding of the anatomy and dynamics of complex systems.

51-401 Senior Design Lab
Fall: 12 units
The Fall semester senior year focuses on design agility and helping students develop new ways of addressing the complexity of design problems. Through a series of three independent labs, students explore three kinds of designerly behaviors - wondering, playing, and speaking. These behaviors are not methods to be learned; they are ways of being agile as a designer that frees and empowers you to be both creative and responsive to the situations in which you are working. These labs serve as the requisite precursor to the Spring capstone project. This course is reserved for senior Design majors only.

51-403 Independent Senior Project n
Fall: 12 units
The senior year offers Design majors the opportunity to explore a variety of advanced topics through project-oriented courses. These project courses typically require an integration of skills and knowledge gained throughout the entire design program. Senior projects are often funded by outside companies or organizations, providing real world clients. This project highlights the role that visual interface designers play in the multi-disciplinary attempt to bridge the gap between functionality and usability and to introduce students to some of the unique challenges of designing within the realm of a digital, interactive medium.

51-404 Senior Project
Spring: 12 units
The senior year offers Design majors the opportunity to explore a variety of advanced topics through project-oriented courses. These project courses typically require an integration of skills and knowledge gained throughout the entire design program. Senior projects are sometimes funded by outside companies or community organizations, providing real world experiences.

51-405 Senior Project: Communication Design
Fall: 12 units
The senior year offers Design majors the opportunity to explore a variety of advanced topics through project-oriented courses. These project courses typically require an integration of skills and knowledge gained throughout the entire design program. Senior projects are often funded by outside companies or organizations, providing real world clients. This project varies from one semester to the next, providing various opportunities in areas such as exhibit design, branding, and web design.

51-406 Senior Project II
Spring: 12 units
The senior year offers Design majors the opportunity to explore a variety of advanced topics through project-oriented courses. These project courses typically require an integration of skills and knowledge gained throughout the entire design program. Senior projects are often funded by outside companies or organizations, providing real world clients.

51-407 Senior Project: Social Impact by Design
Fall: 12 units
The senior year offers Design majors the opportunity to explore a variety of advanced topics through project-oriented courses. These project courses typically require an integration of skills and knowledge gained throughout the entire design program. Senior projects are often funded by outside companies or organizations, providing real world clients. This project focuses on new product development.

51-414 Senior Project III (IPD)
Spring: 12 units
This course provides an integrated perspective on the many processes by which new products are designed, manufactured, and marketed. Under the direction of faculty from Design, Engineering, and Industrial Administration, students will work together in interdisciplinary groups on the development of real products. In addition to the product development project, the course includes lectures on innovation strategy, opportunity identification, designing products, object representation and manufacturability rules, computer-assisted design and prototyping, concept testing and protocol analysis, redesign issues, market testing, manufacturing and production, and product introduction and management. Open to graduate and senior-level engineering students, industrial administration students, and design students.

51-421 Design Center: Data Visualization
Intermittent: 9 units
This is a comprehensive data visualization primer. In Data Visualization course students will learn how to parse and visualize data. Starting with multiple introductory exercises on the foundations of data viz, we will then investigate tools, principles and best practice by which computational design driven data visualizations are operating today. Then, students will decide on a data set of their choice (necessary complexity given), to either create a data visualization with an emphasis on telling a story, or to generate a meaningful data art piece with an emphasis on engagement and experience. Project outcomes can be expressed through a variety of forms of the students choosing, from print posters, websites to mind-bending interactive experiences. These will be documented and presented on the final crit. This course assumes that students are already familiar with elementary programming (in any language), such as for() loops, if() statements, arrays[] and functions(). Participants will use Javascript and very likely popular creative coding toolkits like p5.js, Basil.js, Snap.svg, GSAP, D3.js etc. for their projects.

Course Website: http://bit.ly/CMUDataViz

51-422 Interaction Design Studio
Spring: 9 units
Intended for HCI double majors, this is the spring offering of 51-421 Introduction to visual interface design. This course highlights the role that visual interface designers play in the multi-disciplinary attempt to bridge the gap between functionality and usability and to introduce students to some of the unique challenges of designing within the realm of a digital, interactive medium.

51-423 Pieces 2.0: Social Innovation: Desis Lab
Intermittent: 9 units
In this class, students will identify a social problem and take a holistic design approach to solving it. They will design a product/product line-anything from a set of tools to help older adults lead a more active lifestyle, to re-envisioned collateral for the Lupus Foundation Pennsylvania. After or in tandem with the creation of this product, the student will construct an image, which will entail print media, a Web presence, packaging, and photography. By creating the product and its "marketing" effort from top-to-bottom, the student will gain a diverse set of skills in design as well as a richer understanding of the product. In the end, all the pieces will come together to create a well-refined image.

51-424 Web Portfolio
Intermittent: 4.5 units
This course will provide an opportunity for students to design and code their online portfolio. The course covers basic elements of Web design along with the foundations of HTML, CSS, Javascript and Flash as components of the design process. Prior experience with HTML is encouraged but tutorials will be provided if necessary. This is not an Actionscript programming course.

51-425 Design Center: Beginning Book Arts Lab
Fall and Spring: 6 units
Beginning Book Arts Lab Class. 6units. (This class is a prerequisite for the Advanced Book Arts Workshop Lab Class). This is a class of basic issues regarding hand bookbinding and letterpress printing. It's purpose is to develop a basic structural sense of book forms, of flat format work and of three dimensional forms. Learning hand craft techniques, developing hand skills and the sensitivity to materials are also a goal. Binding projects assigned will target the unique nature of papers, fabrics and archival card-boards. Structural procedures and techniques will be identified with each assigned binding project. The binding projects will be: A hardcover for a paper back book, a single signature book, a multi-signature book with flat spine, and a box construction. The box project is designed and crafted to contain a small letterpress printed class edition, either in book form, or as a set of un-bound pages. The letterpress component teaches the standard issues, unique to the relief process, in press work, handset procedure of cast metal type, page form spacing, lock-up of pages in press, proofing, and production printing. Each semester a small class edition project of text content and image, in two-color registration, is designed, hand set and printed. Image generation can be by hand cut block, assembled type-high forms, or digital process to polymer plate. This class is not to be repeated.

51-426 Beginning Book Arts Lab
Spring: 6 units
Beginning Book Arts Lab Class. 6units. (This class is a prerequisite for the Advanced Book Arts Workshop Lab Class). This is a class of basic issues regarding hand bookbinding and letterpress printing. It's purpose is to develop a basic structural sense of book forms, of flat format work and of three dimensional forms. Learning hand craft techniques, developing hand skills and the sensitivity to materials are also a goal. Binding projects assigned will target the unique nature of papers, fabrics and archival card-boards. Structural procedures and techniques will be identified with each assigned binding project. The binding projects will be: A hardcover for a paper back book, a single signature book, a multi-signature book with flat spine, and a box construction. The box project is designed and crafted to contain a small letterpress printed class edition, either in book form, or as a set of un-bound pages. The letterpress component teaches the standard issues, unique to the relief process, in press work, handset procedure of cast metal type, page form spacing, lock-up of pages in press, proofing, and production printing. Each semester a small class edition project of text content and image, in two-color registration, is designed, hand set and printed. Image generation can be by hand cut block, assembled type-high forms, or digital process to polymer plate. This class is not to be repeated.

51-427 Advanced Book Arts Workshop
Intermittent: 9 units
Students will be required to plan and design projects that relate to binding, or digital printing, or letterpress printing, or hand-setting of cast metal type. Projects utilizing a combination of all processes can be planned as well. Experimental work, or Artists' Books are also encouraged. In this class structure students will be able to plan and design projects that are complete books, with printed content, or with out content. Other flat structures, and three dimensional containers are examples of general forms that will be categorized as binding work. Students who wish to enroll in this course must have already taken Beginning Book Arts, and must also speak to the instructor directly about project ideas. Emphasis for binding is working independently with a greater level of hand craft and a sensitivity to materials. Emphasis for letterpress printing is to learn in depth, and master, the general mechanical process for doing press work. Emphasis for hand typesetting is on gaining an understanding of the system of cast metal type, and to develop a sensitivity to typographic principles. Instruction will be given on an individual basis through consultation at strategic times throughout the semester. Project evaluation will be based on the success of the project work compared to each student's written project proposal at the start of the semester. The Advanced Workshop in Book Arts can be repeated. For more complex project work this class can be continued for the following semester.
Prerequisites: 51-425 or 51-426

51-428 Time, Motion and Communication
Intermittent: 9 units
This course focuses on designing and presenting time-based messages on screen. The differences between paper-based and screen-based communication are discussed and become departure points for projects. Working with word, image, sound, and motion — in Adobe AfterEffects — students develop responses to a variety of project briefs. Brief histories of animation, experimental films, and title sequences, as well as experimental music provide conceptual models to our discussions. An attitude of exploration is stressed, with an emphasis on visual voice, performance, and communication. Content will include personal messages and timely information. Proficiency with AfterEffects is a firm requirement. Preference will be given to junior and senior Design students.

51-431 Revealing Place
Intermittent: 9 units
Revealing Place is a documentary photography class where students will use their cameras to explore a group, idea, and/or location and tell its story. Students will use photography as a way to engage community, document social phenomenon, and define what's happening at that moment in the history of their chosen setting.

51-434 Experimental Form
Intermittent: 9 units
The Experimental Form Studio looks broadly at the discipline of industrial design with an emphasis on creating new paradigms for interactive objects. This course encourages an exploratory study of physical objects and artifacts and provides a creative and intellectual forum to re-imagine our relationship with objects. Each independently-themed project presents opportunities to consider embedded mechanics & technology, objects as interactive media, and experience-driven design. Experimental Form, at its most basic, is a process that blends play and inquiry in an open-ended way finding the unexpected through tinkering and trying something you don't quite know how to do, guided by imagination and curiosity. In this sense, Experimental Form complements the core ID Studio sequence by providing a playground for intellectual discourse, experimental trial and error, and refining individual processes for designing. This is your sandbox. Prerequisites: Junior standing in industrial design. Junior level communication design with instructor permission.
Prerequisites: 51-311 or 51-343 or 51-248

51-435 Presentation & Pitch Design
Intermittent: 4.5 units
Presentation & Pitch Design: The premise of the course is to provide design students with the fundamental tools to effectively present and pitch their designs. The foundation of the course is best explained by Dick Buchanan he states, "The designer, instead of simply making an object or thing, is actually creating a persuasive argument that comes to life whenever a user considers or uses a product as a means to some end." (Buchanan, R. 1985) I am looking to enter into a dialogue with undergraduate and graduate design students based on the notion of creating a "persuasive argument" to their design presentations. More importantly, I am looking to facilitate skill development using narratives as a medium for design students to present and pitch the intent of their designs based on five core principles. intentional positioning (empathize with your audience) restraint in preparation (concise structure) simplicity in design (visual congruence with design artifact) clarity in rhetoric (know your message) naturalness in delivery (be yourself) Upon completion of this class, students will have mastery in the Five Core Principles mentioned. They will be able to: Identify and cater to their audience's needs Empathize with their audience and adjust accordingly Craft a narrative that captures their design intention(s) Visually compliment their design in their presentation Clearly develop their message (pitch) Develop and present in their own style

51-439 Design for Service Studio
Intermittent: 9 units
Services constitute more than 79.2% of the US economy. The service sector has been increasing substantially while the commodities and manufacturing sectors have experienced a steep decline. Yet, service providers have historically under-utilized design in its business strategy and development. During this project course, intended to work in conjunction with Designing for Service Seminar, we will extend the idea of design as more than aesthetics and provide the opportunity for students to practice embodying its perspective and process, mapping design theory to project process. Students will spend the semester in teams, working with the Pittsburgh Post-Gazette to deeply understand their users and stakeholder's experiences, needs, and desires. We will explore the role of journalism and news in society, the volatile sector as a whole, and the challenges facing newspapers in America. The human-centered design approach will employ ethnographic research methods, allowing for teams to uncover insights and observations about patterns. Students will in turn learn to synthesize these findings into appropriate models, prototype concepts, and look for opportunities. The design solutions are intended to inform elements of the paper's competitiveness, creativity, development and future service innovations. The final deliverable will be refined solutions as illustrated in a presentation and process document.

51-441 Foundation of BME Design
Fall: 6 units
This course focuses on the Product Development scope and framing of a new medical device. Students will work together in an interdisciplinary team with Biomedical Engineering students to identify medical professional or patient needs through behavioral research and participatory research methods. This course deliverable requires the team to propose the problem space and develop a design brief and plan for the following Spring semester to implement. Prerequisite: Junior level design or higher with studio training. Solid modeling or surface modeling recommended.

51-442 BME Design Project
Spring: 9 units
This course is the second in sequence of prototyping and testing a proposed medical device product. The course consists of modules for the development of a project plan, background research, hazard analysis, setting product specifications based on user requirements, detailed design and analysis, prototype development and final documentation and presentation. All products developed will respond to the needs of appropriate market segments; resulting products will be deemed safe, effective, useful, usable and desirable by those segments. Students will produce a form model, functional prototype, marketing plan, and manufacturing plan of their product. Prerequisite: 51-441 (3 units, Fall) Foundations of Biomedical Engineering Design (or permission of the instructor). Junior level design or higher with studio training. Solid modeling or surface modeling recommended.

51-451 Fundamentals of Joinery & Furniture Design
Fall: 9 units
Intensive introduction to traditional joinery techniques and the properties of wood through the use of textbook studies and lab experiments. Emphasis placed on how these techniques and properties influence design decisions. Students will learn how to set up, sharpen and use traditional hand powered tools. This acquired knowledge will be applied in the design and realization of a piece of wooden furniture. Limited enrollment. Lab fee and material purchases required.

51-452 Furniture Design II
Spring: 9 units
A continuation of 51-451, this course explores a much broader range of issues related to furniture design. Students will identify and define in a proposal the area of furniture design they intend to investigate and then produce one or more furniture pieces developed from their findings. Materials and processes applied to the project are limited only by the resources the student can bring to bear. Assigned readings and a series of in-class discussions will focus on the influence of workmanship in design, and on how the behavior of the user is influenced by the form or esthetic language of the artifact. Lab fee & material purchases required. Prerequisite: 51-451

51-455 DeXign the Future: Human Centered Innovation for Exponential Times
Intermittent: 9 units
DEXIGN THE FUTURE: Human Centered Innovation for Exponential Times
As corporations, governmental organizations, and civil associations face accelerating change in uncertain times, increasingly they are looking to designers for new ways of thinking and acting. Designers today are engaged as thought leaders, strategists, activists, and agents of change in complex socio-technical problems throughout private, public, civil and philanthropic sectors worldwide. For designers trained to shape futures defined by uncertainty and change, these exponential times represent unprecedented creative opportunities for innovation. In this course, students explore methods and tools for design in exponential times to shape uncertain futures. Students will explore the forces that drive change in the future (i.e., social, economic, political, environmental, technological), and learn to align innovation strategically with the trajectories of those forces. The design project that drives everything else is the future of mega-metropolitan regions, the hubs of innovation where 70% of people in the world and 75% of Americans will live in 2050. In the semester long project, students create scenarios for Life 2050 in Metro 3.0, using Pittsburgh as a locus and focusing on a project within urban systems such as Sustainable Production & Consumption, Lifelong Learning, Human Development and Resilient Community.

51-471 Design Center: Imaginaries Lab: Research through Design
Fall: 9 units
The Imaginaries Lab is a research studio developing design methods to explore and support people's imagining¿both new ways to understand, and new ways to live, in an increasingly complex world. This course, running over three weekends, immerses you in a creative 'research through design' project, including prototyping and using experimental design methods 'in the wild', and in depth. You will learn and develop a variety of tools for conducting innovative forms of research through design, including exploring how people think, understand and imagine complex social and technological concepts, and envision futures, and depending on your expertise or interest, will be able to concentrate on applying particular skills as part of multidisciplinary teams. For example, a project might include speculative design, ethnographic inquiry, physical computing, and novel creative methods. We will aim to turn your work into a published output for a conference or journal, so there is additionally the opportunity to gain experience in this aspect of academic research.

Course Website: http://imaginari.es

51-478 Speculative Critical Design
Intermittent: 9 units
This praxis-based course will actively engage futures research through the integration of findings from critical readings, ethnographic research, mediated storytelling and hybrid prototyping. Using techniques of inversion, defamiliarization, uncertainty scenarios, everyday practice and good old-fashioned humor, we will create objects, systems and experiences that stimulate conversation, debate and understanding. The course seeks to produce a diversity of 'what will?' and 'what if?' cultural provocations that deeply examine possible, unwanted and seductive futures. This course is open to Junior and Senior Design majors, or by permission of the instructor.

51-479 Design for Improved Understanding of Health Information
Intermittent: 9 units
During the course students will use a design framework and proven methodologies to create health communications that aid low health literate individuals to better understand their role in the system of care, evaluate where, when and how to access care and communicate with peers and experts when they need help. Students will work closely with the Regional Health Literacy Coalition and various social institutions to insure relevance, context, and access.

51-480 Design Capstone Project: Service Design & Social Innovation
Spring: 12 units
Learn how to work independently, applying skills/knowledge in Products, Communications, Environments to the research/definition/development/testing of a project that focuses on the design of a service or social innovation that warrants investigation; deepen understanding of service & social innovation design principles and how they are put into practice.

51-481 Design Research Studio
Fall: 12 units
"Design Research Studio" represents a particular social frame for design inquiry in this course directed at future needs that are not clearly known. You will be required to use your traditional and contemporary design skills, and the method of Foresight, to conduct quality speculative thinking and gather meaningful insights from future users that lead to valuable design proposals. Truly addressing complex challenges requires expertise across many multidisciplinary domains of practice, therefore, the course work is team based. This is intended to provide you more of an interdisciplinary learning experience that allows, and requires, you to contribute, negotiate and collectively construct and present compelling well-reasoned arguments to the challenge given leveraging your disciplinary orientations to design - products, communications, environments (P,C,E).

51-483 Debating the Roles & Responsibilities of the Designer
Intermittent: 9 units
Designers are expected to play a role in creating aspirational lifestyles through products and services, and informing and influencing human behavior on small and large scales. However what impact does or should the designer have on our lives, our society, and culture? Through readings, discussions, and team activity, students will construct pro and con arguments and debate the role and responsibility of the designer in a critical and fun way.

51-485 Design Center: Imaginaries Lab: New Ways to Think
Intermittent: 4.5 units
In this course, we'll carry out 'research through design' projects using experimental investigative methods in the wild, focusing on new ways to think and understand in an increasingly complex world. Learn and develop a variety of tools for conducting innovative forms of research through design, focused on exploring how people think, understand and imagine complex social and technological concepts, and envision futures. By the end of the course students will have worked on an interdisciplinary research project, including with an external partner, drawing on a number of disciplinary domains, and have experience with different kinds of design research and practice, from speculative and critical design to participatory design, as well as developing the skills and experience necessary to innovate with, and deploy, those methods. This course is a complement to 51-487 Design Center: Imaginaries Lab: New Ways To Live, but is independent of it, and eitheror bothcourses can be taken without overlap (we will be doing different projects, with a different focus).

Course Website: http://imaginari.es/newways

51-486 Learner Experience Design
Intermittent: 9 units
This course focuses on designing experiences that engage people in educational activities that enhance their learning through meaningful, memorable, and enjoyable interactions with information. Throughout the course, students investigate the intersection of design thinking, UI/UX design, cognitive studies, social sciences, instructional design, and educational pedagogy as a way of developing knowledge and skills in designing experiences for learners. Students study topics that are often difficult to grasp and collaboratively build a taxonomy of content types based on common and differentiating characteristics to identify design opportunities. Through readings, projects, and class exercises, students explore how people perceive and process information, what motivates them to learn, and what constitutes an experience. The course introduces students to traditional and emergent learning tools and methods as a means of defining affordances and limitations of various learning approaches and mediums. It also provides students the opportunity to apply what they learn through the design, testing, and assessment of learning experiences that they create.

51-487 Design Center: Imaginaries Lab: New Ways to Live
Intermittent: 4.5 units
Focusing on new ways to live and experience the world, now and in the future, we'll do practical investigative 'research through design' projects using experimental methods in the wild. Learn and develop a variety of tools for conducting innovative forms of research through design, focused on exploring how people think, understand and imagine complex social and technological concepts, and envision futures. By the end of the course students will have worked on an interdisciplinary research project, including with an external partner, drawing on a number of disciplinary domains, and have experience with different kinds of design research and practice, from speculative and critical design to participatory design, as well as developing the skills and experience necessary to innovate with, and deploy, those methods. This course is a complement to 51-485 Design Center: Imaginaries Lab: New Ways To Think, but is independent of it, and eitheror bothcourses can be taken without overlap (we will be doing different projects, with a different focus).

Course Website: http://imaginari.es/newways

51-489 Design Center: Designing Narratives Across Media
Intermittent: 4.5 units
This studio mini will deal with designing at the intersection of three things: developing rich worlds, i.e. experiences and narratives, understanding how different mediums work and what they do, and understanding how genres work in terms of conventions around content and form. Students will thus be exposed to thought from various disciplines like media, genre, literary and cultural theory in order to create rich, interactive worlds as part of a single design studio project. Specifically, we will be analyzing and reflecting on the phenomenon of interactivity by studying how mediums like interactive print, film and cinema, tangible board/tabletop games, and installation art can be employed using the frame of "Other" futurisms (sinofuturism, afrofuturism, indofuturism etc.) that are part of the general practice of speculative and science fiction throughout the world. We will engage with popular and fringe cultural texts and artifacts, so students should be prepared to spend time watching movies, playing games, reading books etc. in an analytic, reflexive manner in order to better understand the different strategies that authors have developed in order to evoke specific responses in their audiences. In this class, you will bring the technical skills required - the object will be to collaborate with others with complementary skill-sets in order to create one lavish, intricate transmedial project that will draw people into the depth of its world. This is not an art class - we will discuss the designerly applications of this type of work, particularly with reference to design studies, speculative/critical design, ontological design, and decolonial design. The object of the course will be to make "other" ways of designing in the world visible and experiment with the boundaries of design as a practice of cultural production.

51-490 Design Capstone Project: Social Innovation
Spring: 12 units
Learn how to work independently, applying skills/knowledge in Products, Communications, Environments to the research/definition/development/testing of a project that focuses on the design of social innovation that warrants investigation; deepen understanding of social innovation design principles and how they are put into practice.

51-491 Design Research Studio: Designing for Social Innovation
Fall: 12 units
Learn how to work with a group of designers, applying skills/knowledge in Products, Communications, Environments to the research/definition/development/testing of a project that focuses on design of a social innovation that warrants investigation; gain an understanding of social innovation design principles and how they are put into practice; learn how to manage a semester-long project, preferably working with a local client.

51-499 Senior Independent Study
All Semesters
Guidelines for independent study are on the Design Intranet. Proposals must be approved by faculty before pre-registration.

51-667 Design Center: Computational Design Thinking
Fall and Spring: 12 units
This course explores computational concepts, methods, and ideas in the context of design. Students will take computational approaches in design process by building their own programmes that generate a variety of solutions. This course encourages exploratory studies of artifacts and playful experiments through self-driven projects. Basic understanding of creative coding and visual communication is expected. Students will use Javascript (p5.js, and Basil.js) for two projects on algorithmic drawing and generative publication. Preference will be given to junior and senior Design students.

51-880 Experiential Media Design
Intermittent: 12 units
Experiential Media Design focuses on the theory, methodology and history behind the design, development and interpretation of experiential media systems. The class incorporates a multidisciplinary approach to the study of complex media systems as technological, political, economic, socio-cultural and personal experiences. Topics covered include media and communications theory, cultural studies, qualitative and quantitative methodology, design principles, human-computer-interaction, information visualization and representation, user studies and evaluation. Students will create and critique a variety of integrated media systems demonstrating technical competence, aesthetic knowledge, analytic rigor and theoretical relevance

School of Drama

Peter Cooke, Head of School
Location: Purnell Center for the Arts, 221
www.drama.cmu.edu

The School of Drama at Carnegie Mellon University is the oldest drama program in the country. CMU Drama offers rigorous, world-class classical training in theater while providing thorough preparation for contemporary media.

As a member of the Consortium of Conservatory Theater Training Programs, the school chooses students to participate in the program based on their potential ability. Every Drama student is treated as a member of a theatrical organization and must acquire experience in all phases of the dramatic arts. Students are also asked to broaden their knowledge through courses in the other colleges of the university. The undergraduate Drama program, which incorporates approximately 200 students, leads to a Bachelor of Fine Arts in Drama. The options available are: Acting, Music Theater, Design, Production Technology and Management, Directing, Dramaturgy, and Theater Studies. The production of plays, a natural extension of demanding class work, is our lab, and constitutes one of the school's major activities. The choice of texts used is determined by the particular needs of current students. Each semester, 15 to 25 lab productions, directed by faculty, guest directors, and advanced students, are presented in our three theater spaces. The labs range from completely mounted, full-length dramatic and musical works to more simply produced directing projects and one-acts. The Drama program is rigorous and exacting, making demands on students that necessitate good health, a willingness to work and a commitment to professional discipline at all times. Because of full daytime class work and heavy production schedules, much production preparation takes place in the evening. Drama students, therefore, are advised to live in residence halls or in the immediate vicinity of the campus.

The information contained in this section is accurate as of July 31, 2019 and is subject to change. Please contact the School of Drama at drama-relations@andrew.cmu.edu with any questions.

Options in Drama

Acting Option

The Acting option is designed to prepare the student for immediate entry into the profession. It is a sequence-based training program with accumulative skills building upon each other over the course of four years. It is a conservatory training course, and the curriculum focuses primarily on the technique and craft of theater. At the same time it offers skills that are applicable to all media. Courses in acting, voice, speech, movement, and theater history are integral parts of the program at all four levels.

In addition to studio classes, Acting majors are required to take at least one liberal arts class each semester outside the school of drama to expand their intellectual curiosity and worldview.

All students must demonstrate a commitment to growth, show continued progress in their work and in the knowledge of their craft, and show a respect for professional standards in discipline, quality and ethics.

The freshman year is a discovery year and provides an introduction to basic skills-working from self, learning to play objectives and actions and the beginning of character exploration.

In the sophomore year these skills are solidified and deepened as more sophisticated, verbally complex material is introduced, through a focus on in-depth scene study, both contemporary and Shakespeare.

In the junior year students continue to develop their craft by investigating a variety of styles, including Greek, Brecht, and Restoration. Skills are now tested and strengthened through public performance.

The senior year provides a bridge from training to the professional world and offers the opportunity to appear on the School of Drama's main stage.

At the end of the senior year, students are introduced to the profession through Showcase performances in New York City and Los Angeles. The privilege to participate in Showcase is subject to the approval of the School of Drama faculty and as a rule is granted only to students who have obtained the necessary credits for graduation.

Music Theater Option

The students in the Music Theater program share the training philosophy and much of the same curriculum as others in the acting option. In addition, they take courses particular to the demands of Music Theater. These include private voice along with training in a variety of dance techniques (Ballet, Jazz, Tap and Broadway Styles) and music theater styles and skills.

Design Option

Design students are expected to develop artistic ability in the conception and execution of scene, lighting, sound and costume design for plays of all periods under varying theatrical conditions. Students may elect to have a focus on one or two areas but must have a solid background in all four. Freshmen in design receive instruction in drawing and painting, three-dimensional techniques, and in the application of basic design principles through courses in drawing and design. Sophomores learn to apply design principles to the theater through research, play analysis, and studies in the fundamentals of scene, lighting, sound and costume design. Design assignments cover various styles and periods and include the preparation of models, renderings, and working drawings, lighting storyboards, and light plots. Juniors and Seniors take specialized courses in two areas of stage design and are expected to head studio and main-stage production crews. As part of the degree work, juniors may design sets, lights, sound or costumes for a production in the Studio Theater and seniors may design sets, lights, sound or costumes for a Master's thesis show or a main-stage production. Designing for lab productions, both those that are highly resourced and those that are moderately resourced, requires a variety of creative approaches, preparing designers for a variety of real-world situations.

Directing Option

The John Wells Directing Program promotes creativity, intellectual curiosity, a broad and well-rounded understanding of the theater and leadership ability. It provides a detailed exploration of the technique of directing for stage and for camera. The curriculum is designed for those serious about the art of directing and intending to pursue a career in theater, film or television.

Course work in scene design, lighting and costume design develops the students' visual sophistication as well as an understanding of how these elements combine in practical production situations. Stage management skills are studied and practiced. Theater history, criticism, play-writing, play development and theater management classes introduce the student to the wide range of knowledge necessary for directing. There are many avenues open for practical application: scene work in class, a short film written and directed by the students, opportunities in multi-camera directing and a studio project. The broad scope of the directing curriculum encourages the director's interaction with all the theatrical disciplines. Collaboration in all forms, so necessary to the art, is the goal.

Production Technology and Management (PTM) Option

The Production Technology and Management program develops the technologists and managers of the future with an intensive curriculum designed to synthesize academic development and production experience. The curriculum focuses on the production requirements of live performance, in the form of traditional theatrical presentation, while also providing exposure to television, film and emerging technology-based art forms. Integrated in a world class research university environment, the School of Drama is uniquely positioned to contribute to the advancement of the collaborative arts. The goal of the PTM program is to prepare today's students to become tomorrow's leading professionals in the entertainment industry.

All undergraduate students begin with the development of visual and written communication skills. The first four semesters immerse the student in a range of collaborative and individual studies: scenery, costume, sound and lighting design fundamentals; dramatic structure and interpretation; manual and computer-based drafting; perspective and figure drawing, fundamentals of directing; production management and preparation, history of art and history of architecture and décor. The last four semesters focus in the student's analytical skills within their chosen area of concentration: technical direction or stage/production management.

Technical Directors are offered classes in: material applications, metal working techniques, structural design, scenic crafts, fabrication design and detailing, machinery design, rigging techniques, power system and electronic design fundamentals, introduction to sound design, automation system technology, technical management and production management. Technical Directors may take a single semester internship at an approved regional or commercial producing organization, in lieu of one semester of study. Student selected elective courses, outside the School of Drama, provide balance and breadth to the professional undergraduate education offered in the PTM program of study.

Stage Managers and Production Managers are offered classes in: stage management, production planning and scheduling, theater management, introduction to accounting, cash budgeting, producing for television and film, camera lab, computer applications, technical management, organizational behavior, principles of economics, business communications and production management workshop. Stage and Production Managers may take a single semester internship at an approved regional or commercial producing organization, in lieu of one semester of study. Student selected elective courses, outside the School of Drama, provide balance and breadth to the professional undergraduate education offered in the PTM program of study.

Dramaturgy Option

Dramaturgy is the number-one growth field in the entertainment industry. Dramaturgs are theater insiders who thrive on the process of being behind living theater events. They love reading, writing, and thinking and believe in the power of theater to enlighten, stimulate and entertain audiences. Through Carnegie Mellon University's new and innovative Dramaturgy Option you'll become an expert on historical practices and aesthetic theories behind any text, whether in production or waiting to come alive on stage. You will have the insights to reveal playwrights' intentions and the ability to communicate them to producers, directors, performers, and audiences.

The Dramaturg adapts traditional, historical, and classic texts for the modern stage; aids directors, designers, and performers in clarifying their insights; collaborates with artistic directors in choosing exceptional repertory; finds social relevance in every work; links audiences with the ideas behind the productions in program notes, lectures, and talk-backs.

You will receive rigorous, highly structured academic and artistic training; broad and deep historical research; intensive study of aesthetic and critical theories; practical, professional-level experience in full scale theater productions; opportunities to develop diversity by studying with Carnegie Mellon University professors in other arts as well as in the sciences and humanities; opportunities to study abroad; opportunities to work with professional companies in the US, Asia, Latin America, Africa, and Europe.

Your career possibilities include literary management; story editing for films and television; production dramaturgy; teaching: developing the talents and insights of students at educational institutions.

Theater Studies Option

The Theater Studies option offers students from any of the School's conservatory areas of specialized study the opportunity to continue developing their theater related skills while expanding their interests to other artistic and academic areas. This option will only be available to Drama students who have completed their sophomore year in the School of Drama (ie: two years of conservatory training). Students are required to write a proposal outlining their interests in the Theater Studies option, and the proposal must be approved by the Head of the School of Drama.

The goal of the Theater Studies option is to enable students to explore the diverse opportunities for which conservatory drama training can be a basis, and to examine the possibility of post graduate education in a new area of specialization after obtaining a BFA in Drama. As the intent of the Theater Studies option is to broaden your experiences, a semester studying abroad or participating in a recommended internship is required for one semester, either in the fall or spring. Individualized courses of study are established for each student in consultation with an appropriate faculty advisor.

Curriculum

The School of Drama curriculum is continuously reviewed and modified in an effort to provide the best conservatory experience for undergraduate students in the School of Drama. The following curriculum is subject to change. Not all requirements are listed, and units are often variable within each Option based on performances, production assignments, and individual projects.

Acting Option

Freshman Year

Fall		Units
54-011	Introduction to Alexander Technique	1
54-101	Acting I	10
54-103	Speech I	6
54-105	Voice for the Stage I	5
54-107	Movement I	4
54-110	Text for Actors	2
54-175	Conservatory Hour	1
54-177	Foundations of Drama I	6
99-101	Computing @ Carnegie Mellon (usually taken over the summer)	3
76-101	Interpretation and Argument	9
		47

Spring		Units
54-102	Acting I	10
54-104	Speech I	6
54-106	Voice for the Stage I	5
54-108	Movement I	4
54-176	Conservatory Hour	1
54-159	Production Practicum	6
xx-xxx	Non-Drama Elective	6
79-104	Global Histories	9
		47

Sophomore Year

Fall		Units
54-201	Acting II	12
54-203	Voice and Speech II	5
54-207	Movement II	5
54-211	Actor Dance II	3
54-281	Foundations of Drama II or H&SS Approved Elective *	6
xx-xxx	Non-Drama Elective	6
54-213	Singing for Actors II (Optional)	3
62-314	The Art of Personal Finance	6
54-159	Production Practicum (or in spring)	6
		52

Spring		Units
54-202	Acting II	12
54-204	Voice and Speech II	6
54-208	Movement II	3
54-212	Actor Dance II	3
54-242	Improvisation	2
xx-xxx	Non-Drama Elective	6
54-281	Foundations of Drama II or H&SS Approved Elective	6
54-214	Singing for Actors II (Optional)	3
54-159	Production Practicum (if not in fall)	6
		47

Junior Year

Fall		Units
54-301	Acting III	10
54-305	Voice for the Stage III	5
54-307	Movement III	5
54-309	Dialects and Accents	6
54-311	Rehearsal and Performance III	16

54-325	Actor Dance III	2
54-409	Theatre Lab for Undergraduates I	4
xx-xxx	Non-Drama Elective	6
54-317	Singing for Actors III (Optional)	2
54-327	Auditioning for the Stage (Optional)	2
		58

Spring		Units
54-302	Acting III	10
54-310	Dialects and Accents	6
54-306	Voice for the Stage III	5
54-308	Movement III	5
54-312	Rehearsal and Performance III	16
54-326	Actor Dance III	2
xx-xxx	Non-Drama Elective	6
54-318	Singing for Actors III (Optional)	2
54-335	Auditioning for the Screen (optional)	2
		54

Senior Year

Fall		Units
54-285	Alexander Technique (Optional)	1.5
54-381	Special Topics in Drama: History, Literature and Criticism	6
54-407	Movement IV	4
54-411	Rehearsal and Performance IV	16
54-413	Showcase	6
54-493	Business of Acting	3
54-519	Acting for the Camera	6
54-405	Digital Narratives	4
xx-xxx	Non-Drama Elective	6
54-403	Advanced Speech Techniques	3
		55.5

Spring		Units
54-285	Alexander Technique (Optional)	1.5
54-412	Rehearsal and Performance IV	16
54-414	Showcase	9
54-520	Acting for the Camera	6
54-438	Acting IV	3
xx-xxx	Non-Drama Elective	6-9
		41.5-44.5

NON-DRAMA ELECTIVES:

Actors take a minimum of seven Non-Drama Electives, 6-9 units each. The HSS and 62-314 are considered two of the seven electives.

Notes:

* Foundations of Drama II will be taken only one semester in the sophomore year. Sophomore Actors will be required to take an approved Humanities & Social Sciences (HSS) course in the Dietrich College during the semester they are not taking Foundations of Drama II. This H&SS course counts as one of the seven required Non-Drama Electives.

Music Theater Option

Freshman Year

Fall		Units
54-101	Acting I	10
54-103	Speech I	6
54-105	Voice for the Stage I	5
54-107	Movement I	4
54-110	Text for Actors	2
54-123	Ballet I	5
54-125	Music Skills I	4
54-175	Conservatory Hour	1
54-500	Voice Lab	5
99-101	Computing @ Carnegie Mellon (usually taken over the summer)	3
76-101	Interpretation and Argument	9
		54

Spring		Units
54-102	Acting I	10
54-104	Speech I	6
54-106	Voice for the Stage I	5
54-108	Movement I	4
54-124	Ballet I	5
54-126	Music Skills II	4
54-176	Conservatory Hour	1
54-159	Production Practicum	6
54-500	Voice Lab	5
54-177	Foundations of Drama I	6
79-104	Global Histories	9
		61

Sophomore Year

Fall		Units
54-201	Acting II	12
54-203	Voice and Speech II	5
54-205	Ballet II	3
54-207	Movement II	4
54-217	Jazz II	2
54-219	Music Theatre Literature and Repertoire	4
54-223	Tap II	2
54-281	Foundations of Drama II or H&SS Approved Elective *	6
54-500	Voice Lab	5
62-314	The Art of Personal Finance	6
54-159	Production Practicum (or in spring)	6
		55

Spring		Units
54-202	Acting II	12
54-204	Voice and Speech II	6
54-206	Ballet II	3
54-208	Movement II	3
54-218	Jazz II	2
54-224	Tap II	2
54-220	Acting A Song	4
54-159	Production Practicum (if not in fall)	6
54-281	Foundations of Drama II or H&SS Approved Elective *	6
54-500	Voice Lab	5
		49

Junior Year

Fall		Units
54-301	Acting III	10
54-305	Voice for the Stage III	5
54-309	Dialects and Accents	6
54-311	Rehearsal and Performance III	16
54-313	Ballet III	3
54-315	Jazz III	2
54-319	Cabaret	6
54-323	Tap III	2
54-500	Voice Lab	5
		55

Spring		Units
54-302	Acting III	10

54-306	Voice for the Stage III	5
54-310	Dialects and Accents	6
54-312	Rehearsal and Performance III	16
54-314	Ballet III	3
54-316	Jazz III	2
54-324	Tap III	2
54-410	Theatre Lab for Undergraduates II	4
54-500	Voice Lab	5
54-374	Musical Theater Audition	3
		56

Senior Year

Fall		Units
54-285	Alexander Technique (Optional)	1.5
54-381	Special Topics in Drama: History, Literature and Criticism	6
54-411	Rehearsal and Performance IV	16
54-413	Showcase	6
54-418	Songs for Showcase	2
54-403	Advanced Speech Techniques	3
54-415	Broadway Dance Styles	5
54-493	Business of Acting	3
54-500	Voice Lab	5
54-519	Acting for the Camera	6
54-407	Movement IV (Optional)	4
54-436	MT Senior Voice Coaching	1
		58.5

Spring		Units
54-285	Alexander Technique (Optional)	1.5
54-412	Rehearsal and Performance IV	16
54-438	Acting IV	3
54-414	Showcase	9
54-416	Broadway Styles	5
54-500	Voice Lab	5
54-520	Acting for the Camera	6
54-418	Songs for Showcase	2
54-437	MT Senior Voice Coaching	1
		48.5

Notes:

* Foundations of Drama II will be taken only one semester in the sophomore year. Sophomore Music Theater students will be required to take an approved Humanities & Social Sciences (H&SS) course in the Dietrich College during the semester they are not taking Foundations of Drama II.

** Music Theater students are required to take an approved Scientific and Quantitative Reasoning elective. Students usually take 62-314 The Art of Personal Finance to fulfill this requirement.

Design Option

Freshman Year

Fall		Units
54-151	Stagecraft	13
54-157	Production Science	6
54-169	Studiocraft 1	13
54-171	Basic Design 1	6
54-175	Conservatory Hour	1
99-101	Computing @ Carnegie Mellon (Usually completed in summer)	3
54-177	Foundations of Drama I OR	6
xx-xxx	Non-Drama Elective	
76-101	Interpretation and Argument	9
		57

Spring		Units
54-152	Stagecraft	13
54-158	Production Planning	6
54-170	Studiocraft 2	8
54-172	Basic Design 2	6
54-176	Conservatory Hour	1
54-177	Foundations of Drama I or	6
xx-xxx	Non-Drama Elective	6
79-104	Global Histories	9
		55

Sophomore Year

Fall - ALL DESIGN		Units
54-231	Design for the Stage	9
54-249	Stagecraft II	14
54-271	Technical Management	6
54-281	Foundations of Drama II or H&SS Approved Elective *	6
54-284	Fundamentals of Directing	6
		41

Spring - ALL DESIGN		Units
54-361	Production Preparation	Var.
54-281	Foundations of Drama II OR H&SS Approved Elective *	6
xx-xxx	Non-Drama Elective	6-9
54-381	Special Topics in Drama: History, Literature and Criticism Pre-req of Foundations of Drama II	6
54-446	Professional Preparation	3

Spring - SOUND DESIGN (consult with advisor)		Units
54-166	Introduction to Sound Design for Theatre	6
54-666	Production Audio	6
54-117	Design Collaboration Project	3

Spring - COSTUME DESIGN (consult with advisor)		Units
54-162	Introduction to Costume Design	6
54-230	Make-Up for Designers	6
54-346	Introduction to Costume Construction	6
54-447	Figure Drawing	3
54-117	Design Collaboration Project	3

Spring - SCENIC DESIGN (consult with advisor)		Units
54-250	Introduction to Scenic Design	6
54-386	Scenic Design Skills: 3D Model Making	4
54-392	Scenic Design Skills: 2D Drawing and Rendering	4
54-350	Scenic Design Forum	1
54-117	Design Collaboration Project	3

Spring - LIGHTING DESIGN (consult with advisor)		Units
54-252	Introduction to Lighting Design	6
54-368	Lighting Management I	4
54-369	Lighting Management II	4
54-287	Introduction to Lighting Design Skills	2
54-117	Design Collaboration Project	3

Spring - VIDEO & MEDIA DESIGN (consult with advisor)		Units
60-110	Electronic Media Studio: Introduction to the Moving Image This is not a non-Drama elective.	10
54-297	VMD Systems Studio	6
54-XXX	Design "Co-Option"	
XX-XXX	VMD Interdepartmental Course	

Junior Year

Fall - ALL DESIGN		Units
54-361	Production Preparation	Var.

54-381	Special Topics in Drama: History, Literature and Criticism (if needed)	6
xx-xxx	Non-Drama Elective	6

Fall - SOUND DESIGN (consult with advisor)		Units
54-267	Conceptual Sound Design	9
54-389	Composition for Theatrical Sound Design 1	9
54-505	Ear Training	1
54-508	Theatrical Sound System Design 1	9

Fall - COSTUME DESIGN (consult with advisor)		Units
54-245	History of Clothing 1	6
54-341	Fundamentals of Costume Design	9
54-373	Draping for the Designer I	6
54-511	Millinery I OR	9
54-539	Fabric Dyeing I	9
54-473	Drawing for Theatrical Designers	9
54-441	Costume Design for Dance	5

Fall - SCENIC DESIGN (consult with advisor)		Units
54-237	Scenic Painting I	6
54-239	History of Architecture and Decor 1: Ancients to Gothic	Var.
54-331	Scenic Design: Explorations	9
54-383	Introduction to Digital Media	9
54-350	Scenic Design Forum	1

Fall - LIGHTING DESIGN (consult with advisor)		Units
54-349	Automated Lighting Technology	6
54-351	Theatrical Lighting Design	9
54-367	Lighting Design Skills	6
54-469	Dance Lighting Design	3

Fall - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-399	Decoding Media	9
54-405	Digital Narratives	4
xx-xxx	VMD Interdepartmental Course	6-12
54-xxx	Design "Co-option" (for co-option students)	6-9

Spring - ALL DESIGN		Units
54-381	Special Topics in Drama: History, Literature and Criticism (if needed)	6
54-361	Production Preparation	Var.
xx-xxx	Non-Drama Elective	6-9

Spring - SOUND DESIGN (consult with advisor)		Units
54-390	Composition for Theatrical Sound Design 2	9
54-505	Ear Training	1
54-509	Theatrical Sound System Design 2	9
54-328	Advanced Digital Sound Design Skills	6

Spring - COSTUME DESIGN (consult with advisor)		Units
54-246	History of Clothing 2	6
54-442	Costume Design for the Classics	5
54-467	Costume Design with Music	5
54-447	Figure Drawing	3
54-450	Painting for the Theatrical Designer (offered every other year)	9
or 54-470	Costume Rendering	
54-xxx	Costume Crafts Mini (optional)	
54-444	Draping for the Designer II (optional)	3
54-486	Understanding Textiles	3

Spring - SCENIC DESIGN (consult with advisor)		Units
54-238	Scenic Painting II	6
54-240	History of Architecture and Decor 2: Renaissance to the 21st Century	6
54-332	Scenic Design: Boot Camp	9
54-450	Painting for the Theatrical Designer (offered every other year) or approved substitute	9
54-350	Scenic Design Forum	1

Spring - LIGHTING DESIGN (consult with advisor)		Units
54-352	Musical and Opera Lighting Design	9
54-527	Automated Lighting Workshop (optional)	Var.

Spring - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-400	Staging Media	9
xx-xxx	VMD Interdepartmental class	
54-xxx	Design "Co-Option" (for co-options students)	

Senior Year

Fall - ALL DESIGN		Units
54-381	Special Topics in Drama: History, Literature and Criticism (if needed)	6
xx-xxx	Non- Drama Elective	6-9
54-361	Production Preparation	Var.

Fall - SOUND DESIGN (consult with advisor)		Units
54-268	Organized Sound	9
54-505	Ear Training	1
54-275	History of Sound Design	3
54-398	Special Topics in Sound Design	9
54-377	Production Composition Studio	3

Fall - COSTUME DESIGN (consult with advisor)		Units
54-431	Scenography or 54-405 Digital Narratives	9
54-447	Figure Drawing	3
54-511	Millinery I (offered every other year)	9
or 54-539	Fabric Dyeing I	
54-239	History of Architecture and Decor 1: Ancients to Gothic	Var.

Fall - SCENIC DESIGN (consult with advisor)		Units
54-473	Drawing for Theatrical Designers (if needed)	9
54-431	Scenography	9
54-405	Digital Narratives (Optional)	4
54-350	Scenic Design Forum	1
54-239	History of Architecture and Decor 1: Ancients to Gothic (if needed)	Var.

Fall - LIGHTING DESIGN (consult with advisor)		Units
54-469	Dance Lighting Design	3
54-491	Concert Lighting Design	9
54-525	Entertainment Lighting Programming (Optional)	4

Fall - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-xxx	Design "Co-Option" (for co-option students)	6
54-405	Digital Narratives	4
54-521	Video Media Design Senior Thesis (or approved Advanced VMD course)	Var.
54-476	Advanced Media Creation Studio	6

Spring - ALL DESIGN		Units
54-381	Special Topics in Drama: History, Literature and Criticism (if needed)	6
54-446	Professional Preparation	3
54-361	Production Preparation	Var.
xx-xxx	Non-Drama Elective	6-9

Spring - SOUND DESIGN (consult with advisor)		Units
54-372	Theatre for the Ear	6
54-397	Sound Design For Interactive Environments	9
54-505	Ear Training	1

Spring - COSTUME DESIGN (consult with advisor)		Units
54-470	Costume Rendering (offered every other year)	9
or 54-450	Painting for the Theatrical Designer	
54-xxx	Costume Crafts Mini (optional)	
54-240	History of Architecture and Decor 2: Renaissance to the 21st Century	Var.

Spring - SCENIC DESIGN (consult with advisor)		Units
54-432	Scenic Design: Modern Classical	9
54-450	Painting for the Theatrical Designer (or approved substitute) if not taken in junior year	9
54-350	Scenic Design Forum	1

Spring - LIGHTING DESIGN (consult with advisor)		Units
54-452	Architectural Lighting Design	9
54-524	Dance Lighting Design 2	3
54-527	Automated Lighting Workshop (optional)	Var.

Spring - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-xxx	Design "Co-Option" (for co-option students)	
54-521	Video Media Design Senior Thesis (or Advanced VMD course)	Var.
54-880	Graduate Special Topics in Media: Mediated Reality (if offered)	Var.

NON-DRAMA ELECTIVES:

Designers take a minimum of seven Non-Drama Electives, 6-9 units each.

Notes:

* Foundations of Drama II will be taken only one semester in the sophomore year. Sophomore Designers will be required to take an approved Humanities and Social Sciences (H&SS) elective in the Dietrich College during the semester they are not taking Foundations of Drama II. This course counts as one of the required seven Non-Drama Electives.

** All Designers are required to complete Special Topics in Drama: History, Literature and Criticism. It may be taken at any time after Foundations II has been completed.

Directing Option

Freshman Year

Fall		Units
54-167	Acting for Directors I	10
54-107	Movement I	4
54-109	Dramaturgy 1: Approaches to Text	9
54-110	Text for Actors	2
54-121	Directing I: Sources	9
54-159	Production Practicum	6
54-175	Conservatory Hour	1
99-101	Computing @ Carnegie Mellon (usually taken over the summer)	3
54-517	Director's Colloquium	1
79-104	Global Histories	9
		54

Spring		Units
54-168	Acting for Directors I	10
54-122	Directing I: Sources	9
54-176	Conservatory Hour	1
54-159	Production Practicum	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy	9
54-518	Director's Colloquium	1
54-177	Foundations of Drama I	6
76-101	Interpretation and Argument	9
xx-xxx	Non-Drama Elective	
		51

Sophomore Year

Fall		Units
54-233	Acting For Directors II	12
54-221	Directing II: Fundamentals	9
54-257	Directing: Production II	6
54-281	Foundations of Drama II	6
54-517	Director's Colloquium	1
xx-xxx	H&SS Approved Elective *	9
54-271	Technical Management (Optional)	6
62-314	The Art of Personal Finance	6
		55

Spring		Units
54-234	Acting For Directors II	12
54-222	Directing II: Fundamentals	9
54-258	Directing: Production II	6
54-330	Introduction to Stage Management	6
54-518	Director's Colloquium	1
54-117	Design Collaboration Project	3
54-522	Plays and Pitches	6
xx-xxx	Non-Drama Elective	6
		49

Junior Year

Fall		Units
54-322	Directing III: Immersive Theater and Independent Film	9
54-357	Directing: Production III (if available)	12
54-405	Digital Narratives	4
54-381	Special Topics in Drama: History, Literature and Criticism	6
54-517	Director's Colloquium	1
xx-xxx	Non-Drama Elective	6
54-271	Technical Management (Optional)	6
		44

Spring - NYC TEPPER INTERNSHIP SEMESTER		
Tepper Semester courses		45

Senior Year

Fall		Units
54-381	Special Topics in Drama: History, Literature and Criticism (if needed)	6
54-409	Theatre Lab for Undergraduates I	9
54-322	Directing III: Immersive Theater and Independent Film	9
54-431	Scenography	9
54-457	Directing: Production IV **	12
54-517	Director's Colloquium	1
xx-xxx	Non-Drama Elective	6
54-239	History of Architecture and Decor 1: Ancients to Gothic (Optional)	Var.
		52-53

Spring		Units
54-410	Theatre Lab for Undergraduates II	9
54-422	Directing IV	6
54-458	Directing: Production IV **	Var.
54-518	Director's Colloquium	1
xx-xxx	Non-Drama Elective	6-9
54-240	History of Architecture and Decor 2: Renaissance to the 21st Century (Optional)	4
		26-30

NON-DRAMA ELECTIVES:

Directors take a minimum of seven Non-Drama Electives, 6-9 units each.

Notes:

* Sophomore Directors will be required to take an approved Humanities & Social Sciences (H&SS) elective in the Dietrich College and 62-314 The Art of Personal Finance. These courses will also count as two of the seven required Non-Drama Electives.

** One semester of Directing Production IV: Senior Thesis Play is required. Second semester is optional.

Production Technology and Management (PTM) Option

Freshman Year

Fall		Units
54-151	Stagecraft	13
54-157	Production Science	6
54-169	Studiocraft 1	13
54-171	Basic Design 1	6
54-175	Conservatory Hour	1
54-177	Foundations of Drama I OR Non-Drama Elective *	6
99-101	Computing @ Carnegie Mellon (usually taken over the summer)	3
76-101	Interpretation and Argument	9
		57

Spring		Units
54-152	Stagecraft	13
54-170	Studiocraft 2	8
54-158	Production Planning	6
54-172	Basic Design 2	6
54-176	Conservatory Hour	1
54-177	Foundations of Drama I OR Non-Drama Elective	6
79-104	Global Histories	9
		49

Sophomore Year

Fall		Units
54-231	Design for the Stage	9
54-271	Technical Management	6
54-249	Stagecraft II	14
54-281	Foundations of Drama II (or HSS Approved Course) **	6
54-284	Fundamentals of Directing	6
xx-xxx	Non-Drama Elective	6-9
		47-50

Spring - ALL PTM		Units
54-361	Production Preparation	Var.
54-272	Scenic Fabrication and Installation	6
54-330	Introduction to Stage Management	6
54-334	Production Resource Management	6
54-281	Foundations of Drama II OR approved HSS course	6
xx-xxx	Non-Drama Elective	6
xx-xxx	Directed Drama Elective	6

Spring - PTM TECHNICAL DIRECTION		Units
54-264	Intro to Welding (MIG & TIG)	4
54-265	Advanced Fabrication 1	6

Spring - PTM STAGE & PRODUCTION MANAGEMENT (SPM)		Units
54-666	Production Audio	6

Junior Year

Fall - ALL PTM		Units
54-273	Technical Direction I	6
54-333	Production Personnel Management	6
54-361	Production Preparation	Var.
54-381	Special Topics in Drama: History, Literature and Criticism ***	6
xx-xxx	Directed Drama Elective	3-12
xx-xxx	Non-Drama Elective	6-9

Fall - PTM TECHNICAL DIRECTION		Units
54-353	Structural Design I (offered every other year) ~	9
or 54-366	Physics of Stage Machinery	
54-295	Advanced Fabrication 2	6

Fall - PTM SPM		Units
54-266	Stage Management: Cue Lab	3
54-339	Stage Management Seminar	3
54-454	Advanced Topics in Stage Management I	3
54-380	Music Reading for Production	3

Spring - ALL PTM		Units
54-361	Production Preparation	Var.
54-468	Theater Management	6
54-381	Special Topics in Drama: History, Literature and Criticism ***	6
xx-xxx	Non-Drama Elective	6-9
xx-xxx	Directed Drama Elective	
54-355	30 Hour OSHA (offered every other year)	3

Spring - PTM TECHNICAL DIRECTION		Units
54-354	Structural Design II ~	9
or 54-365	Machine Design I	
54-378	Technical Direction II	6

Spring - PTM SPM		Units
54-339	Stage Management Seminar	3
54-453	Production Management Workshop	3
54-368	Lighting Management I	4

Senior Year

Fall - ALL PTM		Units
54-361	Production Preparation	Var.
54-464	PTM Professional Practice	3
54-381	Special Topics in Drama: History, Literature and Criticism ***	6
xx-xxx	Non-Drama Elective	6-9

Fall - PTM TECHNICAL DIRECTION		Units
54-477	Technical Direction III	6
54-353	Structural Design I ~	9
or 54-366	Physics of Stage Machinery	
xx-xxx	Directed Elective	

Fall - PTM SPM		Units
54-339	Stage Management Seminar	3
54-453	Production Management Workshop	3
54-455	Production Data Manipulation	6
54-277	Negotiation and Conflict Management	3

Spring - ALL PTM		Units
54-361	Production Preparation	Var.
54-381	Special Topics in Drama: History, Literature and Criticism ***	6
54-355	30 Hour OSHA offered every other year	6
or 54-468	Theater Management	
xx-xxx	Non-Drama Elective	6-9

Spring - PTM TECHNICAL DIRECTION		Units
54-354	Structural Design II	9
or 54-365	Machine Design I	

54-376	Entertainment Rigging	3
54-480	Technical Direction IV	6

Spring - PTM SPM		Units
54-456	Production Management Workshop	3
54-339	Stage Management Seminar	3
54-475	Advanced Topics in Stage Management II- Mini 3	3
xx-xxx	Directed Drama Elective	
54-277	Negotiation and Conflict Management	3

NON-DRAMA ELECTIVES:

PTM students take a minimum of seven Non-Drama Electives, 6-9 units each.

SMPM Students must complete 4 Directed Drama Electives.

Notes:

* Foundations of Drama I will be taken only one semester in the freshman year. Half of the freshmen PTM students will take it in the fall, the rest will take it in the spring. PTM students take a Non-Drama Elective in the semester they are not taking Foundations of Drama I.

** Foundations of Drama II will be taken only one semester in the sophomore year. Sophomore PTM students will be required to take an approved Humanities and Social Sciences (H&SS) elective in the Deitrich College during the semester they are not taking Foundations of Drama II. This course counts as one of the required seven Non-Drama Electives.

*** All PTM students are required to complete Special Topics in Drama: History, Literature and Criticism. It may be taken at any time after Foundations II has been completed.

~ Classes offered in alternating years.

Dramaturgy Option

Freshman Year

Fall		Units
54-109	Dramaturgy 1: Approaches to Text	9
54-121	Directing I: Sources	9
54-175	Conservatory Hour	1
54-177	Foundations of Drama I	6
54-200	Dramaturgy Forum	1
76-101	Interpretation and Argument	9
82-xxx	Foreign Language *	9-12
99-101	Computing @ Carnegie Mellon	3
54-159	Production Practicum	6
		53-56

Spring		Units
54-176	Conservatory Hour	1
54-159	Production Practicum	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy	9
82-xxx	Foreign Language *	9-12
54-281	Foundations of Drama II	6
xx-xxx	Directed Elective	6-9
54-117	Design Collaboration Project	3
54-122	Directing I: Sources	9
54-200	Dramaturgy Forum	1
		50-56

Sophomore Year

Fall		Units
54-256	Dramaturgy 3: New Play Dramaturgy	9
54-299	Dramaturgy Production:Assistant (or in spring)	9
54-387	Dramaturgy: Production I (by assignment)	9
54-200	Dramaturgy Forum	1
76-xxx	Directed English theory course	9
xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
82-xxx	Modern Language, if needed *	9-12
54-239	History of Architecture and Decor 1: Ancients to Gothic (or 54-240 in the spring)	6
		67-73

Spring		Units
54-299	Dramaturgy Production:Assistant (or in fall)	9
54-387	Dramaturgy: Production I (by assignment)	9
54-363	Dramaturgy 5: Devised and Documentary Theatre (in even years)	9
54-300	Dramaturgy Research Hours	Var.
54-240	History of Architecture and Decor 2: Renaissance to the 21st Century (if not 54-239 in fall)	6
54-522	Plays and Pitches	6
54-200	Dramaturgy Forum	1
xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
82-xxx	Foreign Language, if needed *	9-12
54-446	Professional Preparation	3
		67-74

Junior Year

Fall		Units
54-247	Dramaturgy 4: In Company (in even years)	9
54-487	Dramaturgy: Production II (if not in spring)	12
54-200	Dramaturgy Forum	1
54-381	Special Topics in Drama: History, Literature and Criticism ***	6
54-463	Dramaturgy Research Hours	6
xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
54-245	History of Clothing 1	6
		55-58

Spring		Units
54-xxx	Dramaturgy 5/6	9
54-487	Dramaturgy: Production II (if not in fall)	12
54-xxx	Intro to Design (field of choice)	6
54-468	Theater Management or 93-703 Arts Enterprises in senior fall	6
54-300	Dramaturgy Research Hours (by assignment)	6
54-200	Dramaturgy Forum	1
54-381	Special Topics in Drama: History, Literature and Criticism ***	6
xx-xxx	Directed Elective	9
xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
54-254	New Play Collaboration (or in senior year)	9
		79-82

Senior Year

Fall		Units
54-247	Dramaturgy 4: In Company (if needed)	9
54-200	Dramaturgy Forum	1
54-587	Dramaturgy Production III (by assignment)	12
or 54-585	Dramaturgy Capstone Thesis	
54-381	Special Topics in Drama: History, Literature and Criticism ***	6
54-489	Dramaturgy: Internship ~	9
54-300	Dramaturgy Research Hours (by assignment)	6

xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
93-703	Arts Enterprises: Management & Structures (if needed)	12
		70-73

Spring		Units
54-xxx	Dramaturgy 5/6 (if needed) **	9
54-254	New Play Collaboration (in needed)	9
54-200	Dramaturgy Forum	1
54-381	Special Topics in Drama: History, Literature and Criticism ***	6
54-587	Dramaturgy Production III (if not in fall)	12
xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
54-446	Professional Preparation	3
		55-58

DIRECTED ELECTIVES: ENGLISH		Units
Dramaturgy students take 7 English courses (one theory course, four 200-300 level, two 400-level)		54
Sample Recommended English Electives:		
76-245	Shakespeare: Tragedies and Histories	9
76-247	Shakespeare: Comedies and Romances	9
76-335	20th and 21st Century American Fiction	9
76-431	Chaucer	9
76-432	Advanced Seminar in African American Studies	9
76-438	The Wire: Crime, Realism, and Long-Form TV	9

DIRECTED ELECTIVES: HISTORY	Units
Dramaturgy students take at least 3 History courses (two 200-level and one 300-level). One course must focus on history pre-1900, and one must focus on African, Asian, Latin American, or Caribbean studies.	27

DIRECTED ELECTIVES: EUROPEAN STUDIES	Units
Dramaturgy students take one European Studies course (cannot be an English course, but can be a History course)	9

DIRECTED ELECTIVES: FOREIGN LANGUAGE	Units
Dramaturgy students take at least one Foreign Language course at the 200-level or above.	12

DIRECTED ELECTIVES: DRAMA		Units
Dramaturgy students take at least ONE of the following Drama courses:		
54-101	Acting I (with Instructor Permission)	10
54-187	Introduction to Playwriting	9
54-330	Introduction to Stage Management	6

NON-DRAMATURGY ELECTIVES:

Dramaturgy students take a minimum of seven Non-Dramaturgy Electives, 6-9 units each.

Notes:

* Dramaturgy students starting a modern language at the 100-level should begin in the fall of freshman year.
** Dramaturgy 5 and New Play Collaboration are both required courses and may be taken in any order in the sophomore, junior, and senior year. Dramaturgy 4 and 6 both required and can be taken in the junior and senior year only.
*** Dramaturgy students are required to take a total of 12 units of Special Topics in Drama: History, Literature and Criticism during their junior and senior year.
~ Dramaturgy Internship may be completed in the summer, fall, or spring semester of junior or senior year.

Faculty

WENDY ARONS, Professor, Dramatic Literature – Ph.D., University of California, San Diego; Carnegie Mellon, 2007–

NATALIE BAKER-SHIRER, Associate Professor Emerita, Voice & Speech – M.F.A., University of Pittsburgh; Carnegie Mellon, 1992–

CLAUDIA BENACK, Associate Teaching Professor, Music Theatre – M.F.A., Carnegie Mellon; Carnegie Mellon, 1993–

DICK BLOCK, Teaching Professor, Design – M.F.A., Northwestern University; Carnegie Mellon, 1988–

DAVID BOEVERS, Associate Professor, Production Technology and Management – M.F.A., Yale University; Carnegie Mellon, 2000–

C. TODD BROWN, Associate Teaching Professor, Lighting – B.A., Ohio State University; Carnegie Mellon, 2001–

JAMES CATON, Associate Teaching Professor, Dance Carnegie Mellon, 1988–

JUDITH CONTE, Teaching Professor, Dance – B.F.A., University of Wisconsin/Milwaukee; Carnegie Mellon, 1978–

TOME COUSIN, Associate Professor, Dance Carnegie Mellon, 2011–

RICK EDINGER, Associate Teaching Professor, Music Theater – M.A., City University of New York: Hunter College; Carnegie Mellon, 2018–

MELINDA ESHELMAN, Associate Professor, Costume Design – MFA, Carnegie Mellon University; Carnegie Mellon, 2017–

JANET MADELLE FEINDEL, Professor Emerita, Voice/Alexander – M.F.A., Carnegie Mellon; Carnegie Mellon, 1996–

KYLE HADEN, Assistant Professor, Acting – MFA, Columbia University; Carnegie Mellon, 2016–

ROB HANDEL, Associate Professor, Dramatic Writing – M.F.A., Brown University; Carnegie Mellon, 2009–

HUGH HANSON, Associate Teaching Professor, Costume Production – M.F.A., University of Hawaii at Manoa; Carnegie Mellon, 2015–

JED ALLEN HARRIS, Associate Teaching Professor, Directing – M.F.A., Carnegie Mellon; Carnegie Mellon, 1991–

KEVIN HINES, Associate Teaching Professor, Production Technology & Management – M.F.A., Yale University; Carnegie Mellon, 1998–

GARY KLINE, Teaching Professor, Voice – B.F.A., Carnegie Mellon; Carnegie Mellon, 1990–

GREGORY LEHANE, Professor Emeritus, Directing – M.F.A., Carnegie Mellon; Carnegie Mellon, 1991–

CINDY LIMAURO, Professor, Lighting Design – M.F.A., Florida State; Carnegie Mellon, 1987–

GARY LOGAN, Associate Professor, Voice & Dialects – MFA, American Conservatory Theater; Carnegie Mellon, 2016–

JUSTIN LUCERO, Assistant Professo, Directing – MFA, University of Essex, East 15 Acting School; Carnegie Mellon, 2019–

BARBARA MACKENZIE-WOOD, Raymond W. Smith Professor, Acting – M.F.A., Carnegie Mellon; Carnegie Mellon, 1986–

ANTHONY MCKAY, Associate Professor, Acting – B.F.A., Carnegie Mellon; Carnegie Mellon, 1985–

CATHERINE MOORE, Associate Teaching Professor, Movement – M.F.A., University of Cincinnati, College-Conservatory of Music; Carnegie Mellon, 2000–

ANNE MUNDELL, Associate Professor, Design – M.F.A., Brandeis University; Carnegie Mellon, 1989–

SARAH PICKETT, Associate Professor, Sound Design – M.F.A., Yale University; Carnegie Mellon, 2012–

JOE PINO, Associate Professor, Sound Design – M.F.A., University of Virginia; Carnegie Mellon, 1999–

MEGAN RIVAS, Associate Professor, Dramaturgy – M.F.A., University at Austin, Texas; Carnegie Mellon, 2013–

BRIAN RUSSMAN, Associate Teaching Professor, Costume Production – M.F.A., Ohio State University; Carnegie Mellon, 2009–

TINA SHACKLEFORD, Associate Teaching Professor – M.F.A., University of California, San Diego; Carnegie Mellon, 2004–

LARRY SHEA, Associate Professor, Video and Media Design – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2010–

NARELLE SISSONS, Associate Professor, Design – M.A., Central/St Martins and The Royal College of Art in London, UK; Carnegie Mellon, 2007–

ANDREW SMITH, Assistant Professor, Acting – M.F.A., University of California, San Diego; Carnegie Mellon, 2014–

LISA VELTEN SMITH, Assistant Professor, Voice – MFA , University of California San Diego; Carnegie Mellon, 2019–

AUSAR STEWART, Assistant Professor, Voice – MFA , York University; Carnegie Mellon, 2019–

ROBERT THOMSON, Associate Professor, Lighting Carnegie Mellon, 2014–

SUSAN TSU, Bessie F. Anathan Professor, Costume Design – M.F.A.,Carnegie Mellon, 2003–

DON WADSWORTH, Professor, Voice & Speech – M.F.A., University of Pittsburgh; Carnegie Mellon, 1989–

KAF WARMAN, Associate Professor, Movement – M.F.A., Goddard College, Ecole; Carnegie Mellon, 1996–

KIM WEILD, Associate Professor, Directing – MFA, Columbia; Carnegie Mellon, 2017–

School of Drama Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

54-011 Introduction to Alexander Technique
Fall: 1 unit
TBD

54-012 Warmup
Spring: 1 unit
Drama majors only. Freshman Acting Warm Up is a three-day-a-week course which is designed to help the actor prepare mentally and physically for daily training and/or rehearsal. The preparations are based in yoga exercises and are meant to help the actor gain a greater self-awareness, fuller breathing, a greater degree of being centered, and focused on the immediate moment.
Prerequisite: 54-011

54-101 Acting I
Fall: 10 units
A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is open to Drama majors only.

54-102 Acting I
Spring: 10 units
A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is for Drama majors only.
Prerequisite: 54-101

54-103 Speech I
Fall: 6 units
(Speech & Phonetics) The course introduces students to the pronunciation of the sounds of the Standard American English Dialect. The International Phonetic Alphabet (IPA) is used to teach the students a symbol for each vowel, diphthong and consonant sound of the dialect. This process will strengthen the student's production of the thirty-nine sounds and will eliminate regional characteristics. Intonational patterns of the dialect are also studied and practiced. The work is applied to weekly presentations of poetic texts. Phonetic transcription is required of class participants from the beginning of this course. This course is for Acting and Directing majors only.

54-104 Speech I
Spring: 6 units
(Speech and Phonetics) The second semester is a continued investigation and drill of the thirty-nine sounds of the Standard American English Dialect as well as the music of the dialect. Students apply the principles of the five degrees of stress of the dialect, inflections and intonational patterns and the use of the weak forms of certain parts of speech of the English language to the weekly presentations. The last four weeks of this semester are focused on preparation for a public performance of each student's favorite poet's poetry, all of which is memorized and transcribed phonetically. This course is for Acting and Directing majors only.
Prerequisite: 54-103

54-105 Voice for the Stage I
Fall: 5 units
Introduction to basic speaking voice and Alexander Technique work. Actors explore building a vocal preparation employing the principles of the Alexander for actor's speaking voice through explorations that help develop awareness of the head, neck torso relationship and the movement of the spine; vocal release, breath support, stamina. range, use of resonators and the application to text. Actors learn to identify components of healthy and unhealthy voice usage, basics of vocal anatomy and strategies for maintaining vocal health. Writing exercises are employed to help actors connect the voice to creativity and imaginative, essential for the actor?s development.

54-106 Voice for the Stage I
Spring: 5 units
Introduction to basic speaking voice and Alexander Technique work. Actors explore building a vocal preparation employing the principles of the Alexander for actor?s speaking voice through explorations that help develop awareness of the head, neck torso relationship and the movement of the spine; vocal release, breath support, stamina. range, use of resonators and the application to text. Actors learn to identify components of healthy and unhealthy voice usage, basics of vocal anatomy and strategies for maintaining vocal health. Writing exercises are employed to help actors connect the voice to creativity and imaginative, essential for the actor?s development.
Prerequisite: 54-105

54-107 Movement I
Fall: 4 units
This course serves as a foundation for all future movement studies. Kinesthetic awareness and responsiveness is developed through the introduction of the Viewpoints method of physical training. The importance of physical expressivity and specificity in storytelling is achieved by the creation of physical movement based compositions. This is a required course for all first year undergraduate Acting and Musical Theatre and Directing students.

54-108 Movement I
Spring: 4 units
This course focuses on the ability to make physically specific choices in order to convey character through an introduction to the basic principles of Laban Movement Analysis and further work in the Viewpoints method of actor training. This course is required for all first year undergraduate Acting and Musical Theatre majors
Prerequisite: 54-107

54-109 Dramaturgy 1: Approaches to Text
Intermittent: 9 units
This course focuses on building the skills and knowledge necessary for a dramaturgical analysis of plays for production. Students learn and practice a number of methods of script analysis; critically discuss and analyze plays; practice the art of writing program notes and conducting critiques of productions; and attain an introductory knowledge of literary theory as it pertains to drama. Required for Freshmen Dramaturgs and Directors; open to other majors with instructor permission.

54-110 Text for Actors
Fall: 2 units
This class is in conjunction with Acting I in the School of Drama. The actor/director learns how to investigate the written text and translates it actively for performance.

54-111 Text for Actors
Spring: 2 units
This class is in conjunction with Acting I in the School of Drama. The actor/director learns how to investigate the written text and translates it actively for performance.

54-115 Rhythmic Exploration
Spring: 1.5 units
Optional course.

54-117 Design Collaboration Project
Spring: 3 units
This course is intended to provide students with hands-on experience in the process of collaboration on a design for a production. Students in the course will work in teams to design a hypothetical production of a given play.

54-119 Vocal Technique
Fall: 1 unit
Singing technique for first-year Music Theatre students.

54-121 Directing I: Sources
Fall: 9 units
An interdisciplinary exploration of the directors art through the study of modern art movements. Students will be required to do extensive research on one specific movement i.e. Surrealism or abstract expressionism, and create a performance piece based on the visual and social elements of that particular movement.

54-122 Directing I: Sources
Spring: 9 units
A continuation of the previous semester focusing on Music and Dance of the twentieth century and how they influence the directors art.
Prerequisite: 54-121

54-123 Ballet I
Fall: 5 units
This course uses Classical technique (Ballet) to build body placement, alignment and muscular strength and flexibility. Designed to help the student develop a way of learning how to work and train for any dance form. This technique is the basis of the choreography in American musical theater. This course is for Music Theatre majors only. Permission of instructor.

54-124 Ballet I
Spring: 5 units
This course continues Classical technique (Ballet) to build body placement, alignment and muscular strength and flexibility. Designed to help the student develop a way of learning how to work and train for any dance form. This technique is the basis of the choreography in American musical theater. This course is for Music Theatre majors only. Prerequisite: 54-123 and permission of instructor.
Prerequisite: 54-123

54-125 Music Skills I
Fall: 4 units
The students explore the basics of music theory, which includes intervals, rhythm, notation and musical vocabulary. Emphasis is on acquiring these basic skills through sight singing. For School of Drama MT students only.

54-126 Music Skills II
Spring: 4 units
The students explore the basics of music theory, which includes intervals, rhythm, notation and musical vocabulary. Emphasis is on acquiring these basic skills through sight singing.
Prerequisite: 54-125

54-134 Introduction to Writing for Television
Spring: 9 units
Students will write an original pilot, focusing on structure, character, and an analysis of what makes great TV.

54-135 The Basics of Self-Producing: How to Put Up Your Show in NYC and Get It Reviewed
Fall and Spring: 6 units
For any actor/writer/director/theatre artist in New York City, the time between jobs can feel stressful and frustrating. Self-producing is the quickest way to get your work on stage without permission from anyone else or having to adhere to anyone else's restrictions. From blurbs to budgets to rehearsal space to press releases to equity paperwork, this course covers everything you need to know in order to get your work produced and noticed in New York City without breaking the bank. This course will draw from readings on independent theatre, interviews with working independent producers in New York, and the working experience of Anderson Cook, author/producer of The Disembodied Hand That Fisted Everyone to Death - the Musical!, Blatantly Blaine, Pop Punk High, Donny and Kelly Save the Slumber Valley ASPCA, and more - all produced and reviewed in NYC.

54-151 Stagecraft
Fall: 13 units
The stagecraft class is designed to provide an introductory level of technical training in all the theatrical technical disciplines over the course of two semesters. The intent is to produce people who can capably fill roles on production crews and perhaps serve as an assistant to the head of the crew. Course content will cover materials, tools & equipment, procedures, safety and operations for Carpentry, Props, Paints, Media, Costumes, Lights, Sound, Rigging, and Run Crew. As well as providing opportunity and experience to grow as technicians, this content will also help establish a foundation to begin the process of becoming managers and designers. As craft skills are often best communicated in a master/apprentice environment this course is set up as a mentored practical experience. This course requires significant additional scheduled time on evenings and weekends for crew calls, which are an important element of the course.

54-152 Stagecraft
Spring: 13 units
The stagecraft class is designed to provide an introductory level of technical training in all the theatrical technical disciplines over the course of two semesters. The intent is to produce people who can capably fill roles on production crews and perhaps serve as an assistant to the head of the crew. Course content will cover materials, tools equipment, procedures, safety and operations for Carpentry, Props, Paints, Media, Costumes, Lights, Sound, Rigging, and Run Crew. As well as providing opportunity and experience to grow as technicians, this content will also help establish a foundation to begin the process of becoming managers and designers. As craft skills are often best communicated in a master/apprentice environment this course is set up as a mentored practical experience. This course requires significant additional scheduled time on evenings and weekends for crew calls, which are an important element of the course.

54-157 Production Science
Fall: 6 units
Students in the Production Science course are exposed to the very fundamentals, the primitives, of entertainment technology. The intent is to provide the absolutely strongest beginning for all the work to come, to provide a solid foundation for students and instructors to build upon. Production professionals routinely perform organizational tasks. In order to be able to meet that challenge, students will need to build a toolkit of information and procedures. That toolkit will be comprised of knowledge of the kinds of parameters and techniques that are normally selected, the indices that parameters and techniques are evaluated against, and many of the wide range of issues that might point a manager toward one decision or another. There also exists an entire pantheon of information that people typically learn "on the job." Activities and information presented in this course are designed to try to expose students to as much of this on the job type development as possible with the goal of leapfrogging them past the bottom rung of the workplace ladder. Drama Design/Production majors only, or with instructor permission.

54-158 Production Planning
Spring: 6 units
Students in the Basic PTM course are exposed to the very fundamentals, the primitives, of entertainment technology. The intent is to provide the absolutely strongest beginning for all the work to come, to provide a solid foundation for students and instructors to build upon. Production professionals routinely perform organizational tasks. In order to be able to meet that challenge, students will need to build a toolkit of information and procedures. That toolkit will be comprised of knowledge of the kinds of parameters and techniques that are normally selected, the indices that parameters and techniques are evaluated against, and many of the wide range of issues that might point a manager toward one decision or another. There also exists an entire pantheon of information that people typically learn "on the job." Activities and information presented in this course are designed to try to expose students to as much of this on the job type development as possible with the goal of leapfrogging them past the bottom rung of the workplace ladder. PREREQUISITES: Declared Design/PTM focus in the School of Drama FOR: First Year Undergraduate Students

54-159 Production Practicum
Fall: 6 units
Hands on experience in most aspects of building and running a production.

54-162 Introduction to Costume Design
Spring: 6 units
A rigorous introductory studio course for newly declared School of Drama Costume Design Sophomores in their fourth semester of matriculation. Basics of the design process are covered as well as drawing, sculpture, semiotics, play and character analysis, research and character building are explored. An intensive collaboration project with students of other design disciplines comprises the second half of the course. PREREQUISITES: Basic Design-54-171 and 54-172. All others: interview/portfolio review and instructor permission. FOR: 3rd semester Sophomore Costume Designers and students outside of School of Drama. IDEATE.
Prerequisites: 54-171 and 54-172

54-163 Production for Non Majors
Fall: 6 units
Basic introduction for non-majors to backstage operations through practical experience handling scenery, costumes, props and lighting. Orientation session offered in fall required prior to taking this class. Contact instructor to register and discuss limited openings

54-166 Introduction to Sound Design for Theatre
Spring: 6 units
Students explore the basic principles and theories of sound design from technical, psychological and aesthetic standpoints. Course work includes instruction in the controllable properties of sound, practical planning of sound plots, cue creation, and the design process. Prerequisites: Basic Design and Design For The Stage. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.

54-167 Acting for Directors I
Fall: 10 units
Acting I for Director BFA students.

54-168 Acting for Directors I
Spring: 10 units
A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is for Directing students only.

54-169 Studiocraft 1
Fall: 13 units
The studiocraft course provides beginning level instruction in Drawing, Hand Drafting, and CAD Drafting.

54-170 Studiocraft 2
Spring: 8 units
The studiocraft course provides beginning level instruction in Drawing, Hand Drafting, and CAD Drafting for Design/PTM majors.

54-171 Basic Design 1
Fall: 6 units
A year-long studio course that explores the principles and elements of design utilizing discreet exercises and projects first semester. Research and reports expose the students to designers, theatres and artists of note in the world. Second semester focuses on the semiotics of the visual and aural aspects of theatrical design. Projects fold in each of the disciplines of scene, costume, lighting, sound and media design. PRE-REQUISITE: Declared Design/PTM focus in the School of Drama. FOR: First Semester Design/PTM Undergraduate Students only .

54-172 Basic Design 2
Spring: 6 units
A year-long studio course that explores the principles and elements of design utilizing discreet exercises and projects first semester. Research and reports expose the students to designers, theatres and artists of note in the world. Second semester focuses on the semiotics of the visual and aural aspects of theatrical design. Projects fold in each of the disciplines of scene, costume, lighting, sound and media design. PRE-REQUISITE: Declared Design/PTM focus in the School of Drama. FOR: Second Semester Design/PTM Undergraduate Students only

54-175 Conservatory Hour
Fall: 1 unit
A year-long discussion class for first-year Drama students. Open to non-majors interested in declaring a Drama minor.

54-176 Conservatory Hour
Spring: 1 unit
A year-long discussion class for first-year Drama majors. Open to non-majors interested in declaring a Drama minor.

54-177 Foundations of Drama I
Fall and Summer: 6 units
In this course, students receive training in the basic analysis of scripts to determine key elements of structure, plot, characterization, thematic content, theatricality, and aesthetics. In addition, the course provides training in dramaturgical research and writing. Registration for this course is limited to Drama majors and minors.

54-183 Writing History Plays: Ethics, Authorship, and Hamilton
All Semesters: 9 units
This class will focus on the craft of writing a history play. Students will explore several types of history plays through assigned reading and listening (from Hamilton to Shakespeare) to understand how several dramatists have mined historical narratives to author stories only they can tell, and to examine the ethical implications of dramatizing real events on stage. The class will transition to a workshop environment as students create their own one-act history play, from the research phase to a finished product. Students should have an elementary knowledge of playwriting and theater prior to this course. No need to have extensive history knowledge, just an interest in using history for theatrical purposes.

54-184 Dramaturgy 2: Introduction to Production Dramaturgy
Intermittent: 9 units
This class continues the basic skill training of the dramaturg, emphasizing the history of world theatre from a dramaturgical perspective, a broad grounding in the history of critical theory of drama, and skill-building exercises in research, presentation, and writing. Required for Freshmen Dramaturgs; open to other majors with instructor permission.

54-187 Introduction to Playwriting
Fall: 9 units
This course aims to teach students the fundamentals of playwriting from the basic elements of a script to the necessary guidelines for successful workshop collaboration. Throughout the semester, students will engage in writing exercises— building up to writing short plays (ranging from 10 to 30 minutes long)— as they study master playwrights on the form. Class time will be dedicated to roundtable readings and discussions of each other's writing.

54-189 Advanced Writing for Television
Intermittent: 9 units
In this course students will be introduced to the major components of writing for TV, including character and structure, while analyzing genre television and pilot writing. Exercises designed to familiarize students with the tools available to TV writers will be assigned, and over the course of the semester, students will develop an original TV pilot. (Students who have not taken "Intro to TV Writing" need to seek permission from the instructor, but don't let that deter you!)
Prerequisite: 54-134

54-190 Advanced Playwriting
Spring: 9 units
In this class, students will fine-tune their individual voices as writers. Students will partake in writing exercises meant to tap into creative impulses and receive feedback on their plays throughout the semester, culminating in a short one-act play at the end of the term. The plays read in class will focus on disability, but students do not have to write on the subject of disability. Previous knowledge of playwriting is preferred, but NOT required.

54-191 Acting for Non-Majors
Fall: 9 units
This class is designed for non-acting majors and introduces the student to the basic principles of acting, character study and improvisation. One semester course.

54-192 Acting Ensemble for Non-Majors
Spring: 9 units
This course offers a practical introduction into the work of an actor through collaboration on composition assignments and scene work with undergraduate student directors. Each week actors will be cast in a different composition piece, creating a rotating ensemble so that all actors and directors have the opportunity to work with one another at least once and begin to build collaborative relationships. The second half of the semester students are cast in a scene and focus solely on the one scene working with one director. Students are expected to rehearse a maximum of 4 hours outside of class. Audition required at the beginning of the semester. Admittance to class by permission of professor.*****

54-193 Intro to Screenwriting
Intermittent: 9 units
Ever watched a terrible movie and thought "I can do better than that?!" Or seen a beautiful film and had the opposite reaction: "I could never do that!" Then this is the class for you! This practical skills course will provide students with the tools they need to construct compelling, image-driven screenplays. Students will be writing throughout the semester, ultimately preparing them to complete a polished script of a short film as a final project. Assignments will include reading masterwork screenplays for in-class analysis. Class time will also be dedicated to roundtable readings & discussions of each other's writing.

54-196 Screenwriting
Spring: 9 units
This course is designed to give writers a variety of tools they can use in writing or rewriting a current project full-length screenplay. There will films assigned to watch and analyze. Either a first draft or a rewritten version of a full length screenplay is to be completed by the end of the semester.

54-198 Plays With Words: Exploring Language-Driven Theater
Fall and Spring: 9 units
This course will provide students with an understanding of the category of plays that use language as their main engine of storytelling. Students will learn to identify and analyze the conventions of language plays, as well as practicing techniques to write their own. Some of the elements of language plays discussed in this course include plays with non-naturalistic language, emotionally expressive language, and action-driven language. The course will culminate in a final project in the form of a completed, full-length language play.

54-200 Dramaturgy Forum
Fall and Spring: 1 unit
Programmed and taught by senior students in the Dramaturgy program, this course is required for all Dramaturgy majors and meets once per week to discuss issues and topics of significance to the dramaturgy community.

54-201 Acting II
Fall: 12 units
Scene study: the fundamental techniques needed to participate in the developing conflict within the imaginary world. Character building through unfamiliar behavior and beliefs; relationships; language. Spring semester: The use of classical texts and ensemble playing. The deepening of the actors inner resources to be supported by the craft techniques.
Prerequisites: 54-101 and 54-102

54-202 Acting II
Spring: 12 units
Scene study: the fundamental techniques needed to participate in the developing conflict within the imaginary world. Character building through unfamiliar behavior and beliefs; relationships; language. Spring semester: The use of classical texts and ensemble playing. The deepening of the actors inner resources to be supported by the craft techniques.
Prerequisite: 54-201

54-203 Voice and Speech II
Fall: 5 units
The actors take a more concentrated approach to elevated text. The course focuses on the effective production of classical text. The warm up sessions are geared towards preparing the student actors for the extravagant language from Shakespeare?s plays and sonnets. Meter, imagery and further specific text work is also employed to encourage each student to find clear shape in the work. A repertoire of at least five classical monologues will come from the course work.
Prerequisites: 54-103 and 54-104

54-204 Voice and Speech II
Spring: 6 units
The actors take a more concentrated approach to elevated text. The course focuses on the effective production of classical text. The warm up sessions are geared towards preparing the student actors for the extravagant language from Shakespeare?s plays and sonnets. Meter, imagery and further specific text work is also employed to encourage each student to find clear shape in the work. A repertoire of at least five classical monologues will come from the course work.
Prerequisites: 54-203 and 54-104 and 54-103

54-205 Ballet II
Fall: 3 units
This course is designed to build on the technical foundation, work habits and professional behavior established in Ballet I. The material presented expands the classical dance vocabulary to the next level of difficulty. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-124 and 54-123

54-206 Ballet II
Spring: 3 units
This course continues to build on the technical foundation, work habits and professional behavior established in Ballet I. The material presented expands the classical dance vocabulary to the next level of difficulty. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-205

54-207 Movement II
Fall
This entire term focuses on the Neutral Mask, a completely non-verbal masked movement form, through which actors search for a neutral base, both physically and psychologically, a place of complete presence in the present. The mask allows them to uncover all that is emotional in the body, the "baggage" carried from role to role, and provides techniques to free them from these limitations. Identifications with other forms of energy, the four elements, seasons, materials, colors and plant life give students new insights into the process of character development. The Neutral Mask work is immediately reinforced with applications to scene work in Acting class. Limited to Acting/MT majors only.
Prerequisites: 54-108 and 54-107

54-208 Movement II
Spring: 3 units
This term is divided between two classic physical forms: Commedia dell'Arte and Clowns. In the first half of the semester students wear the half-masks of the archetypal Commedia characters (Harlequin, Pantalone, et al), to learn their psychology and physicality, improvise on historical and contemporary scenarios, and apply Commedia technique to modern comedy. Commedia dell'Arte gives them the tools to tackle physical comedy from any era, past or present. In the second half of the term students discover their personal Clowns. This clown has nothing to do with the American Barnum & Bailey Circus clown; this is not a character or caricature, but rather a revelation of the clown each student hides under the mask of adulthood. Discovering this clown gives them all a way to laugh at themselves, to uncover what makes each individual uniquely funny; it also lets them see how we only laugh at truth and in the personal material lies universal humor. Inside this freedom is the technique to know what's funny and why, and the ability to apply these rules in comedy.
Prerequisites: 54-107 and 54-108 and 54-207

54-209 Lab Review Prep for Dramaturgs and Directors
Spring: 6 units
TBA

54-211 Actor Dance II
Fall: 3 units
This course introduces the basic, fundamental vocabulary of Classical technique (Ballet) to train the body in proper alignment, placement, and muscular strength. Course closed: Only for Acting majors in Drama.
Prerequisite: Permission of instructor
Prerequisites: 54-101 and 54-102

54-212 Actor Dance II
Spring: 3 units
A continuation of Classical technique (Ballet) and a unit of social dance styles, waltz, polka, foxtrot, tango, swing. Course closed: Only for Acting majors in Drama.
Prerequisites: 54-102 and 54-211 and 54-101

54-213 Singing for Actors II
Fall: 3 units
The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.
Prerequisites: 54-101 and 54-102

54-214 Singing for Actors II
Spring: 3 units
The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.
Prerequisites: 54-101 and 54-102

54-217 Jazz II
Fall: 2 units
This course is designed to incorporate the strength of classical dance technique to a jazz dance style. Training the body in a variety of contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, using body isolations and rhythmic patterns. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-123 and 54-124

54-218 Jazz II
Spring: 2 units
This course continues to incorporate the strength of classical dance technique to a jazz dance Training the body in a variety of contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, using body isolations and rhythmic patterns. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-217 and Permission of instructor
Prerequisite: 54-217

54-219 Music Theatre Literature and Repertoire
Fall: 4 units
The students are exposed to many music scores of the basic choral and musical theatre literature. The students learn this repertory, reinforcing the principals of music theory learned in the first year.
Prerequisites: 54-126 and 54-125

54-220 Acting A Song
Spring: 4 units
This class is for Music Theatre majors only. This class explores the personal relationships between performer and song. Exercises include Class Interrogation, Story Telling, and Text Analysis. Based primarily on the personal experience the actor brings to the text, rather than technical aspects. Acting a Song is the prerequisite for Cabaret class.
Prerequisite: 54-500

54-221 Directing II: Fundamentals
Fall: 9 units
Directing II This is a fall-semester course for 2nd-year Directing students and others with special permission introducing the fundamentals of the director's craft: text analysis; the concept of Action & Change, directors units & transitions) Visual Vocabulary & Staging. Tools including planes, levels, body positions, composition, picturization, emphasis &movement, and the ground plan. Work includes unscripted exercises, scene breakdowns, detailed character analysis, and a final 7 to 10 minute devised performance

54-222 Directing II: Fundamentals
Spring: 9 units
A continuation of the work done in the first semester of Directing II. This course is for Directing sophomores and BXA Directing students only.
Prerequisite: 54-221

54-223 Tap II
Fall: 2 units
This course trains the student to develop a comfort level to execute percussive sounds, in a variety of percussive rhythmic patterns while applying the technical foundation of alignment and placement from classical technique. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: Permission of instructor
Prerequisites: 54-124 and 54-123

54-224 Tap II
Spring: 2 units
This course continues to technically train the student in a variety of percussive rhythmic patterns. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-223

54-227 How to Write a Shakespeare Play
Fall and Spring: 9 units
There are dozens of books that present a set of rules for writing a play, but not one of them will result in a play like those written by the world's most beloved playwright. This is madness. Whom should we take as a model if not Shakespeare? Can we invent an alternative set of rules that will permit mad shifts of tone, disregard for unities of time and place, stages shared by people from different social classes, inside-out characters (driven by individual psychology) alongside outside-in characters (driven by archetypal imperative), bad puns, dirty jokes, storms, slapstick, and the raising of unanswered (and unanswerable) questions? In this course, we will ransack our colleague Shakespeare's work to find strategies we can steal and reshape for our own purposes, through a series of writing projects on the level of the line, the speech, the scene, the act, and the play.

54-229 Super Worm Moon
Fall: 9 units
Drama majors only. Required for all Sophomore Design and Production majors. Bring tools.
Prerequisite: 54-172

54-230 Make-Up for Designers
Spring: 6 units
This course is structured as a lecture/demonstration and lab employing and exploring the principles of stage makeup, the variety of materials available and the practical application of these materials. The course is designed to provide the student with a working knowledge of broad-based application procedures, materials and techniques. We will also explore the principles of characterization allowing for the development, planning, and execution of effectual character makeup designs. The student should also be able to determine the stage-worthiness of a makeup application and how light will influence its appearance.

54-231 Design for the Stage
Fall: 9 units
This course is divided into four minis to introduce the student to the design process for costumes, lighting, scenery and sound. For Drama majors only, or instructor permission
Prerequisites: 54-170 and 54-171 and 54-172 and 54-169

54-233 Acting For Directors II
Fall: 12 units
Acting II for Directors

54-234 Acting For Directors II
Spring: 12 units
Acting II for Directors

54-237 Scenic Painting I
Fall: 6 units
This is a one semester studio course in the foundations of scenic painting for theater and related fields. Students will complete projects that address the following topics: preparation of and paint techniques for both soft goods and hard covered surfaces, drawing and painting to scale, representing textures in both 2 and 3 dimensions, and color mixing. Subject matter changes often and may include: architecture, natural and man-made textures, drapery, interior/exterior scenes, the human figure, still life objects.

54-238 Scenic Painting II
Spring: 6 units
This is a studio course in the foundations of scenic painting for theater and related fields. Students will complete projects that address the following topics: preparation of and paint techniques for both soft goods and hard covered surfaces, drawing and painting to scale, representing textures in both 2 and 3 dimensions, and color mixing. Subject matter changes often and may include: architecture, natural and man-made textures, drapery, interior/ exterior scenes, human figure, still life objects.

54-239 History of Architecture and Decor 1: Ancients to Gothic
Fall
This course is a survey of architecture, furniture and interiors from ancient times to the Gothic period. A lecture/slide course, the discussion of architecture is done with reference to social, political and economic history.

54-240 History of Architecture and Decor 2: Renaissance to the 21st Century
Spring
This slide/lecture course is a survey of architecture, interiors and furniture from the Italian Renaissance to the beginnings of the 21st Century.

54-242 Improvisation
Spring: 2 units
This course is for Sophomore Actors only. This course not only sharpens their skills as ensemble performers, but also allows for more playfulness, creativity and exploration, cultivating risk-taking and a certain abandon. The course concentrates on non-verbal psychological improv, helping actors achieve a kind of physical truth and spontaneity, while becoming aware of the importance of the body in conveying information.
Prerequisites: 54-101 and 54-102

54-245 History of Clothing 1
Fall: 6 units
This year-long course surveys the development of garments in the Western World from ancient civilizations to the first half of the 20th century. We will look at the progression of the shapes and forms that aesthetically define the clothing of each period, while also exploring the broader relationship of costume to culture and society through history. The course will comprise visual presentations of the art of each period, especially pertaining to representations of clothing, along with research projects, quizzes and exams.

54-246 History of Clothing 2
Spring: 6 units
The 2nd part of this year-long course surveys the development of garments in the Western World from ancient civilizations to the first half of the 20th century. We will look at the progression of the shapes and forms that aesthetically define the clothing of each period, while also exploring the broader relationship of costume to culture and society through history. The course will comprise visual presentations of the art of each period, especially pertaining to representations of clothing, along with research projects, quizzes and exams.

54-247 Dramaturgy 4: In Company
Intermittent: 9 units
For Dramaturgy majors. Open to non majors with instructor permission.
Prerequisites: 54-109 and 54-184

54-249 Stagecraft II
Fall: 14 units
Stagecraft II presents advanced shop skills and beginning department head skills for Scenery, Lighting, and Costumes. This course will require additional time during the evening and on weekends. Prerequisites: Stagecraft I (two semesters) OR Instructor Permission
Prerequisites: 54-152 and 54-151

54-250 Introduction to Scenic Design
Spring: 6 units
An introduction to the principles and practices of designing scenery emphasizing the interpretation and development of ideas based on a text. Prerequisites: Basic Design, Studiocraft. Drama majors have priority. Non-majors may be allowed in with instructor permission.
Prerequisites: 54-172 and 54-169 and 54-171

54-252 Introduction to Lighting Design
Spring: 6 units
Students explore the physical properties of light in various design applications and develop a process of storytelling that involves analysis, research, exploration, questioning, problem solving and implementation of a successful design product. Prerequisite: Design for the Stage, or instructor permission.
Prerequisite: 54-231

54-254 New Play Collaboration
Spring: 9 units
For Dramaturgy majors.

54-256 Dramaturgy 3: New Play Dramaturgy
Intermittent: 9 units
For Dramaturgy majors and others with instructor permission.
Prerequisites: 54-109 and 54-184

54-257 Directing: Production II
Fall: 6 units
Assignments as stage manager or assistant director.

54-258 Directing: Production II
Spring: 6 units
Assignments as stage manager or assistant director for the Rauh Studio and Chosky Theatres.

54-264 Intro to Welding (MIG & TIG)
Fall and Spring: 4 units
The purpose of this course is to give the student an introduction to and develop practical skills in the MIG (Gas Metal Arc Welding) and TIG (Gas Tungsten Arc Welding) processes. Course will include: comprehensive safety coverage setup, troubleshooting and basic maintenance of all machines basic metal preparation emphasis on identifying proper consumables, machine settings, and determining the success of the welds Work boots/shoes are required for this class.

54-265 Advanced Fabrication 1
Fall: 6 units
This class sets forth to gain a comprehensive understanding of the various tools found in a well-equipped fabrication shop . Shop safety will be emphasized at all times and rigorously promoted per tool. Understanding the differences between tools and when to choose each will be a constant theme. Exploring the various ways of achieving a certain result but with different tools will be a recurring theme. Since most shops use tools for multiple applications, understanding how various materials relate to various tools will be discussed in detail. For TDs only. The first task will be to do an overview of all of the common tools used for woodworking and metalworking. Then we will go through the shop tool-by-tool and make sure everyone understands what the tool was designed for, how it is used, and how it may be utilized for alternative uses.

54-266 Stage Management: Cue Lab
Fall and Spring: 3 units
Required for Production Management / Stage Management majors

54-267 Conceptual Sound Design
Fall: 9 units
Students explore the unique qualities of audio as a design element and the development of a design process through script analysis. Emphasis on the creative application and utilization of the studio in sound shaping and soundscape design. PREREQUISITE: 54-166 Introduction To Sound Design for Theater, 54-231 Design For The Stage. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.
Prerequisite: 54-166

54-268 Organized Sound
Fall: 9 units
Both music and sound design are defined by the presence of a human hand in the organization of sound. This course explores what lies at the intersection of music, technology and sound design. Using compositional techniques in conjunction with the creative application and utilization of studio techniques, field recording, editing and sound manipulation, the student will explore this interstitial landscape. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.
Prerequisites: 54-267 and 54-166

54-269 Studiocraft II
Spring: 3 units
A continuation of 169/170, this course introduces applied drafting practices, perspective drafting, 3D CAD modeling, model building, and other graphical skills. Prerequisites: 54169 and 54170 OR Instructor Permission
Prerequisites: 54-172 and 54-171

54-271 Technical Management
Fall: 6 units
Required for all sophomore Design and PTM students. This class establishes a set of standards for creative project management and introduces students to several software packages that can be utilized within these tasks.
Prerequisites: 54-157 and 54-158

54-272 Scenic Fabrication and Installation
Spring: 6 units
The Scenic Fabrication & Installation course consolidates and builds upon material presented in the first semester of Basic PTM and in the three semesters of Stagecraft class. Whether they intend to pursue careers as technicians, engineers, or managers students much understand how scenery is built and what is involved in the assembly of the scenery in the theatre. Throughout the semester students will explore the materials and equipment used by all kinds of professionals in the fabrication industry. Through this exploration students will become conversant with the kinds of properties, and the advantages and disadvantages of many different items. Along with this exploration is a concurrent investigation of entertainment industry accidents. This material is valuable in how it contextualizes the kind of work students will be involved in, and helps to drive home the very real consequences of errors pertaining to scenery. In the classroom and in lab students in this course will develop their knowledge and processes for building scenery. The course has three basic units. The beginning of the semester focuses on building materials and on tool use. Through the center of the semester course material focuses on traditional scenery practices. The end of the semester material addresses rigging systems and scenery rigging practices. Laboratory assignments tied to this course will consist of carpentry assignments in the shop and carpentry and rigging assignments during load in. Occasionally students pursuing a more customized path may have lab assignments in the paint department in the shop and in the electrics department during install. All students may receive apprentice assignments in the scenery office.

54-273 Technical Direction I
Fall: 6 units
This course is an exploration of techniques and practices of the Technical Director. The class has three main components: classroom presentation of School of Drama production technical direction process, classroom lectures centering on TD process, and project work. Over the course of the semester, students will work on two productions as paper projects. This is an opportunity to have a somewhat less stressful pass through a show, completing estimates, schedules, and drawings designed to help establish a professional foundation for the student as a technical director. All of the course components run concurrently. Prerequisites: 54272 or Instructor Permission
Prerequisites: 54-272 or 54-158

54-274 Seminar in Costume Management
Fall: 4 units
This mini course focuses on the fundamentals of organizational paperwork surrounding costume production and basic operational protocol. The evolution of this paperwork and its usefulness in multiple professional applications is covered.

54-275 History of Sound Design
Intermittent: 3 units
The history of the use of sound in theater from the Greeks to current day including study of the development of the art, significant practitioners and landmark productions.

54-277 Negotiation and Conflict Management
Fall: 3 units
This class is a focused exploration of the process of negotiating, both formally and everyday. We will examine interactions on all levels and environments, with an evaluation of tactics, strategies and the measure of success. From there, the class expands into the nature of conflicts and the manager's role in identifying and confronting them. Throughout the class, we hope to find solutions to implement in our lives and work. In-class exercises and roleplay will be a fundamental part of class activity.

54-278 Stage Management I
Spring: 6 units
This class introduces the student to the work of a stage manager on a theatrical production. Students learn the functions and responsibilities of the stage manager. Also covered: blocking notation, cue organization, rehearsal reports and AEA rules and regulations.

54-281 Foundations of Drama II
Fall and Spring: 6 units
In this course students build on the skills of Foundations I to develop acumen in targeted research in support of production. The students learn the "circles of knowledge" technique to provide evidentiary arguments concerning a play script, its author, the historical contexts in which it was written, the theoretical frameworks that may be applied to its interpretations, its production history, and what knowledge is needed to bring its themes to relevance in a modern production. As in Foundations I, there is a great deal of exposure to significant texts, both artistic and philosophical, from theatre history. Registration for this course is limited to Drama majors. All other majors must request the instructor's permission.
Prerequisites: 54-177 or 54-178

54-284 Fundamentals of Directing
Fall: 6 units
Fundamentals of Directing is a fall-semester course for Drama Design and PTM sophomores. It is an introductory course that examines some of the basic tools of the director. Emphasis is completely on theatrical work although some elements are applicable to television and film.

54-285 Alexander Technique
Fall and Spring: 1.5 units
Required Alexander work for Senior Acting and Music Theatre majors only.
Prerequisite: 54-101

54-287 Introduction to Lighting Design Skills
Spring: 2 units
Students will gain the basic skills and practical experience to use the lighting industry's primary software programs: Vectorworks and Lightwright. The class will be seminar based and allow focused opportunity to acquire the skills to execute some of the assignments in the Introduction to Lighting Design course. This course must be taken simultaneously with Introduction to Lighting Design (54-252).

54-290 IDeATe: Movement for Animators
Fall and Spring: 4 units
Movement serves as a basis for communication and visual storytelling. This course will provide actual physical movement training so that you may better understand its implications and applications for technology-based usage and your own engagement in the creative process with others. Playful participation, observation, and discussion will allow you to consider how to apply physical movement and movement theory in the areas of Animation and Special Effects, Motion Capture, Game Design, and other technology practices and research. Drawing from a number of methodologies you will explore how the variances of Time, Space, Weight, and Energy affect communication, storytelling, character development and narrative structure. We will examine the ways in which movement conveys psychological intent and emotion. This course is designed for students who may range from having no prior movement training experience to those who have some background in sports, dance or theatrical movement.

54-294 Make-Up for Performers
Spring: 2 units
PREREQUISITE: Acting/MT major in the School of Drama. Basic techniques of stage make-up and their adaptation to theatrical styles.
Prerequisite: 54-102

54-295 Advanced Fabrication 2
Fall: 6 units
Continuation of Ad Fab. For Drama PTM-TD only.

54-297 VMD Systems Studio
Spring: 6 units
This course is designed to augment the conceptual background and technical skills of First year Graduate students and newly declared VMD Sophomores, and others interested in learning about media design for theater. The course reviews foundational readings about media, technology and society and explores the skills used in contemporary media work. Through real-world examples, building custom media servers, experimenting with materials and software, rigging multiple types of display systems and visiting artists - students will learn the best practices for bringing their designs to life. A great deal of technical information will be covered including; video compression formats, projector optics, cueing software, projection mapping & custom surfaces, media servers both custom and professional, networking and control protocols, live camera systems, and stage rigging for projection systems. The class will give students a clearer perspective of the field and help them plan a fulfilling course of study, based on their goals and interests. Class projects range from presentations of research to building media installations over at Studio 201. Required for new VMD Sophomores, 1st Year VMD Grads; open to IDeATe and BXA students; others accepted up to class limit.

54-299 Dramaturgy Production:Assistant
Fall and Spring: 9 units
For Dramaturgy majors.

54-300 Dramaturgy Research Hours
Fall and Spring: 6 units
For Dramaturgy majors.

54-301 Acting III
Fall: 10 units
This is a two-semester course in Acting for Third-Year Actors & MTs who will explore performance within directed structure in various non-Fourth-Wall forms of Theatre including: Greek Tragedy, the Greek Chorus, Moliere Comedy & Brecht. This is not a course that will aspire to provide any "correct" way to play various "styles". Rather, it is a course in which to acquire new tools & perspectives when working in new theatrical worlds. Goals include: to find the appropriate level of external expression to meet the demands of the particular text & its directed world, & to "fill the Form" believably & passionately; to make active choices within a directed framework; to learn to work within industry standards; to learn the nature of the actor's "homework" in a directed framework; to include the Audience in the work.
Prerequisites: 54-201 and 54-202

54-302 Acting III
Spring: 10 units
This is a two-semester course in Acting for Third-Year Actors & MTs who will explore performance within directed structure in various non-Fourth-Wall forms of Theatre including: Greek Tragedy, the Greek Chorus, Moliere Comedy & Brecht. This is not a course that will aspire to provide any "correct" way to play various "styles". Rather, it is a course in which to acquire new tools & perspectives when working in new theatrical worlds. Goals include: to find the appropriate level of external expression to meet the demands of the particular text & its directed world, & to "fill the Form" believably & passionately; to make active choices within a directed framework; to learn to work within industry standards; to learn the nature of the actor's "homework" in a directed framework; to include the Audience in the work.
Prerequisite: 54-301

54-305 Voice for the Stage III
Fall: 5 units
Students explore voice work and various methods in more depth and Alexander alignment/awareness work to enhance vocal freedom and full body support of the voice. Areas include: breath support, vocal release, developing freedom in resonating areas, clarity in articulators, building range and stamina. Emphasis is placed on integration of methods with speaking of text. Writing projects are sometimes explored as a way to free the voice creatively and imaginatively. Voice/Alexander 1 is a pre-requisite to registering in this course.
Prerequisites: 54-105 and 54-106

54-306 Voice for the Stage III
Spring: 5 units
Students explore voice work and various methods in more depth and Alexander alignment/awareness work to enhance vocal freedom and full body support of the voice. Areas include: breath support, vocal release, developing freedom in resonating areas, clarity in articulators, building range and stamina. Emphasis is placed on integration of methods with speaking of text. Writing projects are sometimes explored as a way to free the voice creatively and imaginatively. Voice/Alexander 1 is a pre-requisite to registering in this course.
Prerequisites: 54-105 and 54-305 and 54-106

54-307 Movement III
Fall: 5 units
Prerequisite: 54-107, 54-108, 54-207, 54-208, or permission of the instructor. This course introduces students to the basic exercises of physical actor training developed by Tadashi Suzuki and examines more advanced uses of the Viewpoints method of actor training. Physically rigorous, this course challenges not only physical stamina, but also concentration, focus and the actor's sense of discipline. The use of spoken text is incorporated into the exercises in an integration of all the physical aspects of the actor's craft. This course is also designed to complement and inform the actor's entry into rehearsal and performance work. This course is required for all third year Acting majors.
Prerequisites: 54-208 and 54-207

54-308 Movement III
Spring: 5 units
Prerequisite: 54-307, or permission of the instructor This course focuses on the art of stage combat. Basic techniques of unarmed stage violence are studied and an introduction to other weapons such as knife and/or single rapier may be included. Emphasis is place not only on technique, but the acting of scenes of violence found in both classical and contemporary plays. This is a required course for all third year Acting majors.
Prerequisites: 54-208 and 54-207

54-309 Dialects and Accents
Fall: 6 units
TBA

54-310 Dialects and Accents
Spring: 6 units
For School of Drama Acting/MT students only.

54-311 Rehearsal and Performance III
Fall: 16 units
Performance training through projects at different levels of difficulty and staging, directed by students and presented in the studio theatre. The actor has the opportunity to put into practice with his/her peers, in a creative and experimental atmosphere, the principles and techniques developed in the classroom.
Prerequisites: 54-201 and 54-202

54-312 Rehearsal and Performance III
Spring: 16 units
Performance training through projects at different levels of difficulty and staging, directed by students and presented in the studio theatre. The actor has the opportunity to put into practice with his/her peers, in a creative and experimental atmosphere, the principles and techniques developed in the classroom. Note: Tues or Thurs time used as needed for performance critiques.
Prerequisites: 54-201 and 54-202

54-313 Ballet III
Fall: 3 units
This course is dedicated to honing technical skills, expanding the classical dance vocabulary to the next level of difficulty, and addressing issues of strength, stamina, and endurance. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-205 and 54-206

54-314 Ballet III
Spring: 3 units
This course continues to hone technical skills, expand the classical dance vocabulary to the next level of difficulty, and address issues of strength, stamina, and endurance. Course closed: Only for Music Theatre majors in Drama. Prerequisite: 54-313 and Permission of instructor
Prerequisite: 54-313

54-315 Jazz III
Fall: 2 units
This course is to expand the versatility of the student dancer to master more complex exercises, in dynamics, direction and rhythm using Jazz styles examined by decades. Understanding the 20th century historical background of the 20's, 30's 40's, 50's 60's and 70's. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-217 and 54-218

54-316 Jazz III
Spring: 2 units
This course continues to expand the versatility of the student dancer to master more complex exercises, in dynamics, direction and rhythm using Jazz styles examined by decades. Understanding the 20th century historical background of the 20's, 30's 40's, 50's 60's and 70's. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-315

54-317 Singing for Actors III
Fall: 2 units
The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.
Prerequisites: 54-201 and 54-202

54-318 Singing for Actors III
Spring: 2 units
The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.
Prerequisites: 54-201 and 54-202

54-319 Cabaret
Fall: 6 units
The Art of Cabaret: Explores the use of Stories and Song to communicate life experiences within an intimate setting, breaking down the invisible fourth wall for honest communication. The course includes a section on the use of the microphone for singers. This Study produces two Cabarets containing Material on a chosen Theme to provide hands-on Song Expression in a public forum.
Prerequisite: 54-220

54-321 Acting III for Directors
Fall: 9 units
An examination of various directing styles with particular attention to: verse forms including Greek and Elizabethan, comedy/ farce texts and Early 20th century styles including Ibsen and Shaw. On occasion, guest directors for our main-stage productions will be engaged to teach the style of the production that they are presently working on. Alternately, there is the possibility of this semester being used for an applied internship with a major producing organization.
Prerequisites: 54-101 and 54-201

54-322 Directing III: Immersive Theater and Independent Film
Fall: 9 units
Join theatermaker Gab Cody for a practical lab on the creative structures of Immersive Theater. We will work together, as an ensemble, to design a short form site-specific immersive experience. Employing the strategies of devised theater and collaborative creation, each member of the class will participate as a creator, bringing their particular talents and interests to bear. Techniques: documentary and narrative storytelling, immersive frameworks and practical execution, use of recorded mediums (audio and/or video)
Prerequisite: 54-222

54-323 Tap III
Fall: 2 units
This course expands tap vocabulary and clear precision of execution through moderately difficult and extended combinations. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-223 and 54-224

54-324 Tap III
Spring: 2 units
This course continues to expand tap vocabulary and clear precision of execution through moderately difficult and extended combinations. Course closed: Only for Music Theatre majors in Drama. Prerequisite: 54-323 and Permission of instructor
Prerequisite: 54-323

54-325 Actor Dance III
Fall: 2 units
This course uses basic and fundamental contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, to technically train the body using isolations and rhythmic patterns. Course closed: Only for Acting majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-201 and 54-202

54-326 Actor Dance III
Spring: 2 units
This course continues to use basic and fundamental contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, to technically train the body using isolations and rhythmic patterns. Course closed: Only for Acting majors in Drama. Prerequisite: 54-325 and Permission of instructor
Prerequisites: 54-201 and 54-202

54-327 Auditioning for the Stage
Fall: 2 units
An optional course for Junior Acting and Music Theatre majors.
Prerequisite: 54-202

54-328 Advanced Digital Sound Design Skills
Fall: 6 units
Sound Design Majors ONLY. Advanced sound creation and manipulation through student designed and constructed software and hardware. Prerequisite: Conceptual Sound Design I.
Prerequisite: 54-267

54-330 Introduction to Stage Management
Spring: 6 units
This course is intended to provide students an opening to the knowledge and skills of the professional stage manager. It will also illuminate the qualities of a good stage manager specific to personality and human interaction. Within this course we will examine the role of the stage manager throughout the full scope of creating a production, including preparatory work, rehearsal period, technical rehearsal, performance and closing.

54-331 Scenic Design: Explorations
Fall: 9 units
Students will spend the year in an exciting and intensive exploration of the process of Scene Design as well as an examination of the nature of creativity and storytelling. Students will also engage extensively in the skills a professional Scene Designer requires, such as drafting, drawing, model making, painting and general collaborative skills. Students will be expected to deal with in-depth research, scriptual examinations, careful arrangements of space, composition and groundplan, conceptual structure, real life obstacles and the elements of a successful final project. By the end of this course, students will have improved their overall design skills, have some projects they can include in their portfolio and have created new routes toward their creativity. (pre-req, intro to Scene Design)

54-332 Scenic Design: Boot Camp
Spring: 9 units
A rapid-fire design course for scenic design majors. This course offers the students the opportunity to work on six projects over the course of the semester. These projects may include contemporary, classical and non-linear plays, as well as TV workshop and a new plays collaboration with dramatic writing students. Co-taught by Scenic Design faculty.
Prerequisite: 54-250

54-333 Production Personnel Management
Fall: 6 units
Study of the management of production personnel for live theatrical productions. In depth analysis of union contracts from a management perspective: AEA, IATSE, USA. Projects in scheduling and budgeting based on those contracts. Study of hiring, evaluating, and retaining a quality staff. Examination of the role of safety protocols in production. The Course concentrates on the relationship between the Production Manager and all of the personnel that one comes in contact with. For Junior SMPM and TD ONLY or with instructor permission.

54-334 Production Resource Management
Spring: 6 units
This course examines the management of resources for the production of live theatrical productions. We start with analysis of scripts, to find the foundation for resource allocation. Then we move on to study the allocating two of the largest production resources: time and money. A significant exploration of the tracking of time and money extends throughout the course, with half of the class sessions taking place in a computer cluster, where we concentrate on advanced application of Excel, Access, and specialized calendar software.

54-335 Auditioning for the Screen
Spring: 2 units
An optional course for Junior Acting and Music Theatre majors.

54-339 Stage Management Seminar
Fall and Summer: 3 units
This class provides stage managers an opportunity to participate in in-depth discussion about the production process. Specific issues related to CMU productions and troubleshooting problems are a particular focus. The class also presents guest speakers on related topics and will work on longer-term projects as needed.

54-340 Stage Management Seminar
Spring: 3 units
This class provides stage managers an opportunity to participate in in-depth discussion about the production process. Specific issues related to CMU productions and troubleshooting problems are a particular focus. The class also presents guest speakers on related topics and will work on longer-term projects as needed.

54-341 Fundamentals of Costume Design
Fall: 9 units
Multiple studio projects comprise this one semester course that focuses on the principals and elements of design, including color theory, as they relate to Costume Design. Hands-on practical workshops include a Television Workshop component with celebrated CMU alumni, and a dance component that culminates in the second semester Dance/Light Concert. A fabric Identification component rounds out the semester. PRE-REQUISITE: Declared Costume Design Major in School of Drama. All others: Portfolio Review and special permission of teacher required. Drawing For The Theatrical Designer & Figure Drawing may be taken concurrently. FOR: First semester Graduate Costume Design and Costume Production Students, First semester Junior Costume Majors.

54-342 Costume Design for TV and Film
Spring: 5.5 units
A mini course in the second semester that explores the aesthetic and technical processes of designing costumes for the screen. The course introduces film-specific practical skills including the fundamentals of analyzing and breaking down screenplays for costume design, what design means during the pre-production and shooting phases of a production, and the aesthetic and technical differences of designing for the camera's eye compared to designing for the human eye. The course will consist of lectures, visual presentations, including viewing of films that illustrate the processes described in class, script break-down assignments, and design process projects. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: Second year Graduate Costume Design majors and Senior Costume Design students.

54-346 Introduction to Costume Construction
Spring: 6 units
This sophomore level course is designed to provide an intermediate level of training in the area of clothing construction. Students will learn how to read patterns, prepare and cut fabric appropriately for construction purposes, and complete a garment employing necessary finishing techniques. Additionally, students will be exposed to the rudimentary skills necessary for basic flat patterning and begin the process of project time management and comprehension of product value.

54-349 Automated Lighting Technology
Spring: 6 units
Students learn and practice programming techniques on the Hog4 series of lighting control consoles. Advanced programming techniques are explored, including media server control and user-defined commands for the console. Different applications are introduced, but the primary focus is on programming for live music performance.
Prerequisite: 54-369

54-350 Scenic Design Forum
Fall and Summer: 1 unit
Required weekly meeting of all Scenic Designers.

54-351 Theatrical Lighting Design
Fall: 9 units
The student's ability to analyze and translate information in the script to descriptive stage pictures is developed in a more in-depth process. Verbal, written and visual communication of ideas is emphasized and explored through texts and lab work. Issues of collaboration with the director and other members of the design team are discussed as part of the design process. Prerequisites: 54252
Prerequisite: 54-252

54-352 Musical and Opera Lighting Design
Spring: 9 units
Through hands-on lab exercises and preparation of full lighting design plots, students will study lighting design for Musical Theater and Opera. The class will learn to visually analyze the emotional content of music, explore the various forms of musical performance, learn how to develop a design process, create focus in a large-scale space, and strategies for implementing a design.
Prerequisite: 54-351

54-353 Structural Design I
Fall: 9 units
Required for all senior undergraduate Technical Direction students. A concentrated training in Structural Design specifically developed for the theater technician. This course teaches the process of Allowable Stress Design for the engineering of scenic structures in wood and steel. Drama majors only, or with instructor permission.

54-354 Structural Design II
Spring: 9 units
Required for all senior undergraduate Technical Direction students. Upon completion of this two-semester sequence, students are familiar with beam and column design/specification, truss design, tensile systems and structural connections.
Prerequisite: 54-353

54-355 30 Hour OSHA
Intermittent: 3 units
For Production Technology & Management majors.

54-357 Directing: Production III
Fall: 12 units
Assignments as stage manager or assistant director.

54-360 Leadership Workshop: Ethics & Innovation
Intermittent: 6 units
This course will be an exploration of both innovative strategies and the ethics of leadership within the performing arts. It will build on the management principles covered in foundational courses and is designed to offer the student an approach to leadership development that is tailored to the individuals strengths and needs as well as their role within theatrical organizations. For PTM students only or with permission from the instructor.
Prerequisite: 54-333

54-361 Production Preparation
Fall and Spring
Participation in School of Drama productions in design or production roles.

54-363 Dramaturgy 5: Devised and Documentary Theatre
All Semesters: 9 units
Dramaturgy students only. Others by permission.
Prerequisites: 54-109 and 54-184

54-364 Dramaturgy 6: Critical Writing
Intermittent: 9 units
For Dramaturgy majors.
Prerequisite: 54-184

54-365 Machine Design I
Spring: 9 units
Required for all senior undergraduate Technical Direction students. In this course, concepts from Physics of Stage Machinery are applied to the specification, selection, design and assembly of real-world mechanical components for the realization of winches, turntables, wagons and lifts for theatrical use. Drama majors only, or with instructor permission.
Prerequisite: 54-366

54-366 Physics of Stage Machinery
Fall: 9 units
Required for all junior undergraduate PTM students. This is a one-semester pure Physics class designed to give theater technicians a base knowledge of Newtonian Physics, a pre-requisite for later courses in Machine Design. For this course, I have obtained special permission to use an unpublished text by Alan Hendrickson of the Yale University school of Drama. Drama majors only, or instructor permission.

54-367 Lighting Design Skills
Fall: 6 units
Students will concentrate on developing the skills necessary for lighting designers to successfully implement their designs in the theatre. Content includes communication, CAD programs, paperwork, focusing the show, programming conventional and moving light consoles, cue writing and expectations and responsibilities of the design assistant.

54-368 Lighting Management I
Spring: 4 units
Lighting Management I is an overview of the management process within a theatrical lighting department. Topics covered include communication tools, paperwork and physical resources used by department heads to facilitate lighting designs, as well as other duties performed within that role.
Prerequisite: 54-249

54-369 Lighting Management II
Spring: 4 units
Lighting Management II continues the investigation of the role of the department head within a theatrical lighting department, concentrating on skills needed to perform the role within the School of Drama.

54-371 Personalized Responsive Environments
Fall: 9 units
[IDeATe collaborative course] Environmental factors have a significant impact on mood and productivity. Creating responsive environments necessitates the design of surroundings that are able to metamorphose in order to optimize user strengths and available resources and evolve in stride with user needs. This course will investigate the development of spaces that adapt to user preferences, moods, and task specific demands. Both the design and engineering of such personalized environments will be explored. Central course concepts will include, understanding the user, integrating various modalities (e.g., light, heat, sound) to support the changing needs of task and user, and the creation of adaptive environments that learn user preferences over time. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 62-150 or 60-223 or 18-090 or 15-104 or 16-223

54-372 Theatre for the Ear
Spring: 6 units
Survey of aural storytelling with technology focusing on forms with no visual component. Topics include the history of radio drama to present day, radio sound art, cut-up and tape manipulation, comedy records and podcast dramas. Prerequisites: 54-166 Introduction To Sound Design, 54-267 Conceptual Sound Design 1 Restrictions: The course is open to sound design majors or with permission of the instructor.

54-373 Draping for the Designer I
Fall: 6 units
This is a semester introduction to the arena of the draper. This course illustrates what the draper's role is in effectively spearheading garment production, emphasizing the collaboration and discussion skills needed to follow a garment's design from page to stage. The course instills a strong foundation in pattern creation skills through the use of the dress or suit stand and fosters a laboratory environment for imaginative solutions in clothing pattern development and garment creation. Additional skills such as application of research, garment fitting procedures, pattern manipulations and refinements and complete construction plans are explored. This class provides tangential learning through a thorough investigation of fabric, its history and identification, sculptural and spatial relationships, strategic planning, development of fine motor skills, and exposure to a broad spectrum of materials and methods that can be adapted to other purposes.

54-374 Musical Theater Audition
Spring: 3 units
Missing Course Description - please contact the teaching department.

54-375 IDeATe: Robotics for Creative Practice
Fall: 9 units
Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include programmed motion control, pneumatic machine design, closed-loop feedback systems, machine choreography, and human-robot interaction. Discussion topics include contemporary kinetic sculpture and animatronics. This interdisciplinary course is part of IDeATe Physical Computing but is open to any student.

54-376 Entertainment Rigging
Spring: 3 units
This course is a survey of the techniques and practices of theatrical rigging. The course has two main components: permanently installed rigging systems typically found in theatres, and background and technical information concerning the components typically used for stage rigging. Discussion topics include selection criteria for line, hardware, and terminations stressing entertainment industry standards, workplace safety and common industry misconceptions. Time permitting the course will shift from a general discussion of components to their assembly into custom rigging systems & solutions. Instructor's permission only.

54-377 Production Composition Studio
All Semesters: 3 units
This course is a laboratory style studio class. It is designed to support the student through the process of composing music for theatrical & film productions and projects. Students will be required to bring ongoing creative work materials to class.
Prerequisites: 54-389 and 54-390

54-378 Technical Direction II
Spring: 6 units
This course is an exploration of techniques and practices of Technical Designers. The class has four main components: an exploration of the types of strategies used by Technical Designers to arrive at solutions, building an expert vocabulary for discussion of technical design issues, development of actual technical solutions, on paper, in discussion, and in the shop, discussion of any pertinent technical issues for any of the school productions while in development.
Prerequisite: 54-273

54-379 Scenic Design Skills: Drafting
Fall: 4 units
This mini explores careful and clear graphic communication in drafting. A series of weekly drafting exercise, either hand or CAD, take each student through the process of drafting a scenic design. Emphasis is placed on precision, clarity, and appropriate use of standard drafting conventions.

54-380 Music Reading for Production
Fall: 3 units
This class gives the basics of music theory, musical terminology and score reading. Students focus on the difference in various musical scores, ie. piano/vocal, full, hand written scores. Students are guided in classroom listening which a wide variety of music including, opera, musical theatre, ballet, and choral/orchestra works.

54-381 Special Topics in Drama: History, Literature and Criticism
Fall and Spring: 6 units
Every semester, members of the School of Drama's faculty offer seminars on special topics that investigate some aspect of theatre history, dramatic literature, dramatic theory, or a particular author, period, or genre. Like all Dramatic Literature classes, these are academically rigorous, requiring some amount of intensive critical reading and writing. Registration for this course is limited to Drama majors. Spring 2018: Contemporary American Playwrights of Color(s) This course will introduce students to a variety of contemporary plays by African American, Native American, Asian American, Latinx, and Middle Eastern American playwrights. The reading will focus primarily on plays premiered in the past ten years. The reading list will be gender-balanced. The syllabus is still under construction (pending publishing dates for certain plays) but the following is a representative sample of writers whose works are likely to be included: Branden Jacobs-Jenkins Tanya Saracho Hansol Jung Lynn Nottage Larissa Fasthorse Rajiv Joseph A. Rey Pamatmat Qui Nguyen
Prerequisites: 54-281 or 54-282

54-383 Introduction to Digital Media
Fall: 9 units
Software Covered: AutoCAD, Photoshop, Illustrator, InDesign, Sketchup, Vray for Sketchup Concepts Covered: 2D Graphics, Architectural Drafting, 3D Modeling & Rendering, Hybrid Representation Limited to Drama students: Scenic Design Juniors, 1st Year Graduate Students

54-386 Scenic Design Skills: 3D Model Making
Spring: 4 units
In this mini students explore a variety of three-dimensional media techniques as they learn to build models for the Scenic Designer. Students will investigate many aspects of model-making, from basic structural ideas to complex organic and architectural forms, furniture, and advanced techniques such as scale painting, soldering and carving. Through these methods, students will develop a better understanding of space and objects in space in the theatre.
Prerequisite: 54-231

54-387 Dramaturgy: Production I
Fall and Spring: 9 units
Working as a production dramaturg for a Horizons Reading or as an assistant dramaturg.

54-389 Composition for Theatrical Sound Design 1
Fall: 9 units
Composition for Theatrical Sound Design 1 This course will concentrate on developing compositional skills for use in theatrical sound design. The full length of this course is designed to take place over two semesters. The rst semester will examine the building blocks of composition such as rhythm, modes, harmony and counterpoint. The second semester will focus on more advanced skills in composition within a theatrical context. Through projects distributed throughout the semester you will practice the skill-based techniques of music notation, orchestration, synthesis, sequencing, and the creation and utilization of sample-based instruments. This course will also cover textual analysis as it applies to both the inspiration for composition and to the more direct challenge of setting music to text.

54-390 Composition for Theatrical Sound Design 2
Spring: 9 units
This course will concentrate on further developing compositional skills for use in theatrical sound design. The full length of this course is designed to take place over two semesters. This is the second semester and builds on compositional techniques such as writing melody, harmony, counterpoint and orchestration techniques. The second semester focuses particularly on more advanced skills in composition within a theatrical context. Through projects distributed throughout the semester students practice the skill-based techniques of music notation, orchestration, synthesis, sequencing, working with instrumentalists and the creation and utilization of sample-based instruments. This course will also cover textual analysis as it applies to both the inspiration for composition and to the more direct challenge of setting music to text.

54-391 Media Design Skills
Fall and Spring: 3 units
to be determined

54-392 Scenic Design Skills: 2D Drawing and Rendering
Spring: 4 units
This mini offers practice in two-dimensional drawing and rendering for the theatre.

54-397 Sound Design For Interactive Environments
Spring: 9 units
This course will examine the process, execution and implementation of sound design for interactive and non-linear storytelling paradigms. Emerging trends in immersive theater, gaming, installation art and multi-media place unique demands on the sound designer both in terms of content and delivery. The student will explore how these demands effect the fundamental processes of design, development of content and flexible delivery systems. Through a combination of directed readings, exploration of current & emerging trends, and project assignments the student will be encouraged to experiment and explore design modes and methodologies that support this flexible method of storytelling.
Prerequisites: 54-268 or 54-267

54-398 Special Topics in Sound Design
Spring: 9 units
A one semester course covering various rotating topics including the history and critical theories of film sound design, the history of sound recording and technology, Foley sound, recording and editing techniques, and 5.1 audio. Prerequisites: 54-166 Introduction To Sound Design for Theater, 54-267 Conceptual Sound Design. Restrictions: The course is open to Drama sound design majors and minors, Music Technology majors and minors or by permission of the instructor.
Prerequisites: 54-267 and 54-166

54-399 Decoding Media
Fall: 9 units
Media technologies are designed to do a lot with very little effort. This creates a problem of abundance for artists trying to use these technologies in creative ways. One can relatively quickly pull images off the internet and project them huge onstage, but what does it mean? Decoding is the term I'm using to help you keep control of your process and create meaningful (not just dazzling) imagery for the stage. The entire theatrical process can be considered as a series of decodings and re-encodings, first decoding the text/idea (by the creative team), re-encoding (the design) and finally decoding by the audience. This class is designed to give students a solid foundation in contemporary media design skills while simultaneously providing an examination of the function of theater historically and the ways media technologies fill those needs today. Early assignments focus on students use of media in their everyday lives, by keeping media journals and bringing in media objects for examination. Later classes focus on taking ideas from this research and applying them in conceptual stage designs for an ancient Greek play and then a controversial adaptation from the 1990's by Sara Kane. Students learn how to go from textual analysis to a visual interpretation and staging with media. The class takes students through the process of initial creative brainstorming, to communication tools (concept sketches, digital renderings, 3D models), onto specifying a design through CAD documentation, projection optics calculations and final design presentations.

54-400 Staging Media
Spring: 9 units
Staging Media is a practical, process-oriented class, focused on building the skills to go from a conceptual design to an actual completed show. We cover how to create, rehearse with and stage meaningful media designs. Through real-world examples, students will learn the best practices for bringing their designs to life. Students are expected to master a wide range of material. Required for new VMD Juniors, 1st Year VMD Grads; others by permission.

54-401 Through the Lens : Storytelling with the Camera
Fall: 9 units
A unified, cross-disciplinary class focused on the artistic and technical requirements for single-camera storytelling. Students from each discipline will receive theoretical instruction, progress to in-class practicum work, and become an integrated production team on a field film project experience. The idea embraces: a single weekly time-frame for classes across several disciplines, a reintegration of management students; and a retooled Camera Lab class in which actors, writers, designers, managers and directors collaborate. Professional guest artists will be frequent visitors to the classroom and production process. Classes will include topics of universal interest to the larger group as well as discipline specific sessions.

54-402 Through the Lens : Storytelling with the Camera
Spring: 9 units
A unified, cross-disciplinary class focused on the artistic and technical requirements for single-camera storytelling. Students from each discipline will receive theoretical instruction, progress to in-class practicum work, and become an integrated production team on a field film project experience. The idea embraces: a single weekly time-frame for classes across several disciplines, a reintegration of management students; and a retooled Camera Lab class in which actors, writers, designers, managers and directors collaborate. Professional guest artists will be frequent visitors to the classroom and production process. Classes will include topics of universal interest to the larger group as well as discipline specific sessions.
Prerequisite: 54-401

54-403 Advanced Speech Techniques
Fall: 3 units
TBD

54-405 Digital Narratives
Fall: 4 units
Digital Narratives combines options from the School of Drama in a new configuration: through working collaboratively across disciplines, students investigate multimedia approaches to contemporary theater and new ways of storytelling. Directors, designers, actors, and dramaturgs work in groups to generate original ideas, images, texts, and material in a workshop environment. These working groups create projects over the course of the semester which are shown in informal presentations. The emphasis is on process, not product — devising an interdisciplinary performance requires a keen focus on combining creative invention with a rigorous structure of concept development — both of which are explored here. We also examine the work of several significant contemporary theater artists whose work approaches collaboration across a variety of disciplines. Artists have included: Ariane Mnouschkine, Dumbtype, Complicite, Ralph Lemon, Robert LePage, and more. Students learn to define and distinguish these artist's approaches through viewing video excerpts, readings, and discussion. This class is an opportunity to explore avenues outside of traditional production modes and beyond each student's individual discipline. We focus on the process of creating a theatrical language which truly integrates disciplines.

54-406 Media Creation Studio I
Fall: 6 units
Missing Course Description - please contact the teaching department.

54-407 Movement IV
Fall: 4 units
Movement IV is a cross-option course, wherein Sophomore Designers build masks for the Senior Actors to use in the creation of a movement mask piece based on a classic text. The course gives Senior Actors an opportunity to create an original ensemble performance piece, bringing up to 30 masks to life, using skills learned in the previous classes in mask work (Neutral Mask, Commedia dell'Arte, character and larval masks). Due to the necessity of working as an ensemble in the creation of this piece, the students must work together in various roles: as actors, of course, but also as directors, writers, musicians, dramaturges and stage managers; this course offers a rare chance for students to experiment with actor-created theatre, as well as, because it is cross-option, an opportunity for actors and designers to work together to create masks which are able to be brought to life through movement, that are comfortable, offer enough visibility, are secure during activity, etc. A unique learning laboratory for designers and actors to interact involving both artistic and practical issues related to the creation and use of these masks as theatrical metaphor. Limited to Senior Actors/MTs.
Prerequisites: 54-207 and 54-208

54-408 Movement IV
Spring: 4 units
In the Senior year, students may study stage combat, including hand-to-hand, quarterstaff, and single rapier, leading to scene work incorporating these skills. Other studies might include dramatic acrobatics, circus skills, and Eastern disciplines such as yoga, Tai Chi, etc. Focus on personal physical style; application of movement training on the mainstage in performance.
Prerequisites: 54-207 and 54-208

54-409 Theatre Lab for Undergraduates I
Fall
This is a two-semester class which teaches the collaborative process of theatre — including the role of the living dramatic writer. New scripts are written by graduate dramatic writers, then developed and realized by junior actors, senior dramaturgs graduate and undergraduate directors with the playwright. This work results in 10-minute play scripts, one acts, monologue dramas, and the texts for the MFA Thesis Productions. This class is co-taught by the Acting Dramatic Writing, Dramaturgy and Directing Options.

54-410 Theatre Lab for Undergraduates II
Spring
Theatre Lab is a place to practice collaboration. We will examine and explore the relationships between actor, director, and playwright in working on new plays. The objectives are to prepare students to work collaboratively on new play production as it is practiced in the field, to understand the responsibilities of actor, director, and playwright in work on a new text, and to practice being an outstanding collaborator.

54-411 Rehearsal and Performance IV
Fall: 16 units
Participation outside of class requirements in departmental productions. Putting into practice the techniques acquired over the years of training and exploring the development of a performance played before the public over two weeks.
Prerequisites: 54-311 and 54-312

54-412 Rehearsal and Performance IV
Spring: 16 units
Participation outside of class requirements in departmental productions. Putting into practice the techniques acquired over the years of training and exploring the development of a performance played before the public over two weeks.
Prerequisites: 54-311 and 54-312

54-413 Showcase
Fall: 6 units
Senior acting class for actors and Mt's who are in good standing and in position to graduate in the Spring. Preparation for the New York and Los Angeles Showcase presentations.
Prerequisites: 54-301 and 54-302

54-414 Showcase
Spring: 9 units
Senior acting class for actors and Mt's who are in good standing and in position to graduate in the Spring. Preparation for the New York and Los Angeles Showcase presentations.
Prerequisites: 54-301 and 54-302

54-415 Broadway Dance Styles
Fall: 5 units
This course is designed to provide the student with a practical and historical knowledge of the dance repertoire in American Musical Theater using the original choreography from prominent Broadway choreographers. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisite: 54-319

54-416 Broadway Styles
Spring: 5 units
This course continues to provide the student with a practical and historical knowledge of the dance repertoire in American Musical Theater using the original choreography from prominent Broadway choreographers. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-319

54-418 Songs for Showcase
Spring: 2 units
Vocal preparation and Song Arrangements and Song Cuts explored for the Senior Showcase presentation in New York City.
Prerequisite: 54-500

54-419 Voice & Speech IV
Fall: 2 units
For Senior Acting majors only.

54-420 Voice & Speech IV
Spring: 2 units
TBA

54-421 Directing: Text to Stage
Spring: 3 units
TBD

54-422 Directing IV
Spring: 6 units
Encounter major 20th century theatrical and dramatic movements. Specific concentration on directorial innovations in the last half of the 20th century

54-423 Tap IV
Fall: 2 units
This course presents advance tap vocabulary and challenges the ability of the student to master advanced repertoire at a consistent professional level. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-323 and 54-324

54-424 Percussion Ensemble
Spring: 2 units
The course continues to presents advance tap vocabulary and challenges the ability of the student to master advanced repertoire at a consistent professional level. Course closed: Only for Music Theatre majors in Drama. Prerequisite: 54-423 and Permission of instructor
Prerequisite: 54-423

54-430 Master Class/Music Theater Pedagogy
Intermittent: 2 units
In depth exploration and analysis of professional music theater repertoire.

54-431 Scenography
Fall: 9 units
A core design class between scenic designers, costume designers, media designers, and directors collaborating to create projects on paper. This class allows students to experiment away from the pressure of a realized production. The course encourages students to cross traditional boundaries in their own work and to focus on the idea of world building for their projects. This class often includes guest designers and directors.

54-432 Scenic Design: Modern Classical
Spring: 9 units
This is an advanced scenic design class. Scenic design students demonstrate an understanding of visual storytelling through class discussion and practice in the art of theatrical scenic design. Co-taught by Scenic Design faculty built around two plays or musicals, one contemporary and one classical.

54-436 MT Senior Voice Coaching
Spring: 1 unit
No course description provided.
Prerequisite: 54-500

54-437 MT Senior Voice Coaching
Spring: 1 unit
Tbd
Prerequisites: 54-302 and 54-301

54-438 Acting IV
Spring: 3 units
Introduces students to improv performance; gives students an improv vocabulary; increases students freedom on stage; stimulates students sense of play; and increases students awareness of rhythm/timing/build/fall/recovery
Prerequisites: 54-301 and 54-302

54-441 Costume Design for Dance
Fall: 5 units
A mini exploring the design elements specific to the aesthetic and performance requirements of dance. The course will examine the design of costumes at significant points in the history and evolution of dance, from classical ballet to a wide range of modern genres. Coursework will consist of lectures, visual presentations, viewing of filmed footage of notable dance performances, and research and design projects. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: Second year Graduate Costume Design majors and Junior Costume Design students.

54-442 Costume Design for the Classics
Spring: 5 units
This Mini 3 focuses on a range of playwrights and classic theatre genres from among Moliere, Brecht and Shakespeare. Special attention is paid to process, research, critical thinking, character development, style, nuts and bolts and the honing of each individual designer's skills. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: First year Graduate Costume Design majors and Junior Costume Design students.
Prerequisite: 54-341

54-444 Draping for the Designer II
Spring: 3 units
Draping for the Designer II is a continuation and development of the proficiencies established in Draping for the Designer I. This course emphasizes the draper's role in the creation of period women's wear: its history, unique pattern challenges, specific construction techniques, and how to manage its creation in the workroom. The synthesis of historical understanding with requirements for the performing arts is underscored. Through the patterning, fitting and making of a multi-layer, historic costume each student undertakes interrelated projects that allow for the application of research, development of complex patterns, composition of complete construction plans and fostering of effective teamwork. To take this class, the student needs to have taken either 54-373 Draping for the Designer I or 54-814 Draping for the Graduate Designer I or to have a background in draping and gain permission from the instructor.
Prerequisite: 54-373

54-445 Professional Preparation
Fall: 3 units
A brief introduction for design-oriented pre-professionals to the issues, challenges and conventionally-held practices of responsible self-employment. Specific topics such as branding, resumes, cover letters, union contracts, websites and taxes will be introduced through lectures, guests, discussions and handouts. No testing outside of class is anticipated for the successful completion of this course.

54-446 Professional Preparation
Spring: 3 units
An introduction to the issues and conventionally held practices for the development of responsible self-employment by design-oriented professionals. Discussions investigate the challenges of conducting business within the competitive marketplace of performance-based industries.

54-447 Figure Drawing
Fall: 3 units
Costume Majors have priority, then Design Majors. This course explores the realistic and expressive depiction of the human form primarily in two dimensional media. Working primarily from the live model, exercises will be undertaken that address gesture, proportion, movement, anatomy and structure, composition and expressive form. Students will experience a variety of media and formal approaches to the figure, working from nude, draped, and clothed male and female models. A primary goal of the class is to develop the ability to create the human figure from imagination, based on intensive empirical study of the forms and structures of the human body from life.

54-449 Dramaturgy Professional Prep 1
Fall: 3 units
Professional Prep for Dramaturgy students

54-450 Painting for the Theatrical Designer
Intermittent: 9 units
This studio course engages students in watercolor and acrylic study of subjects relative to the development of scene and costume designers. The human figure, architecture, landscape, furniture, clothing, accessories, fabrics, props and building materials for both scenery and costumes are explored. Rigorous practice required. PRE-REQUISITE: Drawing for the Theatrical Designer. All others: Portfolio Review and special permission of teacher required. FOR: All Design/PTM majors- specifically scene and costume design students
Prerequisite: 54-473

54-451 Architectural Lighting Design
Fall: 9 units
Missing Course Description - please contact the teaching department.
Prerequisites: 54-349 and 54-350 and 54-352

54-452 Architectural Lighting Design
Spring: 9 units
tbd
Prerequisite: 54-252

54-453 Production Management Workshop
Fall and Spring: 3 units
Investigates the organization, planning and interpersonal skills required to successfully manage a live theatrical production. Course is discussion based on 1) participants experience in laboratory productions in the School of Drama, 2) current practical examples of experiences of professional production managers, and 3) contemporary management texts. Topics covered include: Budgeting, Scheduling, Communication, and Project Management. Permission of instructor required.

54-454 Advanced Topics in Stage Management I
Spring: 3 units
For Production Management and Stage Management majors.

54-455 Production Data Manipulation
Spring: 6 units
Required for Production Management / Stage Management majors.

54-456 Production Management Workshop
Spring: 3 units
Investigates the organization, planning and interpersonal skills required to successfully manage a live theatrical production. Course is discussion based on 1) participants experience in laboratory productions in the School of Drama, 2) current practical examples of experiences of professional production managers, and 3) contemporary management texts. Topics covered include: Budgeting, Scheduling, Communication, and Project Management. Permission of instructor required.

54-457 Directing: Production IV
Fall: 12 units
SENIOR DIRECTING PROJECT: This is a 90-minute, public, fully-designed presentation directed by a 4th-Year Directing student with the following goals: to publicly realize a playwright's purpose for a live audience; to tell an entire theatrical story with a beginning, progression & ending; to work as a team with actors & design team to shape a cohesive & coherent theatrical presentation; to extend practical understanding of Theatre as a collaborative process; to synthesize & apply prior studies at Carnegie Mellon.

54-458 Directing: Production IV
Spring
SENIOR DIRECTING PROJECT: This is a 90-minute, public, fully-designed presentation directed by a 4th-Year Directing student with the following goals: to publicly realize a playwright's purpose for a live audience; to tell an entire theatrical story with a beginning, progression & ending; to work as a team with actors & design team to shape a cohesive & coherent theatrical presentation; to extend practical understanding of Theatre as a collaborative process; to synthesize & apply prior studies at Carnegie Mellon.

54-459 Future Stages for Undergrad Directors and Dramaturgs
6 units
FUTURE STAGES is a graduate level course (Drama undergraduates by permission only) which combines options from the School of Drama in a new configuration: through working collaboratively across disciplines, students investigate multimedia approaches to contemporary theater and new ways of storytelling. Directors, designers, actors, and dramaturgs work in groups to generate original ideas, images, texts, and material in a workshop environment. These working groups create projects over the course of the semester which are shown in informal presentations. The emphasis is on process, not product — devising an interdisciplinary performance requires a keen focus on combining creative invention with a rigorous structure of concept development — both of which are explored here. We also examine the work of several significant contemporary theater artists whose work approaches collaboration across a variety of disciplines. Artists have included: Ariane Mnouschkine, Dumbtype, Complicite, Ralph Lemon, Robert LePage, and more. Students learn to define and distinguish these artist's approaches through viewing video excerpts, readings, and discussion. This class is an opportunity to explore avenues outside of traditional production modes and beyond each student's individual discipline. We focus on the process of creating a theatrical language which truly integrates disciplines.
Prerequisite: 54-222

54-463 Dramaturgy Research Hours
Fall and Spring
TBD

54-464 PTM Professional Practice
Spring: 3 units
A seminar about issues surrounding a career as a technical manager. In a series of presentations and discussions students will encounter tools and strategies for job seeking and personal promotion. Guest lecturers will present materials on professional obligations like insurance and taxes and non-salary compensation like retirement and health benefits.

54-467 Costume Design with Music
Spring: 5 units
A rigorous second semester exploration of costume design for musicals and opera that engages students in aesthetic and practical techniques applied toward these two genres. Special attention paid to music skills, process, research, designing for principals and chorus, swatching, nuts and bolts and the honing of each designer's individual skills. PRE-REQUISITE: Design/ PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: First year Graduate Costume Design majors and Senior Costume Design students.

54-468 Theater Management
Intermittent: 6 units
to be determined

54-469 Dance Lighting Design
Fall: 3 units
Design for Dance Light.

54-470 Costume Rendering
Spring: 9 units
PRE-REQUISITES: Drawing for the Theatrical Designer, Major in Design Option of School of Drama FOR: Graduate and Undergraduate Design Costume Majors only. Instructor Approval required. DESCRIPTION: this fast-paced course focuses on techniques and exercises specific to the development of refined and versatile costume renderings. A variety of mediums and methods are explored including colored pencil, marker, ink, Doctor Martin's dyes, watercolor and acrylic as well as transfer drawings, resists and the use of other techniques. Color, texture, pattern, nude and clothed human models are carefully studied and rendered. Students also apply course techniques to development of designs for production and portfolio preparation.
Prerequisite: 54-473

54-473 Drawing for Theatrical Designers
Fall: 9 units
This semester-long basic drawing course focuses on developing hand-eye coordination through discreet exercises that allow the theatre student multiple entry points into drawing. Developed for theatrical design students, accurate drawing of proportion while viewing first hand subjects and research images is stressed. Marker and pencil use only. Rigorous practice required. PRE-REQUISITE: Design/PTM major. All others: Portfolio Review and special permission of teacher required. FOR: First semester Graduate Design and Production Students, First semester Junior Costume Majors, other Design/PTM students by consent of instructor.

54-474 Professional Prep for Dramaturgs
Spring: 3 units
TBD

54-475 Advanced Topics in Stage Management II
Fall: 3 units
Special topics in Stage Management for the experienced manager

54-476 Advanced Media Creation Studio
Fall: 6 units
Advanced topics in media creation for the stage. Students will use camera and software based tools to develop content for stage and installation.
Prerequisite: 54-406

54-477 Technical Direction III
Fall: 6 units
Required for all senior undergraduate Technical Direction students. This "capstone" course is the second semester of a sequence requiring application of concepts from earlier courses including Standard Scenery Construction, Production Planning, Structural Design, Stage Machinery Design and Technical Design 1. This is a project-based course requiring weekly presentation of solutions to various "unusual" technical challenges, drawn from actual production experiences. Thorough documentation (shop drawings, budgets, build schedules, etc.) is a requirement for each project.
Prerequisite: 54-378

54-478 Lighting for the Camera
Fall: 3 units
Through hands-on exploration in a studio setting, students will learn the basics of how to light for camera. A professional television lighting designer will mentor the students through the design process in a three-day workshop. Student teams will be formed comprised of a director, writer, lighting designer, costume designer, art director and actors. Each teams script will be produced in the Wells Video Studio as a three-camera shoot. Following the completion of taping each scene, students will view the final results and receive feedback on their work.

54-479 Lighting for the Camera 2
Intermittent: 3 units
Through hands-on exploration in a studio setting, students will learn the basics of how to light for camera. A professional television lighting designer will mentor the students through the design process in a three-day workshop. Student teams will be formed comprised of a director, writer, lighting designer, costume designer, art director and actors. Each teams script will be produced in the Wells Video Studio as a three-camera shoot. Following the completion of taping each scene, students will view the final results and receive feedback on their work.
Prerequisite: 54-252

54-480 Technical Direction IV
Spring: 6 units
The purpose of this class is to prepare Technical Directors as Technical Designers, specifying the engineering and fabrication of discrete scenic elements in a production context. Upon completion of this course, students should be able to: Understand how elements function to support production Recognize the limitations of standard approaches Develop unique approaches to technical challenges where appropriate Work with an ever-expanding body of methods, materials and hardware Integrate knowledge from prior PTM coursework Develop effective drawings and prototypes Iterate technical designs to achieve optimization
Prerequisite: 54-477

54-486 Understanding Textiles
Spring: 3 units
Understanding Textiles is a half-semester introduction to the textiles used for the performing arts. This course begins with an overview of the historical development of textile technology and the role cloth plays in world economies. Next it examines weaving structures and how they impact suitability for particular applications. Techniques for identifying fibers, weaves and fabric density are learned. The course culminates with a project that uses all the explored skills, a fabric in history swatch book. Each student takes an era of history, researches cloth production at that time, finds period appropriate swatches, accurately identifies them and suggests uses for each. These individual chapters are combined into a large resource book, a copy of which each participant keeps for future reference.

54-487 Dramaturgy: Production II
Fall and Spring: 12 units
Working as a production dramaturg for a School of Drama production in the junior year.

54-488 Dramaturgy: Production II
Spring
Working as a production dramaturg for a season show or a professionally-produced show at a LORT or similarly-ranked theatre in the US or abroad, in senior year.

54-489 Dramaturgy: Internship
Fall and Spring: 9 units
Professional internship with a dramaturg at a LORT or similarly-ranked theatre in the US or abroad.

54-490 Dramaturgy: Internship
Spring
Professional internship with a dramaturg at a LORT or similarly-ranked theatre in the US or abroad.

54-491 Concert Lighting Design
Fall: 9 units
Students will explore lighting design for concert touring. Emphasis will be on the conceptual development, design process, music analysis, methods of rendering ideas and strategies for implementation of designs. The course will demonstrate methods of working with the tools, vocabulary and technology available to the concert lighting designer.

54-493 Business of Acting
Fall: 3 units
This course introduces the (advanced) actor to various aspects of the professional world. Emphasis is placed on the audition and interview process for casting directors, talent agents and personal managers. Each student will present either an individual or small group project chosen from a wide ranging list of topics which include performers unions, various production contracts, New York and regional theater season,s professional publications and web sites. Occasional tests are administered on the subject of current Broadway and Off-Broadway seasons. Registration for this course is limited to Drama majors only.
Prerequisites: 54-301 and 54-302

54-497 Directed Study in Design and Production
Fall and Spring
An opportunity to pursue a predefined design project outside of the standard curriculum under the guidance and direction of a School of Drama faculty member. By special permission only.

54-498 Expanded Theater Fusion Studio
Intermittent: 10 units
As the boundaries between theater, art, entertainment and everyday life continue to expand through engagement with new technologies, it is critical that emerging artists and technologists be provided with the tools, language, and vision to thrive in the new millennium. Expanded Theater will reanimate classical modes of performance with media, networks, robotics, locative applications, and mobile systems. Considering theater as an ancient technology of mass participation and social cohesion, this fusion studio explores how emerging technologies can expand upon the basic theatrical relationships in new and culturally relevant ways. Collaboration and integration of design, media and storytelling is critical to this approach. Experimentation with new forms can reanimate the basic values of theater; the essential nature of a live event, the possibility of visionary spectacle, and the creation of meaning in dialogue with an audience. Expanded Theater is an opportunity to explore avenues outside of traditional theatrical production modes and beyond each students individual discipline. The curriculum combines resources from Carnegie Mellons Schools of Art and Drama, Integrative Design, Arts, and Technology (IDeATe), the Emerging Media Masters (EM2), Computer Science, the Robotics Institute, and their collaborators across the university in a new configuration. Expanded Theater will explore domains ranging from site specific and networked-based performance and interventionist practices, to pervasive social media technologies and their influence on interpersonal communication. The goal is to investigate contemporary languages that allow authors, actors and technologists to collaborate in ways that push beyond our present understanding of theatrical production and reception.

54-499 Advanced Digital Image
Intermittent: 6 units
Advanced Digital Image: (Mini) This class is designed to teach students how to conceive, create and present large scale, professional-quality imagery at "realistic" budget levels. Students choose specific theatrical scenes and create a media based solution for them. Through in-class workshops and Media Lab work-time, this class covers High Definition video production, editing, animation & live video systems for the stage as well as a variety of media-server based presentation technologies. For Juniors, Seniors and Grads. No Prerequisite Open to non-majors

54-500 Voice Lab
Fall and Spring: 5 units
FOR MUSIC THEATRE MAJORS ONLY. Singing Voice based on speech-level and classical singing techniques, required of all Musical Theatre Majors Lessons are private, for the duration of one hour per week. Voice Lab combines all students of Musical Theatre in a one-hour performance class, where repertoire is performed for faculty and students alike. Training is progressive, with each semester building on the vocal mastery achieved from the previous semester. Repertoire spans from classical to rock, but with an emphasis on songs extracted from the American Musical Canon.

54-503 Directors' Practicum
All Semesters: 2 units
TBA

54-505 Ear Training
Fall: 1 unit
Ear Training for sound designers and audio technologists. Introduction and development of skills and techniques for discerning, measuring and expressing the physical qualities of sound with accuracy and sensitivity. Topics include recognizing frequencies (1/3 octave and dual-octave) and analyzing effects and processing (pitch, amplitude, time domain and timbral). This course is open to Drama Sound Design majors/minors, Music Technology major/minors or by permission of the instructor.

54-508 Theatrical Sound System Design 1
Fall: 9 units
Intensive course exploring the theory, art and technology of large scale sound system design for entertainment, specifically live theater productions.

54-509 Theatrical Sound System Design 2
Fall: 9 units
Intensive course exploring the theory, art and technology of large scale sound system design for entertainment, specifically live theater productions. Prerequisites: Intro to Sound Design for Theatre and Production Audio, OR permission of instructor.
Prerequisites: 54-166 and 54-666

54-511 Millinery I
Fall: 9 units
This course provides the student with a working knowledge of the basic practices of the theatrical milliner. Focus is given to the development of professional level skills in the areas of buckram, and felt constructions. The student is introduced to industry accepted techniques, materials, and equipment.

54-513 Millinery II
Spring: 9 units
Millinery II (513/914):This course continues the explorations begun in Millinery I. The student undergoes advanced exercises in straw, wire frames, block making and non-traditional millinery materials. Continued emphasis is given to developing professional level skills and assimilation of advanced theories.
Prerequisite: 54-511

54-516 Fabric Painting
Spring: 9 units
This course is structured as a lecture/demonstration and lab employing the principles of fabric painting/printing techniques, fabric painting/printing materials and the practical use of these techniques and materials. The student should learn the basic concepts behind each of the covered processes, the materials and alternate methods involved with each process, and introductory concepts behind pattern registration. Additionally, the world of breakdown and distressing is covered in an ongoing exercise that spans the duration of the semester.

54-517 Director's Colloquium
Fall: 1 unit
Directors Colloquium is a weekly meeting for undergraduate Directing majors and BXA students in directing. Specific topics in directing are discussed and School of Drama productions are critiqued.

54-518 Director's Colloquium
Spring: 1 unit
Missing Course Description - please contact the teaching department.

54-519 Acting for the Camera
Fall: 6 units
This course presents the skills necessary to work as an actor in the film and television industry. We will put into practice proficiencies and techniques acquired during previous training, adapt those tools, and learn the new skills required when working for the camera.
Prerequisite: 54-302

54-520 Acting for the Camera
Fall and Spring: 6 units
This course presents the skills necessary to work as an actor in the film and television industry. We will put into practice proficiencies and techniques acquired during previous training, adapt those tools, and learn the new skills required when working for the camera.
Prerequisite: 54-302

54-521 Video Media Design Senior Thesis
Spring
TBA

54-522 Plays and Pitches
Spring: 6 units
Preparation for Director project.

54-524 Dance Lighting Design 2
Spring: 3 units
DANCE LIGHT!

54-525 Entertainment Lighting Programming
Fall: 4 units
Students learn and practice programming techniques on the grandMA2 series of lighting control consoles. Advanced programming techniques are explored, including media server control and user-defined commands for the console. Different applications are introduced, but the primary focus is on programming for live music performance.
Prerequisite: 54-349

54-527 Automated Lighting Workshop
Spring
In the spring semester of the 2017/2018 academic year the Automated Lighting Workshop course will consist of five distinct modules. The first will focus on the operation and maintenance of equipment that falls into the category of automated lighting. The second module will focus on the programming of media servers using lighting consoles. This year the V476 and MBox will be used. The third module will concentrate on the development of previsualization skills using LightConverse software. In the fourth portion of the class students will design and engineer the automated lighting rig that will be used for the summer and fall of 2018 in the Wells Video Studio. The fifth module will be an introduction to programming on the Hog4 console.
Prerequisite: 54-349

54-534 Costume Crafts: Theatrical Footwear
Spring: 4 units
This introductory course serves to instruct the student in the language, materials and processes of designing, creating and adapting footwear for the stage.

54-535 Costume Crafts: Fabric Modification
Spring: 4 units
This course is intended to introduce the student to processes of fabric modification that utilize techniques beyond painting and dyeing. Students will be encouraged to investigate the world of garment decoration and to actively explore a wide variety of processes and materials ranging from old world needle arts to modern crafts which utilize long established techniques in contemporary context.

54-536 Costume Crafts: Mask Making
Spring: 6 units
This course opens the world of mask creation to the adventurous student. A broad range of techniques are touched upon and explored allowing students to pick and choose those processes which appeal to their aesthetic and apply to their needs.
Prerequisite: 54-538

54-539 Fabric Dyeing I
Fall: 9 units
-This course is designed to provide the student with an introductory level of instruction for a broad range of fabric dyeing and painting techniques. -Students should gain an understanding of the various dye classes and their safe use in dyeing fabric for the theatre. -The student should gain a full comprehension of the processes of each of these classes, including common terminology, and be able to correctly enumerate steps in the processes. -The student should be able to match the appropriate product to the demands of the project. -The student should gain skills necessary to manipulate the dye process to achieve desired results including exercising their understanding of color theory. -The student should gain a basic understanding of several specialty dye techniques that could excite further exploration.

54-561 The Films of the Coen Brothers
Fall and Spring: 6 units
Films of the Coen Brothers

54-585 Dramaturgy Capstone Thesis
Fall: 9 units
No course description provided.

54-587 Dramaturgy Production III
Fall and Spring: 12 units
Working as a dramaturg on a School of Drama production in the senior year.

54-588 Dramaturgy Production III
Spring
For Dramaturgy majors.

54-590 The Post Apocalypse on Film
Spring: 6 units
Cinematic treatments of the end of civilization by filmmakers from all over the world, including animation.

54-592 Costume Crafts: Theatrical Armor
Fall: 4 units
This mini course introduces the student to the world of armor creation for the stage. Techniques covered range from traditional to revolutionary and provide the student with a breadth of possibilities geared toward solving the general conundrum of successful armor for the theatrical production.
Prerequisite: 54-538

54-593 Stanley Kubrick and His Films
Intermittent: 6 units
Stanley Kubrick and His Films Stanley Kubrick and His Films will explore the amazing diversity in this excellent film director's output from 1967-1999. The course will emphasize the psychological and moral issues raised in his films. And the course will focus on his camera techniques, his use of sound and music, and other remarkable innovative elements. With each film, Kubrick seems to re-invent himself, expanding the dimensions of film art. Films that will be shown in class include: "Paths of Glory" (1957), "Lolita" (1962), "Dr. Strangelove" (1964), "2001: A Space Odyssey" (1968), "A Clockwork Orange" (1971), "Barry Lyndon" (1976), "The Shining" (1980), "Full Metal Jacket" (1987) and "Eyes Wide Shut" (1999).

54-599 Woody Allen and Mel Brooks films
Fall: 6 units
TBA

54-617 Independent Study in Dance
Fall and Spring
Independent Study in Dance with faculty approval.

54-633 Grad Film Production
Spring: 6 units
Hands-on workshop based course teaching the fundamentals of post-production and editing. Students will familiarize themselves with workflow, editing strategies, sound design techniques and technical use of adobe premiere. Some seats open to Non-Drama students. Some seats open to non-Drama students.

54-666 Production Audio
Spring: 6 units
Introduction to the theories and technologies used in sound system design for theater and live entertainment.

54-714 Costume Rendering
Spring: 9 units
PRE-REQUISITES: Drawing for the Theatrical Designer, Major in Design Option of School of Drama FOR: Graduate and Undergraduate Design Costume Majors only. Instructor Approval required. DESCRIPTION: this fast-paced course focuses on techniques and exercises specific to the development of refined and versatile costume renderings. A variety of mediums and methods are explored including colored pencil, marker, ink, Doctor Martin's dyes, watercolor and acrylic as well as transfer drawings, resists and the use of other techniques. Color, texture, pattern, nude and clothed human models are carefully studied and rendered. Students also apply course techniques to development of designs for production and portfolio preparation.
Prerequisite: 54-811

54-721 Graduate Directing: Text to Stage
Spring: 6 units
to be determined

54-722 Graduate Directing: Text to Stage
Spring
Missing Course Description - please contact the teaching department.

54-729 Graduate Automated Lighting Workshop
Fall and Spring
In the spring semester of the 2017/2018 academic year the Automated Lighting Workshop course will consist of five distinct modules. The first will focus on the operation and maintenance of equipment that falls into the category of automated lighting. The second module will focus on the programming of media servers using lighting consoles. This year the V476 and MBox will be used. The third module will concentrate on the development of previsualization skills using LightConverse software. In the fourth portion of the class students will design and engineer the automated lighting rig that will be used for the summer and fall of 2018 in the Wells Video Studio. The fifth module will be an introduction to programming on the Hog4 console.
Prerequisite: 54-771

54-755 Drama Practicum
Summer: 3 units
This course provides 3 units of pass/fail credit for students participating in a drama related internship. The student must be registered for this course during the internship, in order to earn the credit. At the end of the term, the student's supervisor must email the academic advisor with a brief statement describing the student's activities, and an evaluation of the student's performance. Students are required to submit a statement, reflecting on insights gained from the internship experience. Upon receipt of both statements, the academic advisor will assign a grade of either P or N, depending on the outcome.

54-756 Graduate Theatre for the Ear
Spring: 6 units
Survey of aural storytelling with technology focusing on forms with no visual component. Topics include the history of radio drama to present day, radio sound art, cut-up and tape manipulation, comedy records and podcast dramas. Prerequisites: 54-767 Graduate Conceptual Sound Design 1 & 54-768 Graduate Conceptual Sound Design 2 OR 54-791 Playwriting I. Restrictions: The course is open to Graduate Sound Design majors, Graduate Dramatic Writers or with permission of the instructor.

54-759 Working with Dramaturgs
Intermittent: 3 units
TBA

54-760 Grad Leadership Workshop: Ethics & Innovation
Intermittent: 6 units
This course will be an exploration of both innovative strategies and the ethics of leadership within the performing arts. It will build on the management principles covered in foundational courses and is designed to offer the student an approach to leadership development that is tailored to the individuals strengths and needs as well as their role within theatrical organizations. For PTM students only or with permission from the instructor.
Prerequisite: 54-749

54-766 Graduate Introduction to Sound Design for Theatre
Spring: 6 units
Students explore the basic principles and theories of sound design from technical, psychological and aesthetic standpoints. Course work includes instruction in the controllable properties of sound, practical planning of sound plots, cue creation, and the design process. Restrictions: Open to all Graduate Drama Majors, CFA graduate students or with permission of instructor.

54-773 Graduate Couture Sewing Techniques
Intermittent: 9 units
-This course is designed to help the student gain an understanding of and appreciation for high-end sewing and finishing techniques and how these techniques improve the quality of the clothing they are employed in. -The student should gain a comprehension of the terminology commonly used in couture sewing and high-end finishing. -The student should gain a full comprehension of the process of each of these techniques and be able to logically enumerate steps in the full process involved with each technique. -The student should be able to appropriately apply each technique and distinguish between techniques when making choices in the sewing process.

54-780 Graduate Fabric Painting
Spring: 9 units
This course is structured as a lecture/demonstration and lab employing the principles of fabric painting/printing techniques, fabric painting/printing materials and the practical use of these techniques and materials. The student should learn the basic concepts behind each of the covered processes, the materials and alternate methods involved with each process, and introductory concepts behind pattern registration. Additionally, the world of breakdown and distressing is covered in an ongoing exercise that spans the duration of the semester.
Prerequisite: 54-845

54-795 Graduate Costume Crafts: Mold Making and Casting
Spring: 6 units
This course is designed to introduce the student to a wide variety of molding and casting techniques that might be encountered in the costume crafts area. Upon completion of this course students should understand basic products and processes available to them to enhance either their design work or their production capabilities. By no means is this an exhaustive survey and further study is encouraged.

54-796 The Basics of Self-Producing: How to Put Up Your Show in NYC and Get It Reviewed
Intermittent: 6 units
For any actor/writer/director/theatre artist in New York City, the time between jobs can feel stressful and frustrating. Self-producing is the quickest way to get your work on stage without permission from anyone else or having to adhere to anyone else's restrictions. From blurbs to budgets to rehearsal space to press releases to equity paperwork, this course covers everything you need to know in order to get your work produced and noticed in New York City without breaking the bank. This course will draw from readings on independent theatre, interviews with working independent producers in New York, and the working experience of Anderson Cook, author/producer of The Disembodied Hand That Fisted Everyone to Death - the Musical!, Blatantly Blaine, Pop Punk High, Donny and Kelly Save the Slumber Valley ASPCA, and more - all produced and reviewed in NYC.

54-815 Graduate Negotiation and Conflict Management
Fall: 3 units
This class is a focused exploration of the process of negotiating, both formally and everyday. We will examine interactions on all levels and environments, with an evaluation of tactics, strategies and the measure of success. From there, the class expands into the nature of conflicts and the manager's role in identifying and confronting them. Throughout the class, we hope to find solutions to implement in our lives and work. In-class exercises and role play will be a fundamental part of class activity.

54-819 Graduate Figure Drawing
Fall and Spring: 3 units
Costume Majors have priority, then Design Majors. This course explores the realistic and expressive depiction of the human form primarily in two dimensional media. Working primarily from the live model, exercises will be undertaken that address gesture, proportion, movement, anatomy and structure, composition and expressive form. Students will experience a variety of media and formal approaches to the figure, working from nude, draped, and clothed male and female models. A primary goal of the class is to develop the ability to create the human figure from imagination, based on intensive empirical study of the forms and structures of the human body from life.

54-822 Graduate Directing: Future Stages II
Spring
Future Stages for second-year Graduate Directors

54-880 Graduate Special Topics in Media: Mediated Reality
Spring
This is an advanced studio course investigating mediated reality technologies and location based interactivity and their potential uses for live performance. The course is technically and conceptually demanding. We will work primarily in Autodesk Maya and Unity 3d, as well as work with various networking technologies for experiencing merged digital and real worlds. The course will start with rapid skills training, then students will work in small groups on developing content rich applications for these technologies. Through readings and discussion of a variety of contemporary works students will come up with testable ideas that will be prototyped in the second half of the semester. Undergrads with permission.

54-884 Graduate Digital Narratives
Fall: 4 units
Digital Narratives combines options from the School of Drama in a new configuration: through working collaboratively across disciplines, students investigate multimedia approaches to contemporary theater and new ways of storytelling. Directors, designers, actors, and dramaturgs work in groups to generate original ideas, images, texts, and material in a workshop environment. These working groups create projects over the course of the semester which are shown in informal presentations. The emphasis is on process, not product — devising an interdisciplinary performance requires a keen focus on combining creative invention with a rigorous structure of concept development — both of which are explored here. We also examine the work of several significant contemporary theater artists whose work approaches collaboration across a variety of disciplines. Artists have included: Ariane Mnouschkine, Dumbtype, Complicite, Ralph Lemon, Robert LePage, and more. Students learn to define and distinguish these artist's approaches through viewing video excerpts, readings, and discussion. This class is an opportunity to explore avenues outside of traditional production modes and beyond each student's individual discipline. We focus on the process of creating a theatrical language which truly integrates disciplines.

54-905 Graduate Ear Training
Spring: 1 unit
Ear Training for sound designers and audio technologists. Introduction and development of skills and techniques for discerning, measuring and expressing the physical qualities of sound with accuracy and sensitivity. Topics include recognizing frequencies (1/3 octave and dual-octave) and analyzing effects and processing (pitch, amplitude, time domain and timbral). This course is open to Drama Sound Design majors/minors, Music Technology major/minors or by permission of the instructor.

54-939 Graduate Entertainment Lighting Programming
Fall: 4 units
Students learn and practice programming techniques on the Hog4 series of lighting control consoles. Advanced programming techniques are explored, including media server control and user-defined commands for the console. Different applications are introduced, but the primary focus is on programming for live music performance.
Prerequisite: 54-771

54-964 Graduate Scenic Design: Moving the Musical
Fall: 5 units
This course will explore methods of designing a musical, emphasizing the ways in which the movement of the scenic units informs the design and helps the audience understand the story being told.

54-972 Graduate PTM Professional Practice
Fall: 3 units
A seminar about issues surrounding a career as a technical manager. In a series of presentations and discussions students will encounter tools and strategies for job seeking and personal promotion. Guest lecturers will present materials on professional obligations like insurance and taxes and non-salary compensation like retirement and health benefits.

54-973 Costume Production Thesis
Fall and Spring: 12 units
TBD

54-997 Graduate Sound Design For Interactive Environments
Spring: 9 units
This course will examine the process, execution and implementation of sound design for interactive and non-linear storytelling paradigms. Emerging trends in immersive theater, gaming, installation art and multi-media place unique demands on the sound designer both in terms of content and delivery. The student will explore how these demands effect the fundamental processes of design, development of content and flexible delivery systems. Through a combination of directed readings, exploration of current & emerging trends, and project assignments the student will be encouraged to experiment and explore design modes and methodologies that support this flexible method of storytelling.
Prerequisites: 54-868 or 54-867

54-998 Graduate Special Topics in Sound Design
Intermittent: 9 units
A one semester course covering various rotating topics including the history and critical theories of film sound design, the history of sound recording and technology, Foley sound, recording and editing techniques, and 5.1 audio. Prerequisites: 54-867 Conceptual Sound Design. Restrictions: The course is open to Drama sound design majors and minors, Music Technology majors and minors or by permission of the instructor.
Prerequisite: 54-867

School of Music

Denis Colwell, Head
Location: College of Fine Arts 105
www.cmu.edu/cfa/music

The School of Music at Carnegie Mellon University offers the best aspects of conservatory training within a great university, combining preparation for a lifetime in performance, composition or music and technology with the advantages of learning in an intense academic environment. Every student in the School of Music is a performance, composition or music and technology major. The School of Music is an accredited institutional member of the National Association of Schools of Music.

Each performance major is challenged to develop through individual instruction with a master teacher. The School's relationship with the renowned Pittsburgh Symphony Orchestra is among the strongest conservatory–symphony orchestra relationships in the United States, and Pittsburgh's uniquely strong sense of musical community fosters close relationships with the Pittsburgh Opera, Opera Theater of Pittsburgh, Pittsburgh Chamber Music Society, and a host of other professional musical organizations.

Regular performing ensembles include the Carnegie Mellon Philharmonic, Wind Ensemble, Baroque Ensemble, Contemporary Ensemble, Jazz Orchestra, Jazz Vocal Ensemble, Chorus, and Opera. Some of the School's ensembles are instrument specific: Chamber Music ensembles and the Percussion Ensemble, among others. Opportunities for performance are stressed – undergraduate performance majors perform junior and senior recitals, chamber music is publicly presented, frequent performance opportunities on and off campus are provided, and community outreach is vigorously supported.

The School of Music has an intense commitment to new music, led by composition faculty, conductors who devote fully rehearsed cycles of the Philharmonic to works by student composers, and studio faculty whose own performing careers regularly feature new works, and including regular performances of student works in almost every Contemporary Ensemble Program, frequent opportunities with the Wind Ensemble and Chorus, and inclusion on student recitals. The School's state-of-the-art recording facilities are an especially important resource for composers beginning their public careers.

All teaching is entrusted to professional faculty — there are no assistant studio teachers or doctoral teaching fellows — and specialists in Musicology, Theory, Analysis, Counterpoint, Composition, Computer Music, Eurhythmics, Solfege, Music Education, Pedagogy, Collaborative Piano and Coaching, Acting and Movement, Diction, Literature and Repertoire, Baroque Music, Chamber Music, Conducting, and Sound Recording and Production provide a broad and rich platform for comprehensive musical preparation. At the same time, the university provides the greatest possible support for students combining their majors with minors in all disciplines, unique joint degree programs, and double major programs. These opportunities significantly increase a student's career options and marketability in the changing professional world of music.

School of music Facilities

The teaching facilities of the School of Music are located on the ground, main, and mezzanine floors of the College of Fine Arts, on the first floor of Margaret Morrison Hall, and in Skibo Gymnasium. Teaching, rehearsal, and practice rooms are equipped with Steinway pianos. Music students also have access to a state-of-the-art recording studio and music technology cluster. Performances take place in Kresge Recital Hall, Carnegie Music Hall, Alumni Concert Hall, and Mellon Institute Auditorium. The Hunt Library houses a fine collection of books, records, and scores. Listening and conference rooms are also available in the library.

School of Music Options

The School of Music offers a Bachelor of Fine Arts in the following areas:

- Performance (Instrumental, Organ, Piano, Voice)
- Composition

To earn a Bachelor's degree in either of these options, a candidate must satisfactorily fulfill all the requirements of the School of Music.

The School of Music jointly with the School of Computer Science and the Carnegie Institute of Technology offers a Bachelor of Science in the following area:

- Music and Technology

Within the options listed above eligible students may elect specializations in the following areas:

- Dalcroze Eurhythmics Certificate
- Piano Pedagogy Certificate
- Collaborative Piano Minor
- Conducting Minor
- Music Education Certification Minor
- Music Technology Minor
- Music Theory Minor
- Sonic Arts Minor

Dalcroze Eurhythmics Certificate

This program is designed to prepare teachers in the Dalcroze approach to music learning. The course of study includes eurhythmics, piano improvisation, and Dalcroze pedagogy. Carnegie Mellon undergraduates may enter the Dalcroze Training Program during their junior year. However, the certificate will be granted only upon completion of their undergraduate degree. This program is recommended particularly to students who would like to incorporate Dalcroze principles into their teaching and to those who want to obtain more experience in this field.

Piano Pedagogy Certificate

A two-year program leading to certification in piano pedagogy is open to current Carnegie Mellon keyboard majors. Piano and organ majors learn to teach piano in a closely supervised environment of class piano instruction. This program has received national acclaim as a model of excellence, with Carnegie Mellon children consistently capturing prestigious awards in national piano competitions.

Collaborative Piano Minor

The collaborative piano minor consists of a six-semester sequence of courses designed to give the students experience with vocalists and instrumentalists. There are individual coaching sessions as well as practical experience in vocal and instrumental studios.

Conducting Minor

This minor is designed for students who are interested in acquiring conducting skills, in anticipation of either graduate study in conducting or a music education career. It includes required courses in conducting techniques for both choral and instrumental ensembles, orchestration, score reading/keyboard harmony, and elective courses in instrumental and vocal methods, diction, and literature and repertoire.

Music Education Minor

This is a five-year minor, with courses starting in the sophomore year. Bachelor of Fine Arts candidates who complete this minor and pass the Praxis tests will receive Pennsylvania state certification in music (K-12), which is recognized in almost all other states.

Music Technology Minor

The student will take a series of courses which may include electronic and computer music, recording technology, the physics of sound, and computer programming. A rich computer music research environment enables talented students to work as programmers with outstanding faculty researchers, whose current projects are gaining international recognition in the areas of computer music and artificial intelligence.

Music Theory Minor

This minor is designed for students who are interested in advanced theory and analysis skills, in anticipation of either graduate study in theory or graduate study that requires a substantial level of theory knowledge. The student will take advanced theory and analysis courses and also support courses in the physics of musical sound and the psychology of music.

Sonic Arts Minor

Students in this minor will explore the processes and products of digital sound and music. They will receive basic training in key component areas: principles of computer music, hybrid instrument building, concepts in sound design. Combining this training with courses that bring together experts from many disciplines, they will create experimental music or explore new, technology-enabled, applications and markets for sound design, music creation, and performance.

Performances and Activities of the School of Music

The School of Music sponsors performances, master classes, and lectures by outstanding national and international guest artists. Announcements of faculty, student, and guest performances are released every week to the students and the community.

General Requirements for BFA Candidates

Candidates for the Bachelor of Fine Arts degree in composition are required to complete a composition for orchestra in their senior year.

Candidates for the Bachelor of Fine Arts degree in performance are required to give public performances in their junior and senior years. Candidates for the Bachelor of Fine Arts degree in string performance are required to give public performances in their sophomore, junior, and senior years.

Candidates for the Bachelor of Fine Arts degree in performance are required to pass one semester (piano majors must pass two semesters) of a course that includes experience with pedagogy for their major studio area.

- Instrumental majors must take the class for their area to fulfill the Pedagogy Course requirement on the Instrumental curriculum (57-023 Bassoon Studio Performance Class, 57-448 Brass Pedagogy, 57-022 Clarinet Studio Performance Class, 57-018 Double Bass Studio Performance Class, 57-020 Flute Studio Performance Class, 57-021 Oboe Studio Performance Class, 57-030 Percussion Studio Performance Class, 57-016 Viola Studio Performance Class, 57-015 Violin Studio Performance Class, 57-437 Literature and Repertoire).
- Bagpipe, organ and saxophone majors must fulfill the pedagogy requirement as part of satisfying all demands outlined in their Major Studio syllabi, 57-522 Major Studio (Bagpipe), 57-502 Major Studio (Organ) and 57-514 Major Studio (Saxophone).
- Piano majors must take 57-273 Piano Pedagogy I and 57-274 Piano Pedagogy II.
- Voice majors must take 57-010 Voice Studio Performance Class.

Candidates for the Bachelor of Fine Arts degree in applied areas other than piano are required to pass a piano proficiency test.

Candidates for all Bachelor of Fine Arts degrees are required to pass four repertoire proficiency tests, and to pass a major choral ensemble or a major instrumental ensemble as assigned and to pass Convocation every semester of residence in the School of Music.

BFA Curriculum

The music curriculum is based on the following five building blocks:

1. Studio
2. Theory
3. History
4. Ensemble
5. Academics

1. Studio — This is the heart of the school. Students receive individualized instruction with senior faculty in their major area of study: performance or composition.

2. Theory — These courses are designed to help students develop listening skills, to acquire theoretical knowledge, to recognize structural techniques and manipulate technological resources. It includes courses in sight-reading, ear-training, eurhythmics, harmony, contrapuntal techniques, analysis of musical forms, 20th-21st century techniques, orchestration, score reading, and electronic and computer music for compositional and educational purposes. One music support course in the piano, organ, and instrumental curricula must be a theory course.

3. History - These courses cover in depth the music of the western world and survey the styles and musical structures of non-western music.

4. Ensemble — This area includes student participation in some of the following ensembles: Carnegie Mellon Philharmonic, Wind Ensemble, Baroque Ensemble, Contemporary Ensemble, Jazz Orchestra, Jazz Vocal Ensemble, Chorus, Opera, Chamber Music ensembles, and Percussion Ensemble.

5. Academics — The School of Music requires one general studies course (outside of the School) each semester and six semesters of elective courses for graduation. These accumulated credits may be applied to minors or majors in other disciplines. Exceptional students in good academic and musical standing within the School are permitted to take additional courses beyond the number required for graduation. There is no charge for extra credits taken at Carnegie Mellon. One elective course in the performance curricula must be a course that includes experience with pedagogy for the student's major studio area.

Minimum units required for B.F.A. in Music	
Voice majors	**407**
Composition majors	**392**
Instrumental, Organ, and Piano majors	**386**

Piano

First Year

Fall		Units
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-193	Collaborative Piano Skills I	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-101	Introduction to Music Technology	6
99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
		55

Spring		
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-194	Collaborative Piano Skills II	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
79-xxx	Designated History Course	9
		55

Second Year

Fall		Units
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-228	Chamber Music: Woodwind and Mixed	3
57-151	Counterpoint in Theory and Application	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
xx-xxx	General Studies Course	6
		49

Spring		
57-100	Convocation	1

57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-228	Chamber Music: Woodwind and Mixed	3
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
xx-xxx	Elective	6
		49

Third Year

Fall		Units
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-228	Chamber Music: Woodwind and Mixed	3
57-273	Piano Pedagogy I	6
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	6
		52

Spring		
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-228	Chamber Music: Woodwind and Mixed	3
57-274	Piano Pedagogy II	6
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	6
		52

Fourth Year

Fall		Units
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-xxx	Performance Elective	9
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	3
		43

Spring		
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-xxx	Performance Elective	9
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	3
		43

Organ

First Year

Fall		Units
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-101	Introduction to Music Technology	6
99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
		55

Spring		
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
79-xxx	Designated History Course	9
		55

Second Year

Fall		Units
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-151	Counterpoint in Theory and Application	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
xx-xxx	General Studies Course	6
		49

Spring		
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
xx-xxx	Elective	6
		49

Third Year

Fall		Units
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-459	Score Reading/Keyboard Harmony	6
57-xxx	Music Support Course (Theory/History)	12
57-xxx	Pedagogy Course	var.
xx-xxx	General Studies Course	9
xx-xxx	Elective	3
		46

Spring		
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	9
		46

Fourth Year

Fall		Units
57-100	Convocation	1
57-502	Major Studio (Organ)	9

57-4xx	Major Ensemble	6
57-xxx	Performance Elective	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	3
		43

Spring		
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-xxx	Performance Elective	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	3
		43

Voice

A voice major must also complete an advanced language course in Italian, German, or French, of at least 9 units. Recommended: a domestic or international program, after the sophomore year, which includes intensive study for credit.

First Year

Fall		Units
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-417	Major Vocal Performance Ensemble	6
57-467	Production: Crew	3
57-191	Keyboard Studies	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-221	Italian Diction	3
57-240	Acting I	6
57-111	Movement and Dance I	3
82-161	Elementary Italian I	12
		61

Spring		
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-417	Major Vocal Performance Ensemble	6
57-468	Production: Crew	3
57-191	Keyboard Studies	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-431	Italian Literature and Repertoire	3
57-241	Acting II	6
57-112	Movement and Dance II	3
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
		61

Second Year

Fall		Units
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-417	Major Vocal Performance Ensemble	6
57-191	Keyboard Studies	3
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-189	Introduction to Repertoire and Listening for Musicians	3
82-121	Elementary German I	12
57-223	German Diction	3
57-339	Acting III	6
57-211	Movement and Dance III	3
		52

Spring		
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-417	Major Vocal Performance Ensemble	6
57-191	Keyboard Studies	3
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
57-435	German Literature and Repertoire	3
57-340	Acting IV	6
57-212	Movement and Dance IV	3
		49

Third Year

Fall		Units
57-100	Convocation	1
57-010	Voice Studio Performance Class	0
57-500	Major Studio (Voice)	9
57-417	Major Vocal Performance Ensemble	6
57-xxx	Production Course	6
57-151	Counterpoint in Theory and Application	6
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
82-101	Elementary French I	12
57-222	French Diction	3
		55

Spring		
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-417	Major Vocal Performance Ensemble	6
57-xxx	Production Course	6
57-408	Form and Analysis	6
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
57-432	French Literature and Repertoire	3
57-101	Introduction to Music Technology	6
79-xxx	Designated History Course	9
		58

Fourth Year

Fall		Units
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-417	Major Vocal Performance Ensemble	6
57-xxx	Production Course	6
57-220	English Diction	3
57-434	Musical Theatre Literature and Repertoire	3
xx-xxx	Elective	9
		37

Spring		
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-417	Major Vocal Performance Ensemble	6
57-xxx	Production Course	6
57-436	English/Contemporary Literature and Repertoire	3
57-434	Musical Theatre Literature and Repertoire	3
xx-xxx	Elective	9
		37

Instrumental

A string major must also complete two semesters of Chamber Music in the sophomore year.

First Year

Fall		Units
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-101	Introduction to Music Technology	6
99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
		55

Spring		
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
79-xxx	Designated History Course	9
		55

Second Year

Fall		Units
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-151	Counterpoint in Theory and Application	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
xx-xxx	General Studies Course	6
		49

Spring		
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
xx-xxx	Elective	6
		49

Third Year

Fall		Units
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-xxx	Chamber Music	3
57-xxx	Music Support Course (Theory/History)	12
57-xxx	Pedagogy Course	var.
xx-xxx	General Studies Course	9
xx-xxx	Elective	6
		46

Spring		
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-xxx	Chamber Music	
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	6
		43

Fourth Year

Fall		Units
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-xxx	Chamber Music	
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	3
		40

Spring		
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-xxx	Chamber Music	
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective	3
		40

Composition

One music support course is recommended to be Creative Orchestration.

First Year

Fall		Units
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-101	Introduction to Music Technology	6
99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
		55

Spring		
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
79-xxx	Designated History Course	9
		55

Second Year

Fall		Units
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6

57-191	Keyboard Studies	3
57-151	Counterpoint in Theory and Application	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
57-257	Orchestration I	6
xx-xxx	Elective	6
		55

Spring		
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
57-271	Orchestration II	6
57-258	20th-21st Century Techniques	6
		55

Third Year

Fall		Units
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-234	Performance for Composers	3
57-332	Introduction to Conducting	6
57-347	Electronic and Computer Music	6
57-xxx	Music Support Course	6
xx-xxx	General Studies Course	12
		43

Spring		
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-236	Performance for Composers	3
57-336	Instrumental/Choral Conducting	6
57-459	Score Reading/Keyboard Harmony	6
57-xxx	Music Support Course	6
xx-xxx	General Studies Course	12
		43

Fourth Year

Fall		Units
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-xxx	Music Support Course	6
xx-xxx	General Studies Course	9
xx-xxx	Elective	12
		43

Spring		
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-349	Supervised Theory Teaching	6
57-xxx	Music Support Course	6
xx-xxx	General Studies Course	9
xx-xxx	Elective	6
		43

Dalcroze Eurhythmics Certificate — 33 units

57-465	Eurhythmics Applications for Performing and Teaching	6
57-466	Eurhythmics Applications for Performing and Teaching	6
57-691	Dalcroze Pedagogy/Practice Teaching	3
57-692	Dalcroze Pedagogy/Practice Teaching	3
57-350	Dalcroze Piano Improvisation	6
xx-xxx	Creative Movement/Choreography	3
57-641	Dalcroze Research Paper	3
57-642	Dalcroze Research Paper	3

Piano Pedagogy Certificate — 36 units

57-273	Piano Pedagogy I	6
57-274	Piano Pedagogy II	6
57-275	Piano Pedagogy III	6
57-276	Piano Pedagogy IV	6
57-429	Beginning Piano for Children I	6
57-449	Beginning Piano for Children II	6

Bachelor of Science in Music and Technology

The Bachelor of Science in Music and Technology is offered jointly by the School of Music, the School of Computer Science, and the College of Engineering.

This program consists of a set of courses that span both music and technology, as well as a capstone composition/design/performance project. Courses in all three areas of study are stipulated in the music and technology undergraduate curriculum and provide for students coming from any of the three areas. In other words, regardless of a student's entry point — an interest in computer science, electrical engineering, or music — the coursework prescribed will allow the student to gain the requisite knowledge and experience in all three areas. Students will work closely with advisors and will be guided in both course selection and capstone projects.

Curriculum

Minimum units required for B.S. in Music and Technology — 380

General Requirements — 85 units

Seminar

57-570	Sound and Music Computing Seminar (8 semesters for a total of 8 units)	1

University

99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
79-104	Global Histories	9

Humanities

xx-xxx	Cognition, Choice and Behavior course	9
xx-xxx	English, History, Modern Languages, Philosophy, or Psychology course	9

Mathematics

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10

Science

33-114	Physics of Musical Sound	9
33-106	Physics I for Engineering Students	12

Electives — 33 units

Music Core — 87 units

57-152	Harmony I	9
57-153	Harmony II	9
57-408	Form and Analysis	6
57-151	Counterpoint in Theory and Application	6
57-258	20th-21st Century Techniques	6
57-257	Orchestration I	6
57-xxx	Music Support Course	6

57-189	Introduction to Repertoire and Listening for Musicians	3
57-190	Repertoire and Listening for Musicians I	3
57-289	Repertoire and Listening for Musicians II	3
57-290	Repertoire and Listening for Musicians III	3
57-181	Solfege I	3
57-182	Solfege II	3
57-183	Solfege III	3
57-184	Solfege IV	3
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-173	Survey of Western Music History	9

Music and Technology Core 120 units

15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	10
15-322	Introduction to Computer Music	9
18-100	Introduction to Electrical and Computer Engineering	12
18-202	Mathematical Foundations of Electrical Engineering	12
18-290	Signals and Systems	12
57-101	Introduction to Music Technology	6
57-347	Electronic and Computer Music	6
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9
57-571	Music and Technology Project	12
57-572	Music and Technology Project	12

Concentration

Students complete either the Music Concentration or the Technical Concentration:

Music Concentration **60 units**

57-5xx	Studio (4 semesters)	36
57-4xx	Major Ensemble (4 semesters)	24

Technical Concentration **57 or 55 units**

21-127	Concepts of Mathematics	10
15/18-213	Introduction to Computer Systems	12

AND EITHER:

18-220	Electronic Devices and Analog Circuits	12
18-240	Structure and Design of Digital Systems	12
15-2xx/18-3xx or above	Electives in ECE or CS	12

OR:

15-128	Freshman Immigration Course	1
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-323	Computer Music Systems and Information Processing	9
15-2xx/18-3xx or above	Electives in ECE or CS	12

Minors

Minor in Collaborative Piano for Piano Majors in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (CFA 108).

36 unitsRequired Courses

57-381	Collaborative Piano I	6
57-382	Collaborative Piano II	6
57-383	Collaborative Piano III	6
57-384	Collaborative Piano IV	6
57-385	Collaborative Piano V	6
57-386	Collaborative Piano VI	6

18 unitsElectives

(choose from the following courses)

57-220	English Diction	3
57-221	Italian Diction	3
57-222	French Diction	3
57-223	German Diction	3
57-332	Introduction to Conducting	6
57-336	Instrumental/Choral Conducting	6
57-431	Italian Literature and Repertoire	3
57-432	French Literature and Repertoire	3
57-433	Musical Theatre Literature and Repertoire	3
57-434	Musical Theatre Literature and Repertoire	3
57-435	German Literature and Repertoire	3
57-436	English/Contemporary Literature and Repertoire	3
57-459	Score Reading/Keyboard Harmony	6
57-607	Vocal Methods	3

Minimum units required for Collaborative Piano Minor: 54

Minor in Conducting for Students in the School of Music

Admission Requirements:

1. The student must apply to enter the program in the office of the Director of Student Services (CFA 108).
2. A 3.0 cumulative overall QPA and good academic standing are required.
3. In addition to passing the prerequisite courses listed below, the student must display superior solfege skills, by passing Advanced Solfege I and II with “A” or “B” grades or by passing Solfege I and II with "A" or "B" grades and with the recommendation of the student's solfege instructor; and the student must also pass Introduction to Conducting with an "A" grade or with a "B" grade and with the recommendation of the student's conducting instructor.

ACADEMIC REQUIREMENTS:

1. Immediately after acceptance into the minor in conducting, the student must schedule an advising appointment with the faculty supervisor of the conducting minor.
2. Instrumental/Choral Conducting must be completed before the senior year with an "A" grade or with a "B" grade and with the recommendation of the student's conducting instructor before the student can register for the advanced conducting courses (see #3).
3. Conducting Practicum must be taken during the same semester as Independent Study in Conducting. Both courses must be taken after completing Introduction to Conducting and Instrumental/Choral Conducting.
4. A 3.0 cumulative overall QPA is required for graduation with the minor in conducting.

30 unitsPrerequisite Courses

57-152	Harmony I	9
57-153	Harmony II	9
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-191	Keyboard Studies	3

39 unitsRequired Courses

Also choose two of the following courses as recommended by the faculty supervisor of the conducting minor:

57-360	Brass Methods	3
57-361	Percussion Methods	3
57-362	Woodwind Methods	3
57-363	String Methods	3
57-557	Vocal Methods	3

57-332	Introduction to Conducting	6
57-336	Instrumental/Choral Conducting	6
57-257	Orchestration I	6
57-459	Score Reading/Keyboard Harmony	6
57-364	Conducting Practicum	3
57-618	Independent Study in Conducting	6

15 unitsElectives

(choose from the following courses)

57-220	English Diction	3
57-221	Italian Diction	3
57-222	French Diction	3
57-223	German Diction	3
57-258	20th-21st Century Techniques	6
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-431	Italian Literature and Repertoire	3
57-432	French Literature and Repertoire	3
57-435	German Literature and Repertoire	3
57-607	Vocal Methods	3
57-227	Jazz Orchestra	3
57-230	Baroque Ensemble	3
57-231	Chamber Ensemble	3
57-420	Jazz Vocal Ensemble	3
57-423	Repertoire Orchestra	3

Minimum units required for Conducting minor:	54

Minor in Music Education for Students in the School of Music

Admission Requirements:

The student should apply to the music education faculty no earlier than spring of the freshman year.

Corequisite General Courses 45 units

76-101	Interpretation and Argument	9
21-xxx	Mathematics Course #1	9
21-xxx	Mathematics Course #2	9
76-xxx	English Literature Course	9
85-xxx	Educational Psychology Course	9

Corequisite Music Courses 18 units

57-391	Keyboard Studies (Music Ed)	3
57-392	Keyboard Studies (Music Ed)	3
57-393	Keyboard Studies Test (Music Ed)	0
57-332	Introduction to Conducting	6
57-336	Instrumental/Choral Conducting	6

General Education Courses 36 units

Also required are three classes offered at other Pittsburgh schools: EDUC 333 Assessment & Adaptation: Students with Special Needs AND EDUC 634 Inclusion: Issues and Strategies, both at Chatham University; and IL 2257 Teaching English Language Learners, at the University of Pittsburgh (27 units).

57-331	Principles of Education	9

Music Education Methods Courses 48 units

General Methods Courses

57-375	Music in the Elementary School	6
57-356	Elementary Guided Teaching	3
57-376	Music in the Secondary School	6
57-355	Secondary Guided Teaching	3

Applied Area Methods Courses

57-207	Secondary Studio	Var.
57-360	Brass Methods	3
57-361	Percussion Methods	3
57-363	String Methods	3
57-362	Woodwind Methods	3
57-607	Vocal Methods	3

Band Methods Courses

Required is either Fundamentals of Marching Band or Stage Direction.

57-334	Fundamentals of Marching Band	3
57-370	Stage Direction	3
57-333	Band and Choral Arranging	6

Music Education Teaching Courses 15 units

57-608	Observation	3
57-603	Practice Teaching (Elementary)	6
57-604	Practice Teaching (Secondary)	6

Minimum units required for Music Education Minor:	99

Minor in Music Technology for Students in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (CFA 108).

Prerequisite Courses 18 units

57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3

Sound Recording Courses 21 units

57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Music Technology/Sound Courses (choose 3) 21 units

Choose three courses. One of the three courses must be either Introduction to Computer Music or Electronic and Computer Music. (Note that 15-112 is a prerequisite for 15-322; 57-101 or 57-171 is a prerequisite for 57-347.) Other courses may be taken with the permission of the music technology minor advisor.

15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music	9
15-323	Computer Music Systems and Information Processing	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-275	History of Sound Design	3
54-505	Ear Training	1
54-666	Production Audio	6
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-478	Survey of Historical Recording	6
60-352	NOISE: Toward a Critical Theory of Sound and Hearing	9

Minimum units required for Music Technology Minor:	60

Minor in Music Theory for Students in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (CFA 108).

Prerequisite Courses 18 units

57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3

Upper Level Theory Courses (choose 3) 21 units

See theory courses on the Music Support Courses Two-Year Rotation list. It is available on the Inside Music website (http://music.cfa.cmu.edu). A graduate course may be taken with the permission of the instructor.

Graduate Theory Courses (choose 1) 6–9 units

See graduate theory courses on the Music Support Courses Two-Year Rotation list. It is available on the Inside Music website (http://music.cfa.cmu.edu). The course is to be chosen with the advisor's approval.

Support Courses 18 units

33-114	Physics of Musical Sound	9
57-377	Psychology of Music	9

Minimum units required for Music Theory Minor: 63

Sonic Arts Minor – IDeATe

The minor in Sonic Arts is offered by the School of Music as part of the Integrative Design, Arts and Technology (IDeATe) network. IDeATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in shared labs and maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of eight areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, and Physical Computing. For more information about the IDeATe network, please see Undergraduate Options (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateoptions/#ideate).

In the Sonic Arts minor, students create experimental music or explore new, technology-enabled applications and markets for sound design, music creation, and performance.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
18-090	Twisted Signals: Multimedia Processing for the Arts Recommended Portal Course for this area	10
16-223	IDeATe Portal: Creative Kinetic Systems	10
60-223	IDeATe: Introduction to Physical Computing	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
99-361	IDeATe Portal	9

IDeATe Sonic Arts Courses - Minimum of 27 Units

		Units
15-322	Introduction to Computer Music	9
15-323	Computer Music Systems and Information Processing	9
18-493	Electroacoustics	12
33-114	Physics of Musical Sound	9
53-376	360 Story and Sound	12
54-166	Introduction to Sound Design for Theatre	6
54-267	Conceptual Sound Design	9
54-509	Theatrical Sound System Design 2	9
57-337	Sound Recording	6
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-421	The Exploded Ensemble	6
57-425	Expanded Music Performance	9

Double-Counting

Students may double-count up to two of their Sonic Arts minor courses toward requirements for other majors or minors.

Full-Time Faculty

DOUGLAS AHLSTEDT, Professor of Voice – M.M., Eastman School of Music; Carnegie Mellon, 1998–

CHRISTOPHER ALLEN, Artist Lecturer in Percussion – M.M. , Temple University;

ALBERTO ALMARZA, Associate Professor of Flute – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1991–

DONNA AMATO, Artist Lecturer in Piano and Staff Pianist – B.M., University of Arizona; Carnegie Mellon, 1998–

JENNIFER AYLMER, Assistant Professor of Voice – M.M, Westminster Choir College;

LEONARDO BALADA, University Professor of Composition – Diploma, The Juilliard School of Music; Carnegie Mellon, 1970–

BRONWYN BANERDT, Artist Lecturer in Chamber Music – M.M., The Juilliard School;

NEAL BERNTSEN, Artist Lecturer in Trumpet – M.M., Northwestern University; Carnegie Mellon, 2003–

JEREMY BRANSON, Artist Lecturer in Percussion – M.M., Temple University; Carnegie Mellon, 2009–

WILLIAM CABALLERO, Associate Teaching Professor in Horn – B.M., New England Conservatory; Carnegie Mellon, 2007–

JUDITH CAGLEY, Artist Lecturer in Solfege – M.S.Ed., Duquesne University; Carnegie Mellon, 2006–

ANDRES CARDENES, Dorothy Richard Starling and Alexander Speyer, Jr. University Professor of Violin Carnegie Mellon, 1989–

ANDREW CARLISLE, Director of Piping

L. MARK CARVER, Associate Teaching Professor in Collaborative Piano – M.M., Carnegie Mellon University; Carnegie Mellon, 1995–

TATJANA CHAMIS, Artist Lecturer in Viola – B.M., Curtis Institute of Music; Carnegie Mellon, 2016–

REBECCA CHERIAN, Artist Lecturer in Trombone – M.M., Yale University; Carnegie Mellon, 1993–

ALEC CHIEN, Artist Lecturer in Piano Literature and Repertoire – D.M.A, The Juilliard School;

DENIS COLWELL, Head and Associate Professor – M.M., Carnegie Mellon University; Carnegie Mellon, 1980–

DANIEL CURTIS, Resident Conductor – M.M. , Carnegie Mellon University;

MICHELE DE LA REZA, Assistant Teaching Professor of Dance – M.S., University of Pittsburgh; Carnegie Mellon, 2007–

CYNTHIA DEALMEIDA, Associate Teaching Professor in Oboe – M.M., Temple University; Carnegie Mellon, 1991–

JEFF DEE, Artist Lecturer in Bass Trombone – M.M, The Juilliard School; Carnegie Mellon, 2017–

ERIC DEFADE, Director of Jazz Ensemble – B.M., University of North Texas; Carnegie Mellon, 2002–

ROBERT DELL, Artist Lecturer in Music Education – Ed.D. , University of Pittsburgh;

MARK DOMENCIC, Artist Lecturer in Music Theory – M.M., Carnegie Mellon University; Carnegie Mellon, 2007–

THOMAS DOUGLAS, Teaching Professor of Voice – M.M., Duquesne University; Carnegie Mellon, 1991–

PAUL EVANS, Artist Lecturer in Percussion – M.M., Temple University; Carnegie Mellon, 1995–

JAMES FERLA, Artist Lecturer in Guitar – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1977–

CYRUS FOROUGH, Professor of Violin – M.M., Conservatoire Royal de Music de Bruxelles; Carnegie Mellon, 2001–

NANCY GALBRAITH, Professor of Composition – M.M., West Virginia University; Carnegie Mellon, 1984–

PAUL GERLACH, Artist Lecturer in Music Education – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1982–

NANCY GOERES, Artist Lecturer in Bassoon – B.M., Boston University; Carnegie Mellon, 1988–

CANDICE GU, Percussion Ensemble Director Duquesne University; Carnegie Mellon, 2015–

PETER GUILD, Artist Lecturer in Double Bass – M.M., University of Michigan;

DAVID HARDING, Associate Professor in Viola and Chamber Music – B.M., The Juilliard School; Carnegie Mellon, 2012-–

JAMES HOULIK, Artist Lecturer in Saxophone Eastman School of Music; Carnegie Mellon, 2018–

MICAH HOWARD, Artist Lecturer in Double Bass – M.M., Duquesne University; Carnegie Mellon, 2010–

ANNIE HSIEH, Assistant Teaching Professor of Music Theory University of California, San Diego; Carnegie Mellon, 2018-–

ROSEANNA IRWIN, Associate Teaching Professor of Coaching and Accompanying – M.M., Duquesne University; Carnegie Mellon, 1990–

JOHN PAUL ITO, Assistant Professor of Music Theory – Ph.D., Columbia University; Carnegie Mellon, 2011–

PAUL JOHNSTON, Artist Lecturer in Music History – B.M.E., Andrews University; Carnegie Mellon, 2005–

ANNABELLE JOSEPH, Professor of Music – D.A., Carnegie Mellon University; Carnegie Mellon, 1986–

KENNETH KEELING, Associate Head and Professor Emeritus of Music – D.M.A., Catholic University of America; Carnegie Mellon, 1996–

SUNG-IM KIM, Staff Pianist – M.M., Carnegie Mellon University; Carnegie Mellon, 2011–

CRAIG KNOX, Artist Lecturer in Tuba – B.M., Curtis Institute of Music; Carnegie Mellon, 2005–

PETER KOPE, Assistant Teaching Professor of Dance University of Dayton; Carnegie Mellon, 2007–

STEPHEN KOSTYNIAK, Artist Lecturer in French Horn – B.M., The Juilliard School;

JASON KUSH, Artist Lecturer in Saxophone – D.M.A., University of Miami; Carnegie Mellon, 2017–

LANCE LADUKE, Artist Lecturer in Euphonium – B.M., Michigan State University; Carnegie Mellon, 2003–

CARLA LAROCCA, Associate Teaching Professor of Keyboard Studies – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1991–

ELIZABETH LAWRENCE, Artist Lecturer in Jazz Voice and Director of Jazz Vocal Ensemble – M.M., Manhattan School of Music; Carnegie Mellon, 1996–

HANNA WU LI, Professor of Piano and Piano Pedagogy – M.M., Northwestern University; Carnegie Mellon, 1969–

CHRISTOPHER LYNCH, Artist Lecturer in Music History – Ph.D., University of Buffalo; Carnegie Mellon, 2018–

LUZ MANRIQUEZ, Associate Teaching Professor in Collaborative Piano – M.M., Carnegie Mellon University; Carnegie Mellon, 1992–

JOHN MARCINIZYN, Artist Lecturer in Guitar and Composition – Ph.D., University of Pittsburgh; Carnegie Mellon, 1991–

JOHN MCCARTHY, String Methods Instructor – B.F.A., Carnegie Mellon University; Carnegie Mellon, 2013-–

LORNA MCGHEE, Artist Lecturer in Flute Royal Scottish Academy of Music and Drama; Carnegie Mellon, 2015–

MONIQUE MEAD, Director of Music Entrepreneurial Studies – M.M., Indiana University-Bloomington;

ANNE MOSKAL, Artist Lecturer in Solfege – M.M., Carnegie Mellon University;

STEPHEN NEELY, Artist Lecturer in Eurhythmics – M.M., Carnegie Mellon University; Carnegie Mellon, 1998–

DJORDJE NESIC, Vocal Coach & Accompanist – M.M., Cincinatti College-Conservatory of Music; Carnegie Mellon, 2016–

RODRIGO OJEDA, Staff Pianist – M.M., Carnegie Mellon University; Carnegie Mellon, 2011–

BENJAMIN OPIE, Artist Lecturer in Music Technology – M.M., Duquesne University; Carnegie Mellon, 2005–

NATALIE OZEAS, Professor of Music Education and Director of Graduate Studies – Ed.D., University of Pittsburgh; Carnegie Mellon, 1989–

DIMITRI PAPADIMITRIOU, Artist Lecturer in Chamber Music – D.M.A., Royal Irish Academy of Music; Carnegie Mellon, 2015–

MILDRED MILLER POSVAR, Artist Lecturer in Voice – B.M., Cleveland Institute of Music; Carnegie Mellon, 1981-–

DAVID PREMO, Artist Lecturer in Cello – M.M., Indiana University; Carnegie Mellon, 1994–

RICHARD RANDALL, Assistant Professor of Music Theory – Ph.D., Eastman School of Music; Carnegie Mellon, 2008–

MICHAEL RUSINEK, Artist Lecturer in Clarinet – M.M., Curtis Institute of Music; Carnegie Mellon, 1998–

VAHAN SARGSYAN, Staff Pianist – M.M, Yerevan Komitas State Conservatoire;

SERGEY SCHEPKIN, Associate Professor of Piano – D.M.A., New England Conservatory; Carnegie Mellon, 2003–

STEPHEN SCHULTZ, Associate Teaching Professor of Music History and Flute – M.M., San Francisco State University; Carnegie Mellon, 2002–

RICCARDO SCHULZ, Associate Teaching Professor and Director of Recording Activities – M.A., University of Pittsburgh; Carnegie Mellon, 1988–

FRANCO SCIANNAMEO, Associate Teaching Professor of Film Musicology and CFA Associate Dean – D.M, Conservatorio di Musica, Santa Cecilia;

MARIA SPACAGNA, Associate Professor of Voice – M.M., New England Conservatory; Carnegie Mellon, 2012-–

JESSE STILES, Assistant Teaching Professor of Sound Media – M.F.A., Rensselaer Polytechnic Institute; Carnegie Mellon, 2015–

STEPHEN STORY, Associate Conductor of Wind Ensemble – M.M., Carnegie Mellon University;

PETER SULLIVAN, Artist Lecturer in Trombone Aspen School of Music; Carnegie Mellon, 2000–

DANIEL TEADT, Artist Lecturer in Voice – M.M, University of Illinois; Carnegie Mellon, 2011-–

MARILYN TAFT THOMAS, Professor of Music – Ph.D., University of Pittsburgh; Carnegie Mellon, 1981–

THOMAS THOMPSON, Associate Teaching Professor of Clarinet and Co-Director of Wind Ensemble – M.M., Northwestern University; Carnegie Mellon, 1986–

KELLY TRUMBULL, Artist Lecturer in Acting – M.A., New York University; Carnegie Mellon, 2015–

REZA VALI, Professor of Composition – Ph.D., University of Pittsburgh; Carnegie Mellon, 1988–

WILLIAM VAN DER SLOOT, Assistant Teaching Professor of Violin – Diploma, International Institute for Chamber Music; Carnegie Mellon, 2017–

GRETCHEN VAN HOESEN, Artist Lecturer in Harp – M.M., The Juilliard School; Carnegie Mellon, 1985–

GEORGE VOSBURGH, Artist Lecturer in Trumpet and Co-Director of Wind Ensemble – B.A., University of Rochester; Carnegie Mellon, 2003–

JAMES WHIPPLE, Artist Lecturer in Music Theory – B.A., Carnegie Mellon University; Carnegie Mellon, 1995–

ANNE MARTINDALE WILLIAMS, Artist Lecturer in Cello – Diploma, Curtis Institute of Music; Carnegie Mellon, 1987–

ALEXA WOLOSHYN, Assistant Professor of Musicology – Ph.D, University of Toronto; Carnegie Mellon, 2016-–

CHRISTOPHER WU, Artist Lecturer in Violin – B.A., Eastman School of Music; Carnegie Mellon, 2009–

LENNY YOUNG, Artist Lecturer in Solfege – M.M., Carnegie Mellon University; Carnegie Mellon, 2015–

MONICA YUNUS, Artist Lecturer in Voice Entrepreneurship – M.M., The Juilliard School; Carnegie Mellon, 2018–

School of Music Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

57-008 Vocal Master Class II
Fall
This is a group coaching class for sophomore voice majors.

57-009 Vocal Master Class II
Fall and Spring
This is a group coaching class for sophomore voice majors.

57-010 Voice Studio Performance Class
Fall and Spring
Vocal Studio Performance Class is a required class for both undergraduate and graduate voice majors. Each student must participate in two singing rotations each semester and will receive written comments from the voice faculty. Students are also required to attend four studio classes each semester. Grading is pass/fail based on attendance.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-015 Violin Studio Performance Class
Fall and Spring
Once a week throughout the semester a "violin studio performance class" takes place. A studio class is a most important performance opportunity as it is a step between the studio lessons and the concert stage. Students perform the repertoire they are working on in front of the class and Prof. Forough. Along with comments from the class, Prof. Forough works one on one with each student. The repertoire performed can be solo pieces or accompanied pieces. This class is for violin majors who are studying with Prof. Forough. Other students may audit the class.

57-016 Viola Studio Performance Class
Fall and Spring
TBA

57-018 Double Bass Studio Performance Class
Fall and Spring
TBA

57-020 Flute Studio Performance Class
Fall and Spring
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-021 Oboe Studio Performance Class
Fall and Spring
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-022 Clarinet Studio Performance Class
Fall and Spring
The purpose of this class is to have performance before an audience (studio class members) to ease performance anxiety. The class meets once a week, is not for credit and is not mandatory. In addition to playing, the class listens to recordings of various styles of clarinet playing.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-023 Bassoon Studio Performance Class
Fall and Spring
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-028 Euphonium Studio Performance Class
Fall and Spring
tba

57-030 Percussion Studio Performance Class
Fall and Spring
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-100 Convocation
Fall and Spring: 1 unit
A weekly meeting for all music students that features lectures, concerts, and other presentations related to professional development.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-101 Introduction to Music Technology
Fall and Spring: 6 units
This course gives an overview of music technology through practical information and several hands-on projects. Concepts such as MIDI and digital audio are introduced and specific topics are covered in detail including sequencing, music notation, digital recording, mixing, and production. Throughout the course, students are required to complete several projects and create musical compositions in styles of their own choosing. The student is not graded on the "musicality" of these compositions, but instead on how well they meet the stated project goals by correctly using specific equipment and/or computer programs.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-102 Finale
Spring: 6 units
This course provides hands-on and in-depth instruction of the Finale music notation program by Coda Music Software. Students will learn how to efficiently use the various notation tools that Finale has to input, edit, and manipulate music. MIDI input, playback, and transcription will also be covered to allow students to quickly notate and hear their music. The goal is to create professional-looking printed scores and parts in a variety of styles from Classical to Contemporary. Open to music majors only except by instructor permission. Introduction to Music Technology (57801/871) or equivalent experience required.
Prerequisites: 57-101 or 57-171

57-103 Elective Studio (Beginning Piano Class)
Fall and Spring: 3 units
TBA

57-109 Elective Studio (Guitar Class)
Fall and Spring: 3 units
Using classical and jazz guitar methods, this course is designed to provide a basic set of techniques that will allow students to pursue the avenue of guitar playing that most interests them. While emphasis will be on developing skills in playing the guitar, a basic understanding of the principles of music theory as applied to the guitar will also be acquired. While few students will find it possible to master all of the materials presented, an exposure to the many possibilities of musical expression available on the guitar and an understanding of basic music theory will help to broaden the students' perspective and make future musical experiences, such as listening and performing, more rewarding. Each student is expected to have his/her own instrument. A guitar in good working condition is essential. An acoustic classical or steel string is preferred, an electric with a small battery operated amp is acceptable. Students having no previous training on the guitar will find this class most valuable.

57-110 Elective Studio (Voice Class)
Fall and Spring: 3 units
Students enrolled in group voice will gain an understanding of basic vocal technique and a variety of singing styles. Students will learn about proper breathing, tone production and posture. Vocal styles will include pop, jazz, musical theater and classical. Students will also explore harmonization, improvisation and audition techniques for the singer. This class is geared towards the beginning student.

57-111 Movement and Dance I
Fall: 3 units
The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-112 Movement and Dance II
Spring: 3 units
The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.
Prerequisite: 57-111

57-149 Basic Harmony I
Fall: 9 units
This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. Section assignment is determined by a placement test. It includes work on fundamentals for inexperienced students.

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-150 Basic Harmony II
Fall: 9 units
This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. It includes work on fundamentals for inexperienced students.
Prerequisite: 57-149

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-151 Counterpoint in Theory and Application
Fall: 6 units
In Counterpoint in Theory and Application, students begin by learning the traditional five species of counterpoint in a tonal context. They then build on this foundation, learning to analyze music in terms of the underlying counterpoint and to apply this analysis to performance, and producing original tonal compositions in two voices.
Prerequisites: 57-150 or 57-153

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/CTP/CTPMain.html

57-152 Harmony I
Fall: 9 units
This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. Section assignment is determined by a placement test.

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-153 Harmony II
Spring: 9 units
This course is a continuation of the study of common practice harmony, exploring dissonant and chromatic harmony.
Prerequisite: 57-152

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-161 Eurhythmics I
Fall: 3 units
Dalcroze Eurhythmics is a unique approach to music learning based on the recognition that meaningful rhythmic movement experience, associated with ear-training and improvisation, reinforces understanding of music concepts, enhances musicianship, and focuses awareness on the physical demands of artistic performance. All concepts are experienced in a musical context. Rhythm reading, notation, analysis, and improvisation are integral to the course. Eurhythmics I covers basic binary and ternary metric units and rhythm patterns in relation to these metric units within simple and compound meters.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-162 Eurhythmics II
Spring: 3 units
Eurhythmics II introduces combinations of binary and ternary metric units, mixed meters, changing meters, and notation and performance of cross-rhythms.
Prerequisite: 57-161

57-163 Eurhythmics III
Fall: 3 units
Eurhythmics is a unique approach to music learning developed by the Swiss composer and educator Emile Jaques-Dalcroze (1865-1950). Dalcroze discovered that meaningful rhythmic movement experiences away from their instrument allows students to focus awareness on the physical demands of artistic performance while demonstrating knowledge and understanding of the expressive/interpretive as well as the theoretical aspects of music. Sight reading, conducting, notation, analysis and improvisation are integral to the course. Eurhythmics III Course Content: Divisive vs Additive rhythm, Metric transformation, Irregular subdivisions of metric units, Cross rhythms of 3 against 4, 3 against 5, 4 against 5.
Prerequisite: 57-162

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-164 Eurhythmics IV
Spring: 3 units
Eurhythmics is a unique approach to music learning developed by the Swiss composer and educator Emile Jaques-Dalcroze (1865-1950). It is a process for awakening, developing and refining innate musicality through rhythmic movement, ear training and improvisation. Through rhythmic movement, students demonstrate knowledge and understanding of the expressive/interpretive as well as the metrical/structural aspects of music. Sight reading, conducting, notation, analysis and improvisation are integral to the course. Eurhythmics IV Course Content: More complex rhythmic problems encountered in composed music, Changing meters and changing metric units within a composition, Rhythm reading of patterns using small note values, Messiaen rhythm techniques.
Prerequisite: 57-163

57-171 Introduction to Music Technology (self-paced)
Fall and Spring: 6 units
This course gives an overview of music technology through practical information and several hands-on projects. Concepts such as MIDI and digital audio are introduced and specific topics are covered in detail including sequencing, music notation, digital recording, mixing, and production. Throughout the course, students are required to complete several projects and create musical compositions in styles of their own choosing. The student is not graded on the "musicality" of these compositions, but instead on how well they meet the stated project goals by correctly using specific equipment and/or computer programs. This is a self-paced version of 57-101. Material will be covered during weekly class sessions, though students are expected to make time in the evenings or weekends to work on their projects in either the MTC (MM119A) or some other cluster. Students with prior experience may pass out of certain classes and projects by providing teacher with equivalent work (pending teacher approval). In addition to the required projects, there is a final exam which is administered during the last class session.

57-173 Survey of Western Music History
Fall and Summer: 9 units
This course surveys the development and contexts of European art music and its global adaptation. While keeping in view the chronology from Gregorian chant to the present, this survey emphasizes key personalities and issues, particularly issues relating to period style and interpretive decisions in performance.

Course Website: https://cmu.app.box.com/files/1/f/9350209729/1/f_33705395781

57-180 Basic Solfege I
Fall: 3 units
This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test. It includes work on fundamentals for inexperienced students.

57-181 Solfege I
Fall: 3 units
This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-182 Solfege II
Spring: 3 units
Continues 57-181 Solfege I.
Prerequisites: 57-181 or 57-180

57-183 Solfege III
Fall: 3 units
Continues 57-182 Solfege II. Students are given assignments of classical music written in the treble, bass, soprano, alto, and tenor clefs. Writing consists of two-part contrapuntal dictations.
Prerequisite: 57-182

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-184 Solfege IV
Spring: 3 units
Continues 57-183 Solfege III. Students learn to read atonal music and practice three-part contrapuntal dictations as well as harmonic dictations.
Prerequisite: 57-183

57-185 Advanced Solfege I
Fall: 3 units
This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test. It includes advanced work for experienced students and those with perfect pitch.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285566497

57-186 Advanced Solfege II
Spring: 3 units
Continues 57-185 Advanced Solfege I.
Prerequisite: 57-185

57-188 Repertoire and Listening for Musicians
Fall: 1 unit
This course is the required co-requisite listening component for Survey of Western Music History (57-173). In this course, students listen critically to essential music which has stood the test of time and to superior performances. It features 2-3 hours of listening per week.

57-189 Introduction to Repertoire and Listening for Musicians
Fall: 3 units
One of the most important ways of achieving musical excellence is to listen. In this course, students listen critically to essential music which has stood the test of time and to superior performances. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for freshman music majors.

57-190 Repertoire and Listening for Musicians I
Spring: 3 units
One of the most important ways of achieving musical excellence is to listen. In this course, students listen critically to essential music which has stood the test of time and to superior performances. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. This semester introduces full scores for chamber and orchestral music. Midterm and final listening tests. This course contains midterm and final listening tests. Proficiency requirement for freshman music majors. Other students admitted with instructor's permission.

57-191 Keyboard Studies
Fall and Spring: 3 units
All undergraduate music students are required to take four semesters of keyboard studies during their freshman and sophomore years. The emphasis of this course is to develop a practical keyboard facility, which includes keyboard theory and technique, sightreading, solo and ensemble repertoire, transposition, and a variety of creative activities such as harmonization and improvisation.

57-193 Collaborative Piano Skills I
Fall: 3 units
A required course for first year piano majors. The skills include sightreading, basic keyboard harmony, transposition, and improvised accompaniments for popular or musical theater songs from either a piano reduction or a lead sheet. The students participate in collaborative situations such as juries, recitals, and class presentations. The presentations are critiqued by the instructor and by other students.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-194 Collaborative Piano Skills II
Spring: 3 units
Continues 57-193 Collaborative Piano Skills I.
Prerequisite: 57-193

57-207 Secondary Studio
Fall
Provides the opportunity for students to pursue study in a secondary instrument or area. By special permission only.

57-208 Secondary Studio
Spring
Provides the opportunity for students to pursue study in a secondary instrument or area. By special permission only.

57-209 The Beatles
Intermittent: 9 units
This course will focus on the phenomenon of the Beatles. Their songs will be studied, with analysis of the musical and lyrical content and structural elements. What musical styles do the songs address? What were their musical influences? In what ways did their music change over the years? Also, the music's social context will be studied. Why were the Beatles so popular and influential? What exactly caused Beatlemania? How did the group form, grow, and end? The Beatles are the most famous rock group in history; the reasons for this are as much cultural as musical, and we'll study the two elements simultaneously. Open to all undergraduate students.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285571361

57-211 Movement and Dance III
Fall: 3 units
The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.
Prerequisite: 57-112

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-212 Movement and Dance IV
Spring: 3 units
The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.
Prerequisite: 57-211

57-220 English Diction
Fall: 3 units
This one semester course helps singers sing English songs from the Classical and Musical Theater repertoire with clarity, accuracy, ease, uniformity, and expressiveness; to illuminate meaning; and to improve tonal quality through diction.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-221 Italian Diction
Fall: 3 units
A study of the fundamentals of Italian diction and development of legato vocal style through the analysis of grammatical usage, word construction, vowel colorization, and consonant articulation. Included are in-class performance evaluations, listening assignments, critiques, and private coachings.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-222 French Diction
Fall: 3 units
This course is designed primarily for singers specializing in French Art Songs of the 19th and 20th centuries. It deals with the use of the International Phonetic Alphabet, its application to singing in French, the use of the liason and the preparation of the text of a song or aria. One-third of the course is theory and two-thirds of the course is spent on application by performance with piano accompaniment.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-223 German Diction
Fall: 3 units
In-depth study of German diction - development of legato vocal style in German through the analysis of grammatical usage, word construction, vowel colorization and consonant articulation. Included are in-class German diction evaluations, peer assessment, and emphasis on competency in using the International Phonetic Alphabet.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-227 Jazz Orchestra
Fall and Spring: 3 units
This ensemble incorporates a comprehensive approach to Big Band performance and study. The music performed is drawn from all eras of big band repertoire with occasional programs of specific composers and genres. The ensemble is carefully coordinated with the Jazz Vocal Ensemble and major ensembles in order to challenge and prepare students for professional music career opportunities. The ensemble performs on the regular School of Music concert series (2-3 shows per semester) and for on-campus events. Admission of undergraduate and graduate students is by competitive audition and placement is by the director. Grading is based on attendance, preparation, and consistent progress.
Prerequisite: 57-227

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-228 Chamber Music: Woodwind and Mixed
Fall: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-229 Chamber Music: Woodwind and Mixed
Fall and Spring: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-230 Baroque Ensemble
Fall and Spring: 3 units
Carnegie Mellon Baroque is a performing ensemble of 15-25 players consisting of winds, strings and keyboard. Students in this ensemble explore the orchestral and chamber music of the 18th Century. The Ensemble performs on modern instruments, incorporating performance practice ideals of the Baroque era. Throughout the rehearsal process, students are encouraged to study original source materials and arrive at historically informed and musically satisfying performances.

57-231 Chamber Ensemble
Intermittent: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. Low Brass Ensemble: The low brass ensemble pushes the boundaries of what is "supposed" to be played by an ensemble of this type. Players will be involved in the programming, arranging and planning pf performances and will learn valuable musical, creative, promotional and organizational skills.

57-232 Chamber Music: Guitar
Fall and Spring: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-233 Sonatas
Fall and Spring: 3 units
This course focuses on coaching of performance groups with two members. It parallels Chamber Music, which focuses on coaching of performance groups with three or more members.

57-234 Performance for Composers
Fall: 3 units
This course is for composition majors who choose to fulfill the performance elective requirement in the junior year by completing an independent performance project in the fall semester. Examples of projects can include producing a recital of his/her compositions, or pursuing other performing interests, such as writing music for a School of Drama production. Registration by composition faculty permission only.

57-236 Performance for Composers
Spring: 3 units
This course is for composition majors who choose to fulfill the performance elective requirement in the junior year by completing an independent performance project in the spring semester. Examples of projects can include producing a recital of his/her compositions, or pursuing other performing interests, such as writing music for a School of Drama production. Registration by composition faculty permission only.
Prerequisite: 57-234

57-240 Acting I
Fall: 6 units
The basics of acting will be established throughout the first year following the guideposts described in Audition, by Michael Shurtleffís. Structured improvisations, monologues, scene work, songs, and arias will provide a platform for the development of stage presence and effective communication. Each semester will finish with a group project that provides an opportunity for the students to begin to work together as a cast.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285564193

57-241 Acting II
Spring: 6 units
Continues 57-240 Acting I.
Prerequisite: 57-240

57-257 Orchestration I
Fall: 6 units
This is an introductory course for all music majors and required for sophomore composition majors. The characteristics of each instrument of the orchestra are studied thoroughly. Orchestral textures from the classics to contemporary music are studied and analyzed.
Prerequisites: 57-156 or 57-150 or 57-153

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-258 20th-21st Century Techniques
Spring: 6 units
This course is open to all music majors and required for sophomore composition majors. The most important techniques from Debussy to the present will be reviewed in terms of melody, harmony, and form. Tonality, serialism, and aleatoric devices will be studied. Compositional techniques of the 20th Century are put into perspective and compared with other developments in the arts. The class is conducted as an open forum in which discussions are encouraged.
Prerequisite: 57-151

57-271 Orchestration II
Fall: 6 units
Students will analyze music from the Classical to Avant-Garde and use the knowledge acquired to orchestrate piano scores in the appropriate style. Style, practicality, color, and imagination are encouraged. This course is designed for junior composition majors. Other students may register with instructor permission after an interview.
Prerequisites: 57-257 and 57-521

57-273 Piano Pedagogy I
Fall: 6 units
This course offers an historical overview of piano pedagogy including its significant developments over the past forty years. Topics covered include beginning piano techniques, the sequencing of concepts and materials, common problems among beginning pianists, practicing, motivation, and parental involvement. Current representative beginning piano methods will be surveyed.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-274 Piano Pedagogy II
Spring: 6 units
Beyond the beginning years: this course covers piano pedagogy of intermediate and early advanced level students. Topics include "What is a good piece?" Standard literature and technical development repertoire lists will be studied. The business of piano teaching and the instruction of college keyboard skills for non-piano majors will be discussed.
Prerequisite: 57-273

57-275 Piano Pedagogy III
Fall: 6 units
Continuation of 57-274. Intermediate literature, analysis, teaching, and performance will be covered. Topics include "What is style?"
Prerequisite: 57-274

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-276 Piano Pedagogy IV
Spring: 6 units
Continuation of 57-275. Early advanced literature, analysis, teaching, and performance will be covered.
Prerequisite: 57-275

57-283 Music History I
Fall: 9 units
This class will be an in-depth analytical study of music of the Medieval, Renaissance, and Baroque Periods. It will emphasize selected genres and forms by representative composers in order to trace the evolution of musical style and to clarify the main characteristics of these periods, to set the musical developments in broader cultural contexts, and to apply this knowledge to practical decisions made by today's musician.

57-284 Music History II
Spring: 9 units
This class will be an in-depth analytical study of music of the Classical and Romantic periods. It will emphasize selected genres and forms by representative composers in order to trace the evolution of musical style, to clarify the main characteristics of these periods, to set the musical developments in broader cultural contexts, and to apply this knowledge to practical decisions made by today's musician.
Prerequisite: 57-283

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-285 Music History III
Spring: 9 units
This class will be an in-depth analytical study of music from the 20th and 21st centuries. It will emphasize selected genres and approaches by representative composers in order to trace the various threads of musical style, to clarify the main characteristics of the period's music, to set the musical developments in broader cultural contexts, and to apply this knowledge to the lives and musical practices of musicians today.
Prerequisites: 57-284 and 57-283

57-289 Repertoire and Listening for Musicians II
Fall: 3 units
This is a continuation of the School of Music's four-semester listening curriculum. Students listen critically to essential music which has stood the test of time and to superior performances. This semester's repertoire includes units focusing on contrapuntal masterpieces from the Middle Ages through 20th Century, and further builds score-reading experience. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for sophomore music majors. Other students admitted with instructor's permission. Repertoire and Listening for Musicians I and II are not prerequisites.

57-290 Repertoire and Listening for Musicians III
Spring: 3 units
This is the culmination of the School of Music's four-semester listening curriculum. Students listen critically to essential music which has stood the test of time and to superior performances. Highlights of this semester's repertoire include units on Middle and Late Beethoven as well as a decade-by-decade survey of the 20th Century. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for sophomore music majors. Other students admitted with instructor's permission. Repertoire and Listening for Musicians I-III are not prerequisites.

57-293 Keyboard Studies Test (Degree)
Fall and Spring
This is the keyboard proficiency test which is a requirement for all undergraduate music majors who are not piano majors.

57-294 Beginning Piano Test
Fall and Spring
This is the keyboard proficiency test which is a requirement for all music performance, music composition, music technology, and music theory minors.

57-300 Advanced Bagpipe and Drum Band
Fall and Spring: 3 units
The Pipe Band at Carnegie Mellon is a competitive Grade 3 band in the Eastern United States Pipe Band Association. The band competes at various Scottish festivals and Highland Games during the school year. The band also performs at university activities throughout the year. These include Convocation, Homecoming, Spring Carnival, and Commencement. Other engagements are Spring Concert at CMU and the St. Patrick's Day Parade in Pittsburgh. The band has also played as an opening act for the Pittsburgh Steelers and a Rod Stewart concert.
Prerequisite: 57-299

57-301 Bagpipe History
Intermittent: 3 units
This course covers all types of bagpipe music, including Ceol Mor and Ceol Beag, and studies the prominent composers from MacCrimmon to the present day. Students compose their own material in all time signatures commonly used. The course covers Piobaireachd, Marches, Strathspeys, Reels, Hornpipes, and Jigs, as well as harmony and the ability to write out tunes from repetitive listening.

57-303 Bagpipe Literature and Repertoire
Intermittent: 3 units
This course will cover the origins of the bagpipe and Piobaireachd, bagpipe music in competition, military, and dance. We will also cover major piping competitions, famous bagpipe players, and piping today.

57-304 Bagpipe Maintenance
Intermittent: 3 units
All aspects of bagpipe maintenance are covered in this course, from basic hemping and tying in bags to reeds set-up and manipulation. The course includes study of all types of reeds, cane and synthetic, as well as drone and chanter, and recognition of pipemakers' patterns and distinctive hallmarks.

57-305 Bagpipe Reedmaking
Intermittent: 3 units
This is a hands-on course where the student learns how to make pipe chanter reeds by the traditional method of gouging, shaping, and tying up. This course follows 57-304, Bagpipe Maintenance. Further analysis of chanter and drone reeds will be covered also.
Prerequisite: 57-304

57-306 World Music
Fall: 9 units
A study of major musical traditions from around the world, including classical music from Asia (broadly defined) and the Middle East, as well as traditional musics in Africa, Europe, and the Americas. This course will examine music in its socio-cultural context, and will demonstrate how learning about music from diverse cultures increases cross-cultural understanding. This course will engage with readings, listening examples, multi-media presentations, in-class discussions, music-making activities, and special guests (virtual and in person).

57-307 Bagpipe Theory
Intermittent: 3 units
This course prepares students for 57-302, Bagpipe Construction. All aspects of Bagpipe Theory are covered, including time signatures, grand staff, musical rudiments, musical terms and definitions, and writing of simple tunes from memory.

57-313 Topics in Movement and Dance: Techniques
Fall: 3 units
This intermediate level course furthers the dance foundation practiced in the first two years of the School of Music movement curriculum. This modern dance technique class will explore momentum based phrase material, body alignment and release, movement dynamics, inversions and floor work. This course focuses on the information and the tools needed to extend movement technique, skills, and performance quality.
Prerequisite: 57-212

57-314 Topics in Movement and Dance: Movement Lab
Spring: 3 units
This intermediate level course will encourage an understanding of dance through the practice of creative improvisation and composition. The course is designed to develop the process of exploration and creation of movement and its performance applications.
Prerequisite: 57-212

57-329 Beginning Piano for Minors
Fall and Spring: 3 units
This is a small group lesson for music performance, music composition, music technology, and music theory minors who cannot pass the required beginning piano test.

57-330 Beginning Piano for Minors
Spring: 3 units
This is a small group lesson for music performance, music composition, music technology, and music theory minors who cannot pass the required beginning piano test.

57-331 Principles of Education
Fall: 9 units
This course introduces students to the art and science of being an educator. Content includes views of the academic and social structure of the school, physiological & social characteristics of learners that influence instruction, widely recognized research on learning & teaching, and appropriate & effective class preparation and teaching strategies.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-332 Introduction to Conducting
Fall: 6 units
This course develops the basic skills needed to conduct instrumental ensembles or a small orchestra. It is primarily focused on conducting technique, body language and body coordination and communication. It also deals with learning and translating an instrumental or orchestral score into actual music. The goal is to achieve a clear and communicative technique upon which an artistic interpretation can be built. The student works periodically with a pianist or a small chamber ensemble.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-333 Band and Choral Arranging
Spring: 6 units
This course presents basic techniques of arranging music for elementary and secondary school choral and instrumental ensembles. Instruments and voices are reviewed for best scoring properties and systematic aural & visual score analyses of repertoire are used to reveal various approaches to scoring ensemble sound.
Prerequisites: 57-153 or 57-150

57-334 Fundamentals of Marching Band
Fall: 3 units
A marching band, due to its visibility and high degree of student involvement, is an integral part of secondary school music programs. The well-schooled music education graduate must have knowledge of this unique form of music performance. This course, designed primarily for those seeking a career in teaching, will accommodate students with no experience and others who have participated in marching band. Among the many areas of concentration will be: philosophy, show charting, marching fundamentals and commands, logistical awareness, and budget formulation. Observation of and active assistance with Carnegie Mellon Kiltie Band will be part of the course content.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-336 Instrumental/Choral Conducting
Spring: 6 units
This course is a continuation of Introduction to Conducting. The course offers a more detailed conducting technique, adding those subjects related to choral conducting. This is followed by the study and the analysis of interpretation from the point of view of the conductor and ends stressing a set of important practical items, including the psychological attitude and the leadership a conductor must develop as well as the organization and achievement of a fruitful rehearsal technique. The students work periodically with a pianist, a soloist or a chamber ensemble on traditional works and on their own compositions in the case of composition majors.
Prerequisite: 57-332

57-337 Sound Recording
Fall and Spring: 6 units
Sound Recording (57337, 57947) centers around the Vlahakis Recording Studio in the College of Fine Arts: how the studio works, and how to record various types of music. The method of instruction is to learn by doing, and the goal is to achieve professional-sounding results. Equipment includes a complete 24-track Pro-Tools system, professionally designed control room that can accommodate up to 24 people, outboard preamps and other gear, and an interesting array of microphones. All recording is direct to hard disc. Grading is based on recording projects, class attendance, mastering studio hardware and software, and several quizzes.

57-338 Sound Editing and Mastering
Fall and Spring: 6 units
The raw recording is just the first step in the process of creating a professional finished audio product. "Editing" is the art of piecing together different takes to make one final 'good take.' "Mastering" is the art of polishing the 'good take' to perfection—balancing all the instruments and tracks, adding special effects, setting final levels. If 'recording' seems like an high-energy activity—involving engineers, musicians, producers—'editing and mastering' are the necessary counterparts—long tedious hours of solitary confinement honing the skills of the mastering engineer. Those taking this course are expected to have significant music skills: actively playing a musical instrument (or composition), and/or the ability to read a piano score at the least, and a full orchestra score from any recent century, including our own, at the most. Class attendance is essential; work outside of class is necessary.
Prerequisites: 57-337 or 57-341

57-339 Acting III
Fall: 6 units
This course will build upon the foundation laid in the first year, with a more concentrated look at scene work, an audition workshop that focuses on cold readings as well as monologues, and a character-development project that works to identify specific issues that inhibit freedom on stage. More in-depth work on songs and arias will lead into a musical scene project. The semester will close with a classical text project in which the students will work with verse.
Prerequisite: 57-241

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285564705

57-340 Acting IV
Spring: 6 units
Continues 57-339 Acting III.
Prerequisite: 57-339

57-343 Interdisciplinary Studies in Listening, Culture, and Technology
Intermittent: 9 units
The proliferation of portable as well as computerized audio technologies has radically changed the way the human beings listen, consume, and produce music and sound. With the emergence of "cloud" storage services like Dropbox, Amazon, and Google you can effortlessly store and share music files anonymously or with friends. Services like Facebook, Pandora, Spotify, Last.fm, Amazon, and iTunes use finely tuned algorithms to make musical recommendations and in the process further personalize your experience as a consumer of music. All of these services, many of which are virtual, have come to mediate our intensely personal and communal experiences with music. The Listening Spaces seminar seeks to understand the overwhelming impact these mediating technologies have had on our social, political and personal interactions with music. Foundational readings will include Jonathan Sterne's MP3: The History of a Format, Alexander Galloway's Gaming: Essays on Algorithmic Culture, Trebor Scholz's Digital Labor: The Internet as Playground and Factory. The seminar will be focused around developing and completing critical projects that cross technological and humanistic boundaries.

57-344 Experimental Sound Synthesis
Intermittent: 9 units
This is a course that will guide students into the world of experimental approaches to music and sound production, with particular emphasis in some of the key practices and concepts developed in the 20th and 21st centuries. We will examine a variety of ways in which sound works are made and perceived; understanding the historical perspectives and critical viewpoints of each approach through the application of hands-on practicum. The topics covered in the course are divided into three large areas: the art of sound, the use of technology in the production of sound works, and the creation of interdisciplinary sound installation. Students from different disciplines will work together to collaborate on the designing, prototyping and execution of a series of ambitious projects in response to the topics covered in class.

57-345 Hacking the Music World
Fall and Spring: 9 units
In this course we will perform a series of real-world experiments that examine new models for music creation, promotion, and distribution. We will produce original music videos, explore social media marketing & optimization, examine new platforms for monetization, and officially release digital albums and apps. The proliferation of digital music distribution has revolutionized how music is experienced in the 21st century. Technologies for music listening, music sharing, and music discovery are in a state of rapid and limitless evolution. There is no longer a single model for a rewarding life in the world of music ? we must learn to adapt to the constantly evolving landscape of the 21st century. We must hack the music world! While examining new approaches to distribution and publication, we will also explore the question of how electronic media is redefining our understanding of music-making itself. Does a new album necessarily need to be a fixed set of sound recordings? What if it was a mobile app that reacts to the listener?s environment? What if our new album used mutating algorithms to generate new musical experiences every time the listener hits play? Throughout the semester we will form teams combining musicians, software programmers, artists, and entrepreneurs. Our teams will work together to produce new music, to design new music distribution methodologies, and to perform social media experiments that enhance the visibility of our work. Students participating in the course should have proficiency in one or more of the following areas: Social Media Optimization, Music Recording or Video Production, Leveraging Web Application API?s, Mobile Application Design & Implementation. Prerequisites are the IDeATe portal courses or permission of the instructor. Please note that there will be a lab usage fee associated with this course.
Prerequisites: 18-090 or 60-223 or 16-223 or 62-150 or 15-104

57-347 Electronic and Computer Music
Fall: 6 units
This course builds on the concepts learned in Introduction to Music Technology (57-101) and gives added knowledge in the areas of composition using digital and analog devices as well as various computer programs. Building computer models of both analog and digital synthesizers as well as drum machines, loop players and various other sound processing effects will be covered in detail. Students will be required to produce several projects throughout the course demonstrating their understanding of various concepts in electronic music. More emphasis is placed on the overall quality of the end musical product than in 57-101 in order to prepare students for music production in a professional setting.
Prerequisites: 57-101 or 57-171

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-349 Supervised Theory Teaching
Fall and Spring: 6 units
This course provides teaching skills in theory for students who have already completed the theory program at Carnegie Mellon University or who have demonstrated theory competence. The students will attend all sessions of the assigned theory class and will assist the professor by correcting homework, delivering a short lecture, developing a class syllabus and tutoring individual students. The work is done under direct supervision and advice from the regular professor who is always present in the class. Enrollment limited to a maximum of two students per class.

57-350 Dalcroze Piano Improvisation
Fall and Spring
These courses are required for candidates in the Dalcroze Certification program. They are designed to develop keyboard improvisation skills necessary for teaching Eurhythmics.

57-351 Dalcroze Piano Improvisation
Fall and Spring
These courses are required for candidates in the Dalcroze Certification program. They are designed to develop keyboard improvisation skills necessary for teaching Eurhythmics.
Prerequisite: 57-350

57-352 Dalcroze Piano Improvisation
Fall and Spring
These courses are required for candidates in the Dalcroze Certification program. They are designed to develop keyboard improvisation skills necessary for teaching Eurhythmics.
Prerequisite: 57-351

57-353 Dalcroze Piano Improvisation
Fall and Spring
These courses are required for candidates in the Dalcroze Certification program. They are designed to develop keyboard improvisation skills necessary for teaching Eurhythmics.
Prerequisite: 57-352

57-355 Secondary Guided Teaching
Spring: 3 units
This course enables students to apply instructional strategies in local secondary school music classes. School visits provide opportunities to work with band, choral, & orchestral ensembles and general music classes. Seminar discussions with the cooperating teachers familiarize students with both school-wide and classroom management issues that affect teaching, learning, motivation, and the administration of music programs.
Prerequisites: 57-360 and 57-356 and 57-336 and 57-332 and 57-361 and 57-608 and 57-607 and 57-375 and 57-363 and 57-362

57-356 Elementary Guided Teaching
Fall: 3 units
This is the second level of field experience in the public schools. This course provides for observation and closely supervised teaching experiences with elementary age children in a school setting.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-359 Career Strategies for Musicians
Intermittent: 3 units
This course will assist students in developing the necessary expertise and materials to transition successfully from music student to professional musician. Four major areas will be covered: 1.) The multifaceted activities of today's professional musicians, individual assessments to determine strengths and challenges related to these activities, and strategies for addressing challenging areas; 2.) Developing promotional materials for entrepreneurial and salaried opportunities. Entrepreneurial materials include business cards, letterhead, photo, bio, performance resume, email list, press release, flyers, grant proposals, demo CD and website. Salaried materials include an employment resume and cover letter; 3.) Self-employment considerations, including budgeting, taxes, health insurance, and unions; and, 4.) Communications, including handling auditions, introducing pieces, introducing group members, and pitching ideas. You have the talent, determination, and work ethic to succeed. Now learn the marketing, business and communications skills to close the gap.

57-360 Brass Methods
Fall: 3 units
This music education course develops basic brass playing and teaching techniques for beginning and intermediate instrument classes. The course includes training in beginning band program design, aural & visual diagnosis of individual and ensemble playing problems, and methods of accelerating music reading independence in young players. The course requires two off-campus field teaching experiences in local schools. Each field teaching experience will require about 3 hours to complete — students should allow enough time in their schedules to complete this requirement.

Course Website: https://cmu.app.box.com/files/1/f/11681158556/1/f_106285571873

57-361 Percussion Methods
Fall: 3 units
This class gives the non-percussion major a background in the fundamentals of teaching percussion. The main focus of the course is snare drum. The students spend most of their time learning the basic concepts of beginning snare drum so they will be prepared to teach beginning students of any grade level. Much time is devoted to proper stance, grip, and stroke in order to insure a good foundation for a beginning student. Also covered are the various mallet instruments, timpani, and all small hand percussion. Students will learn about purchasing proper equipment for the various levels of learning in common school programs.

57-362 Woodwind Methods
Spring: 3 units
This music education course develops basic woodwind playing and teaching techniques for beginning and intermediate instrument classes. The course includes training in beginning band program design, aural & visual diagnosis of individual and ensemble playing problems, and methods of accelerating music reading independence in young players. The course requires two off-campus field teaching experiences in local schools. Each field teaching experience will require about 3 hours to complete — students should allow enough time in their schedules to complete this requirement.

57-363 String Methods
Spring: 3 units
String Methods prepares music educators for work in the public schools. A major portion of class time will be applied to violin and cello techniques. Upon completion of the course, the student will be expected to demonstrate the technical skills of a second year beginning string student. Students will also be introduced to various method books, string supplies, and repairs.

57-364 Conducting Practicum
Fall and Spring: 3 units
This course provides applied conducting experience for the conducting minor and other students by instructor permission.

57-370 Stage Direction
Spring: 3 units
This course provides an internship working with a middle or high school music theater production. Students may participate in coaching, direction, and choreography. In addition, they keep a journal of their experience and submit a final paper describing what they have learned from working with the teachers or professional directors who were responsible for the production. It is suggested that this course be taken during the spring semester when most music theater productions are scheduled.

57-374 Music in the Urban School
Fall and Spring: 9 units
This course will involve workshops with nationally known instructors in eurhythmics, world drumming, contemporary popular music, and classroom management. The course will require attendance at workshops, classroom observations and closely supervised teaching experiences. Schools involved are all inner city schools with a poverty level of 75% or above. This course is offered as the result of a grant received from the Federal Department of Education by the School of Music, the Pittsburgh Public Schools, and the Wilkinsburg School District.

57-375 Music in the Elementary School
Fall: 6 units
This course is designed to provide a philosophical background for teaching music in the elementary school and to provide a variety of pedagogical techniques, which are essential when teaching music from Preschool through Grade 6.
Prerequisite: 57-331

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-376 Music in the Secondary School
Spring: 6 units
This course covers a variety of topics related to the development and the management music programs in secondary schools. Emphasis is placed on the leadership, classroom management, general music & performance course content, and routine administrative planning.
Prerequisite: 57-331

57-377 Psychology of Music
Intermittent: 9 units
Music cognition is an interdisciplinary approach to understanding the mental processes that support musical behaviors, including perception, comprehension, memory, attention, and performance. Like language, music is a uniquely human capacity that arguably played a central role in the origins of human cognition. This course is survey of current approaches to and theories about the perception and cognition of music. Topics covered include psychoacoustics; the cognitive neuroscience of music; relationships between music and language; the nature of musical knowledge; and debates about aesthetics, evolutionary psychology, and musical universals. At the end of this course a student should be able to identify key theories and hypotheses in music cognition as they relate to memory, emotion, physiology, neurology, acoustics, language, and evolution. They will be able to comparatively evaluate hypotheses and place them in an intellectual context. These objectives will be achieved though critical reading, discussions, and written exercises. There are no prerequisites for this course. It will be helpful for you to know some basic elements of music theory (such as the names for chords, Roman numerals, and so on), but some extra help will be available to cover these topics. Some notational basics will be covered in the first lecture.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-378 Introduction to Music Cognition Research
Intermittent: 9 units
This course explores the roles of cognitive processes in the experience of music with a focus on carrying out a collaborative laboratory project in order to understand first-hand the challenges of the experimental study of music. In readings, lectures, discussions, and demonstrations we will become acquainted with the relevant psychological theories of perception, memory and learning, and review and critically analyze selected experimental findings on the psychology of music. We will examine the use of psychological principles (e.g. Gestalt laws of perception, limitations on working memory, categorical perception, chunking, schemas, modularity) to explain musical phenomena. The emphasis will be on applying an experimental approach to music perception and cognition, but we will also consider ongoing debates about larger issues (such as musics adaptive value to the human species, and the determinants of musical taste).
Prerequisite: either Harmony 1 or Intro to Cognitive Psychology.
Prerequisites: 57-152 or 57-149 or 85-211

57-381 Collaborative Piano I
Fall and Spring
This class is the first in a series of hands-on courses which allow the student to accumulate experience accompanying in a professional venue. Students will be assigned to a vocal and/or instrumental studio and will have the opportunity to coach repertoire with a professional accompanist. Assignments may include playing for instrumental juries.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-382 Collaborative Piano II
Fall and Spring
Continues 57-381 Accompanying I.
Prerequisite: 57-381

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-383 Collaborative Piano III
Fall and Spring
Continues 57-382 Accompanying II.
Prerequisite: 57-382

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-384 Collaborative Piano IV
Fall and Spring
Continues 57-383 Accompanying III.
Prerequisite: 57-383

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-385 Collaborative Piano V
Fall and Spring
Continues 57-384 Accompanying IV.
Prerequisite: 57-384

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-386 Collaborative Piano VI
Fall and Spring
Continues 57-385 Accompanying V.
Prerequisite: 57-385

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-391 Keyboard Studies (Music Ed)
Fall and Spring: 3 units
This course develops piano skills necessary for work in the elementary and secondary schools. Special emphasis is placed on transposition, score reading, harmonization and sight-reading. This course is required for all music education majors.
Prerequisite: 57-191

57-392 Keyboard Studies (Music Ed)
Fall and Spring: 3 units
Continues 57-391 Keyboard Studies V. This course is required for all music education majors.
Prerequisite: 57-391

57-393 Keyboard Studies Test (Music Ed)
Fall and Spring
This is the keyboard proficiency test which is a requirement for all undergraduate music majors who are music education minors.

57-399 Music-Cinema-Culture
Intermittent: 9 units
The first 100 years of the 20th Century's only original art form, whose advent has brought about tremendous social and cultural changes. Students view selected films, learning first the basics of film theory, cinema's working structures and the function of music. Ultimately, they are able to analyze, in the form of a written essay, the function and value of the music in a particular film and the impact such music has had on society.

57-403 Yoga for Musicians
Fall: 3 units
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-404 String Quartet: A Social History
Intermittent: 9 units
The string quartet is at once a medium and a genre, even a form which for more than two hundred years has had a special, unparalleled place in Western music. This course examines the development of the string quartet - from its function as an intimate and conversational social setting for amateurs, to its role as a secret repository of composers' most daring thoughts. The string quartet repertoire under discussion spans the first attempts at string quartet writing in the 17th Century, to serialism and microtonal disintegration in the 1960s, to contemporary Pop-Rock fusion experiments. This course also deals with the social and personal histories of four individuals who freed themselves from hegemonic orchestral rules in favor of an instrumental democratic microcosm. The program analyzes great music performed by the greatest quartets.

57-405 Concerto: Virtuosity and Contrast
Intermittent: 9 units
The Concerto, one of the most popular forms of music, is also a dramatic form, a drama of contrast between the strength of one body of sound and another (volume), between one type of sound and another (tonal distinction), between the individual and the masses, and finally, between the "Solo" virtuoso and the less gifted "Tutti" players. The goal of this course is to examine the greatest concerti written for all instruments; from Vivaldi's "Concerto for Two Mandolins" to John Adams's "Grand Pianola Music," and much more, while dealing with the social and personal histories of unforgettable virtuosi and the concerti that became their "Battle Horses." The program analyzes great concerti performed by the world's greatest soloists and orchestras.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-408 Form and Analysis
Spring: 6 units
This course provides a working understanding of all styles and genres of Western classical and contemporary repertoire. Students will explore various aspects of the compositional process, from basic organizational structures to the details of individual musical phrases. They will learn to see and to hear the most important compositional features of a piece of music and will develop a deeper understanding of the music they perform, conduct, and compose.
Prerequisite: 57-151

57-409 Puccini's Operas
Intermittent: 9 units
Standing between the 19th and 20th Centuries, Puccini witnessed extraordinary socio-political and cultural shifts sweeping across Europe. His operas reflect such changes through their gradual stylistic adherence to modernity. From theatrical and literary plots to complex relationships with poets, publishers, impresarios, singers, conductors, and political censors, Puccini's operas offer excellent grounds for interdisciplinary dialogue and cultural analysis.

57-412 Opera Since Wagner
Intermittent: 9 units
In the 400-year arc of opera history, the last 125 years have seen the genre's apogee, perigee, and current renaissance. Between the Wagnermania of the late nineteenth century and today's vogue for both opera and "popera," new opera production slowed greatly in the third quarter of the last century as composers rejected its traditions and audiences turned increasingly to rock and pop. In this course, we will survey this trajectory by viewing and analyzing eight repertory staples: Wagner Parsifal Debussy Pelléas et Mélisande Puccini Turandot Berg Wozzeck Gershwin Porgy and Bess Britten Peter Grimes Messiaen Saint François d'Assise Reich Three Tales We will also become acquainted with other works related to these staples, from Strauss to Saariaho and Tan Dun, and ask numerous questions. What can these operas' characters and techniques tell us about late modern subjectivity? What happened to the great national traditions? In what musical styles has opera flourished and languished? How have audiences changed? How has the notion of opera itself changed, from the nature of its heroes and heroines to its performance forces and media? The goals of this course are to 1) promote intimate knowledge of the eight core operas; 2) encourage familiarity with numerous related opera plots, opera composers, and twentieth- and twenty-first-century musical styles; 3) broaden literary and musical analytical tools to include historical, aesthetic, and (multi)cultural perspectives on opera; and 4) improve oral and written communication skills about opera. Requirements: Attendance at opera screenings, readings, quizzes, small written assignments, and a 17 to 20-page research paper on an opera of your choice written since 1850. Required text: Mervyn Cook, ed. The Cambridge Companion to Twentieth-century Opera (2005).
Prerequisite: 57-284

57-413 The Interpretation of Music
Intermittent: 6 units
What does it mean to "interpret" music? How does performance differ from interpretation? How do we distinguish a good interpretation from a bad one? To answer these questions, this course examines Metaphor, History, Influence, Meaning, Analysis, Performance, Musicology, and other concepts, applying them to works like the Mendelssohn Violin Concerto, Chopin's Fantasie Impromptu, Beethoven's "Ghost" Trio, and Debussy's "Voiles." Our readings draw mainly from Lawrence Kramer's Interpreting Music (2011). Our goal is to appreciate the complexity and nuance inherent in the process of music making and to formulate our individual values in the interpretation of music.

57-414 Music and Nature
Intermittent: 9 units
Musicians and philosophers have long explored the rapport between music and nature, tracing music's origins alternatively to nature and human culture and defining nature differently according to their time and place. This course will examine the opposition between nature and culture through both musical compositions and philosophical writings. We will study theories of the origin of music (from Lucretius to biomusicology), theories of music that seek justification by appealing to nature (from Boethius to Grisey), and theories that question whether natural sounds can be music. We will also examine musical representations of place, weather, and animals through the perspectives of ecocriticism and notions of the pastoral. Repertory will include Vivaldi's "Spring" Concerto, Beethoven's "Pastoral" Symphony, Wagner's Ring of the Nibelung, Mahler's Symphony No. 3, and Debussy's La Mer. We will compare landscapes by Sibelius and Copland, birds by Dvorak, Bartók, Ravel, Stravinsky, and Messiaen, and whales by Crumb and Hovhaness. We will also treat statements on the environmental crisis by composers Harrison Birtwistle, Philip Glass, Peter Sculthorpe, and John Luther Adams. Reading, listening, discussion, 2 short papers, 1 long paper, oral presentation.
Prerequisite: 57-285

57-415 Mozart Operas
Fall: 6 units
In the genre with the highest stakes and the highest failure rate, Mozart composed the earliest operas to have staked a permanent place at the center of the repertory. This course seeks to account for his success, to explain why he succeeded where others failed and what has made his operas beloved for over 225 years. We begin with a brief overview of all of Mozart's operas and discuss the types of opera in circulation in late 18th century Austro-Hungary, especially opera seria, opera buffa, and Singspiel, and the pressures that shaped the music and libretto of each production, from the type of patronage to the style of recitative. Then we examine The Marriage of Figaro, Don Giovanni, and The Magic Flute at a pace of about one act per class session, looking at poetry, dramaturgy, stagecraft, acting, performance practice, character development, theme, and politics, always through the filter of Mozart's music, especially its melody, reform elements, blurring of genre and affect, vocal counterpoint, use of topics, and musical symbolism.
Prerequisite: 57-285

57-416 Globalization of Classical Music: USA, Turkey, Japan
Intermittent: 6 units
What sounds are made when cultures clash? What issues are at stake when composers and performers approach music with strong ties to music of other cultures, such as Debussy's Iberia and Copland's El Salon Mexico, or when, like Bartok, they introduce elements of a stylized folk music into the concert hall? How did the Western classical tradition come to be mastered in countries worldwide? Where is it resisted and why? When composers from non-Western traditions engage with classical traditions, what do they give up and what do they gain? In what ways do they seek to retain style traits or instruments from their home country? and why? Do countries all adopt this tradition in the same way and for the same reasons? How do such varied negotiations of cultures define national identities? This course addresses such questions by focusing on the role of Western classical music in the history of the United States, Turkey, and Japan - countries with very different histories of engaging with European culture, yet sharing a decisive adoption of European-based modernity in the twentieth century.
Prerequisite: 57-285

57-417 Major Vocal Performance Ensemble
Fall and Spring: 6 units
There are two choral ensembles. Concert Choir is a select ensemble of approximately 40 voices of superior vocal/musical talent and experience in the choral idiom. Performance requirements are more stringent than those of the Repertory Chorus. Repertory Chorus is an ensemble of undetermined size. Emphasis is placed on vocal technique and development, musical skills in the rehearsal with minimum performance requirements. Audition required.

57-418 Major Instrumental Ensemble
Fall and Spring: 6 units
There are two instrumental ensembles: Orchestra and Wind Ensemble. Rotating seating plans, within and between ensembles, will prevail at the discretion of the Director of Orchestral Studies and the Director of the Wind Ensemble. The instrumental faculty will be consulted. All music majors who are required to enroll in an instrumental ensemble must audition for placement and enroll in Major Instrumental Ensemble. Audition required.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-420 Jazz Vocal Ensemble
Fall and Spring: 3 units
A highly selective group of mixed voices who perform contemporary jazz and pop vocal arrangements. Open to all CMU students. Audition required.
Prerequisite: 57-420

57-421 The Exploded Ensemble
Fall: 6 units
The Exploded Ensemble is a group dedicated to the performance of music that pushes the boundaries of traditional performance and composition. The ensemble has a strong emphasis on electro-acoustic performance technique, experimental approaches to staging and amplification, and visuals (live video, computer controlled lighting, wearable technology, etc.). The group will perform works by new/experimental/electro-acoustic composers and will create new arrangements of works for which scores may not currently exist - for example, music by rock bands, electronic musicians, and sound artists. The overall goal of the ensemble is to explode the idea of traditional concert music performance. In so doing we shall advance student skills in music performance, music appreciation, and advance the very important conversation on the future of concert music. For undergraduate and graduate students. Registration is by special permission after an audition and interview.
Prerequisite: 57-425

Course Website: https://courses.ideate.cmu.edu/57-421

57-423 Repertoire Orchestra
Fall and Spring: 3 units
This course thoroughly acquaints participants with the standard works one would expect to encounter as part of a career as an orchestral player. Assigned repertoire will be read each class session. All students are eligible to register for this course by special permission. Students who are not placed in the Carnegie Mellon Philharmonic are given priority for registration.

57-424 Percussion Ensemble
Fall and Spring: 3 units
This ensemble is open to all percussion majors.

57-425 Expanded Music Performance
Intermittent: 9 units
In his 1970 manifesto Expanded Cinema, Gene Youngblood presented the idea that emerging video technology would lead to an new form of cinematic expression in which art and life are united. In this course we will explore this idea in the realm of music through the creation of new technologies that will expand the possibilities of live performance. The technologies we develop will be used in a series of public concerts by CMU's Exploded Ensemble, a group of high-caliber musicians dedicated to electro-acoustic performance of avant-garde concert music. The course will work closely with the Exploded Ensemble to develop expansive technologies that will transform the music the group performs. These transformations may take place in many different modalities. In the realm of sound we will investigate several areas: the development of new software for sound processing and synthesis, the creation of new instruments, and experimental methods of sound amplification and distribution. In the visual realm, we will develop software for live video performance, will investigate experimental techniques for video projection including mapping and the use of depth cameras, and will develop tools for computer controlled lighting systems. In the physical realm we will develop wearable technologies for performers, sensor-based responsive systems, and will explore experimental approaches to costume and decor.

57-427 Advanced Seminar in Film Musicology
Intermittent: 9 units
This course has been designed primarily for advanced students wishing to apply to film scores analytical methodologies pertaining to historical musicology, cultural studies, and genetic criticism. The films screened and the music analyzed in this course follow at first the historical development of cinema. Then, the syllabus focuses on the film music of Ennio Morricone in honor of his 90th birthday and on final presentations of film soundtracks selected by the students. Prerequisites include some knowledge of music history, theory, practice, or the instructor's permission.

57-428 Theatre Orchestra
Intermittent
Instrumental ensemble which accompanies a production in the School of Drama.

57-429 Beginning Piano for Children I
Fall and Spring: 6 units
This course is the first of two courses in a year-long internship in the piano teaching of young children, combining class and private instruction: a study of the basic teaching/learning process as applied to piano teaching, covering comprehensive step-by-step presentation in reading, rhythm, ear training, sight reading, technique, and musicianship. Under supervision, students will teach the weekly group class and private lessons. Weekly conferences will be held for learning the presentation of materials for class teaching, analyzing pedagogical problems, and developing communication skills with both young pupils and their parents.
Prerequisite: 57-273

57-430 Music of Iran
Intermittent: 9 units
The Iranian civilization is one of the oldest continuing civilizations in the world. Music has played an important role in the continuation and preservation of this ancient culture. In this course, the traditional, folk, and contemporary music of Iran will be studied and discussed. The focal point of the course will be the Persian modal system, the Dástgâh. Starting with a historical survey of the ancient and medieval Persian music. different aspects of the Dástgâh system will be demonstrated and discussed. In addition, religious music and folk music of Iran as well as Iranian contemporary music will be discussed during the course.

57-431 Italian Literature and Repertoire
Spring: 3 units
The course provides a bibliography of repertoire in the Italian language. Material will include art songs and cantatas and will be presented via individual student performances in class, listening to recordings and group survey of repertoire. Reading and writing assignments will serve to establish historical perspective as well as programming considerations.

57-432 French Literature and Repertoire
Spring: 3 units
This course examines French songs for solo voice. Representative works from 18th through 20th centuries will be studied in the context of music history, style and programmatic considerations. Classes consist of individual performance, listening to recordings, and group survey of repertoire. Reading and written assignments establish historical perspective as well as programming considerations.

57-433 Musical Theatre Literature and Repertoire
Fall: 3 units
This class covers music theatre repertoire for two semesters, beginning chronologically with the operetta and concluding with current theatre composers. Each student will be assigned songs to prepare from these musicals. These songs can also be used for music theatre auditions. Students are expected to research all assigned songs and perform them in the proper style. Notebooks must be kept which include all lecture notes, class song assignments and music for songs performed individually.

57-434 Musical Theatre Literature and Repertoire
Spring: 3 units
Continues 57-433 Musical Theatre Literature and Repertoire.
Prerequisite: 57-433

57-435 German Literature and Repertoire
Spring: 3 units
The course examines German repertoire composed for solo voice. Representative works from the Baroque period through the 20th Century are studied in the context of musical style, vocal demands and programmatic considerations. Repertoire focuses on art songs and cantatas, but also includes certain oratorio excerpts, which are included frequently in recital programs. A bibliography of German repertoire is compiled through individual or group performance of songs, listening to recordings and through research assignments, the latter of which focuses upon the works of specific composers. Reading assignments are included to establish an historical perspective.

57-436 English/Contemporary Literature and Repertoire
Spring: 3 units
The course provides a bibliography of repertoire in the English language. Material will be limited to art songs and will be presented via individual student or group performances in class, and recorded performances. Research assignments will be required for selected anthologies or for works by specific composers. Repertoire will be examined according to vocal requirements, musical style, and programmatic function. The repertoire will consist primarily of works by British and American composers, but works by Russian and Spanish composers will also be included.

57-437 Literature and Repertoire
Fall and Spring: 3 units
This course deals with literature and repertoire for orchestral instruments. There are multiple sections organized by instrument categories or specific instruments.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-438 Multitrack Recording
Fall and Spring: 9 units
This course builds upon the ideas learned in Sound Recording (57-337), but with an emphasis on close microphone techniques and popular music styles. Students will work in small groups and complete at least two recording projects. $10.00 materials fee.
Prerequisites: 57-337 or 57-341 or 57-357

57-441 Analysis of 19th Century Music
Intermittent: 9 units
This course will provide students with a variety of tools for the analysis of music from Schubert to Mahler and early Schoenberg. The primary emphases will be on small-scale (chord-to-chord) harmonic organization, on the larger-scale organization of tonal centers, and on form, but other issues will also be explored (e.g. rhythm and meter, text/music relations). The course will sample a wide range of repertoires, including solo piano music, orchestral music, and opera, and it will have a special emphasis on chamber music including the German Lied.

57-442 Analytical Techniques
Fall: 9 units
Analytical Techniques is a "Music Support" course for Juniors and Seniors who have completed the undergraduate core course of study in harmony and counterpoint. This course provides an in-depth knowledge of all styles and genres of Western classical and contemporary repertoire. The course will cover units in harmonic and motivic analysis, Schenkerian analysis, graphic analysis, twelve-tone analysis, set-class theory, rhythmic analysis and other analytical techniques. The primary goal of the course is for students to develop independent skills in analyzing their own repertoire as performers, conductors, composers and teachers.
Prerequisite: 57-408

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285568801

57-444 Principles of Counterpoint
Intermittent: 9 units
This course explores the development of Western music composed with multiple independent parts. The first half of the course traces the history of part-writing from medieval organum to the twenty-first century. Emphasis is given to study of pre-Baroque and twentieth-century music, and to the conceptual shifts that occurred moving in and out of the common-practice period. The second half of the course examines, across multiple musical styles, specific contrapuntal techniques such as imitation and ground bass forms. Assignments include both writing exercises and analysis, culminating in a term project on a topic selected by the student.
Prerequisite: 57-408

57-445 Counterpoint in 18th Century Composition
Intermittent: 6 units
In this course the student will study how to write two-part counterpoint within the harmonic framework of 18th-century instrumental music. The focus of study will be J.S. Bach's inventions, and writing will be directed towards composing several complete inventions in that style. Prerequisites: Harmony I and Harmony II or permission of the instructor. This course is designed for composers, theory minors, Bach lovers, keyboard majors, and anyone who wants to seriously sharpen their tonal writing skills.
Prerequisite: 57-408

57-446 Renaissance Counterpoint
Intermittent: 6 units
In this course the student will study how to write vocal counterpoint using the classic "species" approach, based on the style of Renaissance masters Palestrina, Lassus, and Victoria. The latter part of the course will extend the study to instrumental music of the 16th century, and explore the development of chromaticism in avant-garde composers of the time. Reading about and listening to Renaissance music and composers will be included as background context for the theory work. Daily writing exercises in the first part of the course will lead to a term project producing a performable piece of music by the end of the semester. This course is designed for composers (both for writing technique and college teaching preparation), theory minors, early music lovers, choral singers and conductors, church musicians, and anyone who wants to sharpen their writing skills. Prerequisite: Harmony I or permission of the instructor (demonstrated competence in reading treble and bass clef, and intervals).
Prerequisite: 57-408

57-447 Harp Pedagogy
Fall and Spring: 3 units
TBA

57-448 Brass Pedagogy
Fall: 3 units
In this course we introduce the "Art of Teaching". In this case, to teach, develop and encourage young brass players just starting an instrument or who are in their early stages of development. Concepts of basic brass pedagogy will involve the following topics: Music as Metaphor; Teaching young students; Listening; Developing a Concept of Sound; Posture; Breathing; Embouchure; Articulation: Single Tonguing, Multiple Tonguing; Mouthpiece playing; The Warm-up; Slurring; Intonation; The Upper Register; Endurance; Vibrato; Dental Braces; Orchestral Playing; Performance Preparation; Taking Auditions Brass students will leave CMU with a basic understanding of the pedagogical needs and requirements of beginning and inexperienced students, so that they may begin private teaching studio upon graduation.

57-449 Beginning Piano for Children II
Fall and Spring: 6 units
This course is the second of two courses in a year-long internship in the piano teaching of young children, combining class and private instruction: a study of the basic teaching/learning process as applied to piano teaching, covering comprehensive step-by-step presentation in reading, rhythm, ear training, sight reading, technique, and musicianship. Under supervision, students will teach the weekly group class and private lessons. Weekly conferences will be held for learning the presentation of materials for class teaching, analyzing pedagogical problems, and developing communication skills with both young pupils and their parents.
Prerequisite: 57-429

57-450 Audience Development
Intermittent: 6 units
TBA

57-451 Teaching Artist Training
Intermittent: 6 units
This course puts you in a working relationship with experts who serve as teaching artists to inspire people of all ages to engage with music in meaningful ways. You will also learn how to build a successful private studio. For those interested: in Fall 2017 we have been asked to develop and implement a music program for Brightside Academy, a daycare for underserved children in Pittsburgh.

57-452 Collaborative Project in Music Entrepreneurship
Intermittent: 6 units
Responding to requests from the Pittsburgh community, Audience Engagement teams spearhead innovative performance projects that serve organizations such as the CMU Philharmonic, Pittsburgh Symphony, Hillman Cancer Center, Carnegie Carnegie Hall, and the Pittsburgh Parks Conservancy, among others. A strong résumé builder, this course offers business connections and professional experience. No prerequisites.
Prerequisites: 57-454 or 57-457 or 57-453

57-454 The Freelance Musician
Intermittent: 6 units
This course will teach skills that are essential to your success on the stage and beyond, including stage presence, attire and etiquette, public speaking, taking auditions, receptions, programming, and more. Music majors may take this course as individuals or together as, for example, a chamber music ensemble.

57-455 Shaping Time in Performance
Intermittent: 9 units
This course will look at basic questions that performers face: Which level of pulse do I want to feel as the main one? How can I shape a pulse expressively? Which measure in a phrase is felt as a main goal, especially when the phrase contains an unusual number of measures? How can multiple tempi be meaningfully related? Among many important formal arrival points, which are the most important? In addition to these questions, we will also look at recent work on ways in which 18th-century musicians may have understood meter very differently from most musicians today. These alternate perspectives open new possibilities for hearing and shaping the flow of musical time in baroque and classical music. These issues will be pursued from two directions. We will develop simple theoretical tools that can make score analysis a helpful input to the decisions that performers make about such questions. We will also examine audio and video recordings by famous artists to see both how they dealt with these issues and what new questions are raised. Week-to-week work will include reading, listening, and score analysis. Students will write term papers that either use one of the main perspectives developed in class (starting from scores or starting from recordings) or else combine the two. They will also give presentations about their projects to the class.

57-456 Communication and Marketing
Intermittent: 6 units
What is your message? Who is your audience? How do you reach them? These are among the topics we'll explore in this course. Group projects and case studies help us identify the key aspects of one of the most important aspects of any music career. Being a great musician won't do you any good if no one knows you exist! By the end of the semester, students should be able to understand such concepts as branding, marketing, reach and advertising; identify audience segments and target messages to those segments; create compelling marketing materials, including bios, group and program descriptions, websites and flyers; work with teams to try out a variety of marketing strategies in real-world circumstances; learn to capitalize on social media and use it to effectively build and communicate to an audience; learn to write effective and powerful marketing copy (bios, sales pieces, etc.); examine competitors and market leaders to look for opportunities and best practices.

57-457 Stagecraft: mental training for peak performance
Intermittent: 6 units
Does your best playing happen in the practice room? Would you like to feel more comfortable on stage? Music faculty from every department are collaborating in this course to help you perform at your peak. On the Kresge stage, you will perform regularly for guest musicians, receive feedback and hear about their strategies for overcoming performance anxiety. The course finishes with four weeks of performances for a live audience from CMU's Osher Lifelong Learning program. Musicians include Lorna McGhee, Pete Sullivan, Alberto Almarza, Sergei Schepkin, Craig Knox, Bill Van der Sloot, and many more.

57-459 Score Reading/Keyboard Harmony
Spring: 6 units
This course is a practical, hands-on learning experience. Students learn by doing and observing other students. All work is done at the keyboard. It is for graduate collaborative piano majors, junior and senior composition majors, and junior and senior conducting minors. Other music majors with good keyboard skills can take this course with instructor permission.
Prerequisite: 57-408

57-460 Collaborative Project in Music Entrepreneurship
Intermittent: 6 units
This is an advanced entrepreneurship course, designed to simulate the atmosphere of "real world" project collaborations. You will develop leadership as you work on real projects that make a positive impact in the community. Monique Mead serves as your primary consultant, helping you keep the project on track and connecting you with others who can support your cause. Outside of class time, you will hold planning sessions with team members, perform interviews, and meet with outside collaborators. Project for Fall 2017 is a continuation of Spring 2017: Create a greater sense of community at the School of Music.

57-463 Eurhythmics for Non-Majors
Fall: 6 units
Rhythm is about time and timing. Dalcroze Eurhythmics is an exploration of the rhythm inside us. Experiencing rhythm through music and movement brings awareness and understanding of our own inner rhythm as well as rhythm in all the arts and beyond. This class is for juniors and seniors only.

57-464 Eurhythmics Applications for Non-Majors
Fall: 6 units
Rhythm is about time and timing. Dalcroze Eurhythmics is an exploration of the rhythm inside us. Experiencing rhythm through music and movement brings awareness and understanding of our own inner rhythm as well as rhythm in all the arts and beyond. This class is for juniors and seniors only.

57-465 Eurhythmics Applications for Performing and Teaching
Fall: 6 units
Rhythm is about time and timing. Dalcroze Eurhythmics is an exploration of the rhythm inside us. Experiencing rhythm through music and movement brings awareness and understanding of our own inner rhythm as well as rhythm in all the arts and beyond. For musicians, meaningingful rhythmic movement reinforces understanding of music concepts while focusing awareness on the physical demands of artistic performance. This approach to musical problem solving is applicable also to studio and classroom teaching.
Prerequisite: 57-164

57-466 Eurhythmics Applications for Performing and Teaching
Fall: 6 units
Rhythm is about time and timing. Dalcroze Eurhythmics is an exploration of the rhythm inside us. Experiencing rhythm through music and movement brings awareness and understanding of our own inner rhythm as well as rhythm in all the arts and beyond. For musicians, meaningingful rhythmic movement reinforces understanding of music concepts while focusing awareness on the physical demands of artistic performance. This approach to musical problem solving is applicable also to studio and classroom teaching.
Prerequisite: 57-164

57-467 Production: Crew
Intermittent: 3 units
Technical crew for the fully staged production presented by the 57-471 Production: Performance class. Class participants serve as build and run crew for the production.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-468 Production: Crew
Spring: 3 units
Technical crew for the fully staged production presented by the 57-472 Production: Performance class. Class participants serve as build and run crew for the production.

57-469 Production: Scenes
Fall: 6 units
Preparation of operatic and musical theatre scenes with a public performance of the scenes at the end of the semester. Specific repertoire based upon the proficiency of the individual student.
Prerequisites: 57-340 and 57-212

57-470 Production: Scenes
Spring: 6 units
Preparation of operatic and musical theatre scenes with a public performance of the scenes at the end of the semester. Specific repertoire based upon the proficiency of the individual student.
Prerequisites: 57-340 and 57-212

57-471 Production: Performance
Fall: 6 units
Preparation of an operatic or musical theatre production with a fully staged public performance of the production at the end of the class.
Prerequisites: 57-212 and 57-340

57-472 Production: Performance
Spring: 6 units
Preparation of an operatic or musical theatre production with a fully staged public performance of the production at the end of the class.
Prerequisites: 57-212 and 57-340

57-476 How Music Works: An Affective History
Intermittent: 6 units
This is an historical survey of (a) aesthetic theories about music and human agency—music's affects and effects, thus its significance and even its very existence—and of (b) actual utilizations of music. Theories range from Aristotle's catharsis to trauma theory and neuromusicology in our time. The applications range from the biblical David's therapeutic harp playing in the court of King Saul (11th C. BCE) to U.S. interrogators in Iraq (21st C. CE); from Vodun and exorcisms in other cultures to MUZAK in our own. In short, it's a chronological survey of what peoples have believed about music's powers and, consequently, how music has been used and abused. The dialectic between theory and applications is reflected in the assignments. This seminar is heavily focused on reading, as well as written and verbal discussion. There is also a long-term field project.

57-477 Music of the Spirit
Intermittent: 6 units
This guided listening course is a musical exploration of spirituality, a musicological and ethnomusicological survey organized around comparative religions. While the majority of repertoire will be from the Western Classical tradition, musics of a variety of cultures will be included. The music will be organized by particular religious traditions and by universal themes, such as community, death/afterlife, birth/new birth, martyrs/heroes, transcendence/immanence, meditation/contemplation/trance, etc. Most course materials, including streaming audio, are online, with one meeting per week in the classroom. Will include participatory introductions to numerous forms of chant. Requires oral and written reports. No prerequisites.

57-478 Survey of Historical Recording
Intermittent: 6 units
The histories of music and technology have long been intertwined. Their symbiosis intensified with the harnessing of electricity in the third wave of the Industrial Revolution. This course will expose you to many of the best practitioners of music. But it will do so with an eye—an ear—towards the media by which we have known them. In short ... The music. The personalities. The media. This seminar is heavy on listening (guided playlists online via Canvas). Writing includes reviews and a researched feature article.

57-480 History of Black American Music
Fall: 6 units
Come and explore the rich musical heritage of Black America. This course will survey the music of Black America beginning with the African legacy and continuing through the music of the Twentieth Century. Class sessions will involve discussions, listening, viewing of films, and reports by students on topics of individual interest. Discussions will involve, historical, cultural and political perspective, as well as the music and composers themselves. Lecturing will be at a minimum. Innovative testing in quiz show format will be used. No prerequisites required. Open to upper level undergraduate students.

57-485 History of the Symphony
Intermittent: 9 units
TBA

57-487 Advanced Solfege III
Fall: 3 units
Covers the same concepts as Solfege IV in more challenging material, from Bach chorales in open score to excerpts by Bartok, Honegger, Stockhausen, or Boulez. Dictations are three-part contrapuntal and difficult harmonic three and four parts.
Prerequisite: 57-186

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285567265

57-488 Advanced Solfege IV
Spring: 3 units
Continues 57-487 Advanced Solfege III.
Prerequisite: 57-487

57-489 Practice Teaching (Elementary)
Fall and Spring
Experience in working with elementary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-490 Practice Teaching (Secondary)
Fall and Spring
Experience in working with secondary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty. Students may choose a vocal or instrumental emphasis in the secondary placement.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-496 BXA Studio
Fall and Spring: 9 units
TBA

57-497 BXA Studio
Fall and Spring: 9 units
TBA

57-498 BXA Studio
Fall and Spring: 9 units
TBA

57-499 BXA Studio
Fall and Spring: 9 units
TBA

57-500 Major Studio (Voice)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-501 Major Studio (Piano)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-502 Major Studio (Organ)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-503 Major Studio (Harp)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-505 Major Studio (Violin)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-506 Major Studio (Viola)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-507 Major Studio (Cello)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-508 Major Studio (Double Bass)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-509 Major Studio (Guitar)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: http://www.music.cmu.edu/pages/insidemusic-coursesyllabi

57-510 Major Studio (Flute)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-511 Major Studio (Oboe)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-512 Major Studio (Clarinet)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-513 Major Studio (Bassoon)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-514 Major Studio (Saxophone)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-515 Major Studio (Horn)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-516 Major Studio (Trumpet)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-517 Major Studio (Trombone)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-518 Major Studio (Euphonium/Baritone)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-519 Major Studio (Tuba)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-520 Major Studio (Percussion)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-521 Major Studio (Composition)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-522 Major Studio (Bagpipe)
Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-557 Vocal Methods
Spring: 3 units
This course enables each student to develop a pleasant, healthy, and musically expressive voice and effective vocal pedagogy.

57-558 Observation
Fall and Spring: 3 units
This music education offering is an independent study course designed to introduce students to a range of K-12 instructional practices through observation of elementary and secondary school teachers. Students will identify strategies that impact learning in the areas of pedagogy, student motivation, classroom management, and accommodations for special learners. Students complete this course by arranging 20 prescribed classroom observations in local schools - multiple observations may be completed at each school visit. In order to complete the observations in one semester, students should schedule an open 3-hour time block one day per week between 8 am and 3 pm.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

57-570 Sound and Music Computing Seminar
Fall and Spring: 1 unit
The Sound and Music Computing Seminar is a weekly meetingto discuss topics in the areas of computer music, electronic music, musical acoustics, music perception, music technology, music information retrieval, music interfaces, music systems and software, and music theory. Presentations on these various topics are made by graduate students and faculty. The seminar is open to the University and broader community, but students should only enroll if the seminar is part of their degree requirements.

57-571 Music and Technology Project
Fall and Spring: 12 units
TBA

57-572 Music and Technology Project
Fall and Spring: 12 units
TBA

57-588 Junior Recital Voice
Fall
tba

57-589 Senior Recital Voice
Fall
tba

57-590 Internship
All Semesters
TBA

57-591 Dalcroze Pedagogy/Practice Teaching
Fall: 3 units
This course gives hands-on experience in applying Dalcroze principles in teaching situations. It is designed for students interested in learning about the teaching of Eurhythmics, general Music Education, and for those considering the Dalcroze Certificate. The class will meet in a three week rotation of two Thursday evenings followed by a Saturday morning with the Preparatory School children's classes.

57-597 Senior Composition Project
Fall and Spring
A composition for orchestra required of all senior composition majors.

57-598 Junior Recital
Fall and Spring
A half recital required of all junior performance majors.

57-599 Senior Recital
Fall and Spring
A full recital required of all senior performance majors.

57-603 Practice Teaching (Elementary)
Fall and Spring
Experience in working with elementary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty.
Prerequisites: 57-355 and 57-393

57-604 Practice Teaching (Secondary)
Fall and Spring
Experience in working with secondary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty. Students may choose a vocal or instrumental emphasis in the secondary placement.
Prerequisites: 57-355 and 57-393

57-607 Vocal Methods
Spring: 3 units
This course enables each student to develop a pleasant, healthy, and musically expressive voice and effective vocal pedagogy.

57-608 Observation
Fall: 3 units
This music education offering is an independent study course designed to introduce students to a range of K-12 instructional practices through observation of elementary and secondary school teachers. Students will identify strategies that impact learning in the areas of pedagogy, student motivation, classroom management, and accommodations for special learners. Students complete this course by arranging 20 prescribed classroom observations in local schools - multiple observations may be completed at each school visit. In order to complete the observations in one semester, students should schedule an open 3-hour time block one day per week between 8 am and 3 pm.

57-610 Internship
Fall and Spring
A student can receive credit for an unpaid internship in a music related field. The amount of credit is determined by the number of internship hours.

57-611 Independent Study in History
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-612 Independent Study in Theory
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-613 Independent Study in Research
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-614 Independent Study in Performance
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-615 Independent Study in Literature and Repertoire
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-616 Independent Study in Sound Studies
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-617 Independent Study in Electronic and Experimental Music
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-618 Independent Study in Conducting
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-619 Independent Study in Opera
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-620 Independent Study in Solfege
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-621 Independent Study in Eurhythmics
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-622 Independent Study in Sound Recording Production
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-623 Independent Study in Studio Recording Project
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-624 Independent Study in Special Music Project
Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-627 Independent Study in Music Entrepreneurship
Fall and Spring
TBA

57-641 Dalcroze Research Paper
Fall: 3 units
Candidates in the Dalcroze Certification Program are required to submit a research paper based on their understanding of Dalcroze principles based on their experience and supported by appropriate literature.

57-642 Dalcroze Research Paper
Spring: 3 units
Candidates in the Dalcroze Certification Program are required to submit a research paper based on their understanding of Dalcroze principles based on their experience and supported by appropriate literature.

57-691 Dalcroze Pedagogy/Practice Teaching
Fall: 3 units
This course gives hands-on experience in applying Dalcroze principles in teaching situations. It is designed for students interested in learning about the teaching of Eurhythmics, general Music Education, and for those considering the Dalcroze Certificate. The class will meet in a three week rotation of two Thursday evenings followed by a Saturday morning with the Preparatory School children's classes.

57-692 Dalcroze Pedagogy/Practice Teaching
Spring
This second semester of a two semester course focuses on applications of Dalcroze pedagogy and practice teaching with upper elementary and middle school age students.

57-829 Contemporary Soundscapes
All Semesters: 9 units
In the late 1960s on Canada's West Coast, composer R. Murray Schafer started the "World Soundscape Project" (WSP). Originally conceived as an inquiry into the growing problem of noise pollution in Vancouver, the Project expanded to encompass the wider study of the relationship between sonic environments and human communities, both historical and present. From a small group of sound researchers making field recordings in natural landscapes and urban areas has grown the modern study of Acoustic Ecology on a global scale, and also the creative practice of Soundscape Composition, in which recorded elements of sound environments are expressively explored through electronic music. Beginning with a history of the WSP, this course surveys aspects of the field of Acoustic Ecology as an aesthetic, political, and ethical phenomenon, with special attention to its relationship with the creative and sound practices of "Soundwalking," "Deep Listening," and Soundscape Composition. This course will also contextualize the WSP within a broader history of music and sound in the background, including Satie's Furniture Music, Muzak®, and coffee shop music. Throughout the course, students will participate in the activity and design of soundwalking, sonic field documentation / recording and sonic-environmental sampling, and the performance of background music. The course will culminate in a soundscape project entailing the composition of a Soundscape work, or the presentation of a creative mapping of aspects of their own sound environments; special guests will provide students with instruction in sound capture and manipulation.

57-911 Music Since 1945
Intermittent: 9 units
A survey of Western art music from WWII to the present, with a focus on compositional techniques, influential trends, and experimental approaches. This course will address total serialism, aleatory music, the rise of technology, minimalism, and soundscape composition, among others. Students will engage with primary sources, close listening, multi-media resources, and secondary sources, and demonstrate competency through varied assessments, including in-class performance activities and presentations.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2

Dietrich College of Humanities and Social Sciences

Richard Scheines, Dean

Sharon Carver, Associate Dean for Educational Affairs

Joseph E. Devine, Associate Dean for Undergraduate Studies

Ana Maria Ulloa-Shields, Assistant Dean and Director, Dietrich College Academic Advisory Center

Jennifer Keating, Assistant Dean for Educational Initiatives
www.hss.cmu.edu

The Dietrich College of Humanities and Social Sciences is one of Carnegie Mellon's seven principal colleges. The college consists of the undergraduate program in Economics; the departments of English, History, Modern Languages, Philosophy, Psychology, Social and Decision Sciences, and Statistics and Data Science; an interdepartmental program in Information Systems; and the Institute for Politics and Strategy. The college accounts for approximately one-fifth of the university's undergraduate population; 81% of the college's students are undergraduates. The college is staffed by 210 faculty (98% of whom are full-time).

Like its Carnegie Mellon counterparts in engineering, science, computer science, business, and the fine arts, the college has three primary and interrelated foci: undergraduate education, graduate education, and research or creative pursuits. Thus, the college shares in the university's mission of merging first-rate, innovative research and creativity with undergraduate and graduate education.

Liberal/Professional Education

Edward Fiske, former Education Editor of The New York Times and author of the Fiske Guide to Colleges, long ago noted that the college and university have done “perhaps the most original thinking of any American university in pursuing the twin goals of liberal-professional education.” These goals continue to guide the college's educational enterprise. The college's educational program is "liberal" in that it stresses breadth and invites wide-ranging inquiry, both through its general education curriculum and through programs in the humanities, behavioral sciences, and social sciences. The “professional” dimension of the college's educational program derives from practical application of analytical and problem-solving skills that prepare students for a range of career fields as well as for graduate or professional school. In its belief that these two types of knowledge (“liberal” and “professional”) are highly complementary, Dietrich College embraces a philosophy that has its roots in Carnegie Mellon's institutional origins: namely, that the traditional liberal arts disciplines merit close, rigorous study, while at the same time practical skills are also mastered and applied.

The rationale for this liberal/professional approach stems from the premise that the intellectual foundations of a challenging liberal education and meaningful professional education are essentially the same. Knowledgeable and effective citizens are as much in need of broad intellectual perspectives, analytical skills, and problem-solving strategies as are most professionals. Moreover, as leaders in American higher education generally agree, undergraduate education is not well served if professional specialization in undergraduate programs is achieved prematurely. The challenge is to strike a balance between breadth and depth, both within and outside of one's specialty. Such a balance insures versatility in one's profession and the knowledge and ability to keep pace as individuals and citizens with changes in our social, technical, and cultural environments. Thus, the objectives of both liberal and professional education can and should work in tandem to complement and enhance one another.

Degree and Program Options

Dietrich College offers a wide range of majors and minors. In addition, there are a number of special programs which add breadth and enhance a student's overall experience.

Dietrich College Majors

Department	Name of Major (Degree Options)
Economics	**Economics (B.A./B.S.)**
English	**English (B.A.)**
English	**Creative Writing (B.A.)**
English	**Film and Media Studies (B.A.)**
English	**Professional Writing (B.A.)**
English	**Technical Writing and Communication (B.S.)**
History	**Global Studies (B.A.)**
History	**Social and Political History (B.A./B.S.)**
Institute for Politics and Strategy	**International Relations and Politics (B.S.)**
Interdepartmental (1)	**Economics and Mathematical Sciences (B.S.) (by admission)**
Interdepartmental (2)	**Economics and Politics (B.S.)**
Interdepartmental (3)	**Economics and Statistics (B.S.)**
Interdepartmental (4)	**Ethics, History, and Public Policy (B.A./B.S.)**
Interdepartmental	**Environmental Policy (additional major only)**
Interdepartmental	**Information Systems (B.S.) (by admission)**
Interdepartmental (5)	**Linguistics (B.A.)**
Interdepartmental (6)	**Neuroscience (B.S.)**
Interdepartmental (7)	**Psychology and Biological Sciences (B.S.)**
Interdepartmental (8)	**Statistics and Machine Learning (B.S.)**
Interdepartmental	**Student-Defined (B.A./B.S.) (by admission)**
Modern Languages	**Chinese Studies (B.A.)**
Modern Languages	**French and Francophone Studies (B.A.)**
Modern Languages	**German Studies (B.A.)**
Modern Languages	**Hispanic Studies (B.A.)**
Modern Languages	**Japanese Studies (B.A.)**
Modern Languages	**Russian Studies (B.A.)**
Philosophy	**Logic and Computation (B.S.)**
Philosophy	**Philosophy (B.A.)**
Psychology	**Cognitive Science (B.S.)**
Psychology	**Psychology (B.A./B.S.)**
Social and Decision Sciences	**Behavioral Economics, Policy & Organizations (B.A.)**
Social and Decision Sciences	**Decision Science (B.S.)**
Social and Decision Sciences	**Policy and Management (B.S.)**
Statistics and Data Science	**Statistics (B.S.)**

Notes:

[1] Offered jointly by the Undergraduate Economics Program and the Department of Mathematical Sciences

[2] Offered jointly by the Undergraduate Economics Program and the Institute for Politics and Strategy

[3] Offered jointly by the Undergraduate Economics Program and the Department of Statistics and Data Science

[4] Offered jointly by the Departments of History and Philosophy

[5] Offered jointly by the Departments of English, Modern Languages, Philosophy and Psychology

[6] Offered jointly by the Department of Biological Sciences and the Center for the Neural Basis of Cognition

[7] Offered jointly by the Departments of Psychology and Biological Sciences

[8] Offered jointly by the Department of Statistics and Data Science and the Department of Computer Science

Additional Majors

Dietrich College students may pursue additional majors and/or minors in the college, as well as in other Carnegie Mellon colleges. An additional major refers to the completion of the requirements for a second major while also completing the requirements for the primary major and degree.

Most Dietrich College majors are also available as additional majors; one (Environmental Policy) is available **only** as an additional major. Students from outside Dietrich College can pursue additional majors offered by the college, and would be required to complete only those courses in the college's general education program that are prerequisites to courses required for the Dietrich College major in question.

Minors

Minors are like majors in that they consist of coherent programs of study in a department, or across departments. Minors differ from majors in the number of the courses required and in the breadth and depth of the curriculum in the minor's area(s) of study. Dietrich College students can also pursue minors offered and made available by other Carnegie Mellon colleges and departments.

There are two types of minors in Dietrich College: departmental minors, which are housed in a single Dietrich College academic department; and interdepartmental minors, which are sponsored by more than one academic department and administered through the faculty advisor's academic department. The college's minors are available to students from all colleges in the university.

Department	Name of Minor
Economics	**Economics**
English	**Creative Writing**
English	**Humanities Analytics**
English	**Professional Writing**
English	**Technical Writing**
History	**Anthropology**
History	**Social and Political History**
Institute for Politics and Strategy	**Cybersecurity and International Conflict**
Institute for Politics and Strategy	**International Relations and Politics**
Institute for Politics and Strategy	**Politics and Public Policy**
Interdepartmental	**African and African American Studies**
Interdepartmental	**Film and Media Studies**
Interdepartmental	**Gender Studies**
Interdepartmental	**Global Systems and Management**
Interdepartmental	**Health Care Policy and Management**
Interdepartmental	**Linguistics**
Interdepartmental	**Neural Computation**
Interdepartmental	**Religious Studies**
Interdepartmental	**Science, Technology and Society**
Interdepartmental	**Sociology**
Interdepartmental	**Student-Defined (by admission)**
Modern Languages	**Arabic Studies**
Modern Languages	**Chinese Studies**
Modern Languages	**French and Francophone Studies**
Modern Languages	**German Studies**
Modern Languages	**Hispanic Studies**
Modern Languages	**Japanese Studies**
Modern Languages	**Russian Studies**
Philosophy	**Ethics**
Philosophy	**Logic and Computation**
Philosophy	**Philosophy**
Psychology	**Cognitive Neuroscience**
Psychology	**Psychology**
Social and Decision Sciences	**Decision Science**
Social and Decision Sciences	**Policy and Management**
Statistics and Data Science	**Statistics**

Multiple Degrees

"Multiple degrees" is defined as more than one undergraduate degree granted by the university (whether simultaneous or sequential). One diploma is awarded for each degree; each degree has one primary major associated with it, and the possibility of an additional major and/or minor.

Dietrich College undergraduate students who wish to earn an additional undergraduate degree with a primary major also from Dietrich College must:

- Satisfy all requirements for the primary major to be linked to the additional degree.
- Complete at least 90 units beyond the total number of units required for the first degree. If the major associated with the additional degree requires less than 90 units, the student would earn additional elective units to reach the 90-unit minimum. If the major associated with the additional degree requires more than 90 units, the student would perforce exceed the 90-unit minimum in order to fulfill all of the requirements for the additional degree’s primary major.
- Comply with Carnegie Mellon's Statute of Limitations Policy: All units required for an undergraduate degree, whether earned in residence, transferred from another institution or granted via advanced placement, must have been earned within eight (8) years prior to the date on which the degree is granted.

Non-Dietrich College undergraduate students at Carnegie Mellon who wish to earn an additional undergraduate degree with a Dietrich College primary major must complete all of the requirements listed above, plus any portion of the Dietrich College general education program not already fulfilled by prior undergraduate course work.

Bachelor of Arts & Bachelor of Science

Some Dietrich College majors lead to a Bachelor of Arts (B.A.) degree and others lead to a Bachelor of Science (B.S.) degree option. In some majors students may choose between a B.A. and a B.S. degree. B.A. degree programs usually require less course work in technical and/or quantitative disciplines, and more depth and breadth in various humanities and social science fields, and (in some cases) the arts. In contrast, B.S. degrees are offered in majors requiring more technical, quantitative or scientific competencies.

Dietrich College General Education Program

www.hss.cmu.edu/gened

Carnegie Mellon's educational legacy emphasizes the connection between theoretical and practical knowledge. Similarly, the university's interdisciplinary approach to education embraces the practical application and analysis of knowledge in institutional, social, historical, and global contexts. The Dietrich College general education program (hereafter referred to as the "GenEd program") supports the development of that expertise and ensures that students gain well-informed perspectives and methodologies by providing the foundational knowledge and skills required for subsequent in-depth study. Additionally, the Dietrich GenEd program provides freshmen and sophomores - whether they have a specific interest, multiple interests, or are undecided about majors - with a systematic, intentional way of sampling the many options available in order to formulate, pursue and achieve their academic goals.

Categories

To transcend narrow disciplinary boundaries, the Dietrich College GenEd program focuses on five broad intellectual pursuits that are exercised in nearly all disciplines: communicating, reflecting, modeling, deciding and creating. These form the bases for the Dietrich College GenEd curriculum categories, in which suitable courses are included from all parts of the university.

The five categories are:

1. Communicating (http://www.hss.cmu.edu/gened/gened-category.asp#Communicating): language and interpretation

2. Reflecting (http://www.hss.cmu.edu/gened/gened-category.asp#Reflecting): societies and cultures

3. Modeling (http://www.hss.cmu.edu/gened/gened-category.asp#Modeling:_Mathematics): mathematics, the physical and natural sciences, and experiments

4. Deciding (http://www.hss.cmu.edu/gened/gened-category.asp#Deciding): social sciences and values

5. Creating (http://www.hss.cmu.edu/gened/gened-category.asp#Creating): designs and productions

Courses

1. Communicating: Language and Interpretation (18 units minimum)

Courses in this category give special attention to the study of language as interpretation, expression and argument within and across multiple discourses. Students examine language for its internal logics and structures. They also explore its rhetorical, historical, cultural, or philosophical dimensions, assessing how language functions while expanding writing skills and sharpening analytical abilities.

Required (University First Year Writing Requirement)		Units
OPTION 1:		
76-101	Interpretation and Argument	9
- OR -		
76-102	Advanced First Year Writing: Special Topics	9
OPTION 2 (must be completed back-to-back within a single semester):		
76-106	Writing about Literature, Art and Culture	4.5
76-107	Writing about Data	4.5
76-108	Writing about Public Problems	4.5
xx-xxx	One additional "Communicating" course	9

Note: In their first semester, non-native English speakers may be placed into 76-100 Reading and Writing in an Academic Context (9 units), instead of a University First-Year Writing Requirement option. After successful completion of 76-100, they must fulfill the University First-Year Writing requirement by way of one of the two options described above. For these students, 76-100 plus the course(s) taken to fulfill the University First-Year Writing requirement will fulfill the GenEd "communicating" requirement category.

* For a list and descriptions of additional courses approved for this category, visit the Dietrich College General Education web site (http://www.hss.cmu.edu/gened)

2. Reflecting: Societies and Cultures (18 units minimum)

This category emphasizes the study of history, society, and culture from local and global perspectives. Courses investigate contemporary societies as well as those of the past, along with their rich array of cultural products, artifacts, ideas, values, and belief systems. They encourage a comparative and reflective approach to the understanding of the past and what it can bring to the study of present social relations and cultural outlooks.

Required		Units
79-104	Global Histories	9
xx-xxx	One additional "Reflecting" course*	9

* For a list and descriptions of additional courses approved for this category, visit the Dietrich College General Education web site (http://www.hss.cmu.edu/gened).

3. Modeling: Mathematics, Physical and Natural Sciences, and Experiments (27 units minimum)

Courses in this category stress the interplay of mathematical (formal) theories and experimental work. Some courses investigate the internal structure of theories, whereas others use them as models for producing real-world knowledge. Such models may be drawn from a variety of disciplines including the natural and mathematical sciences, but also such fields as psychology and computer science. The interactions between theorizing and experimenting (observing) can be understood within an intellectual framework that invites comparative assessment.

- mathematical sciences (complete a minimum of 9 units)
- natural sciences (complete a minimum of 9 units)
- one other modeling course (complete a minimum of 9 units)

* For courses approved for this category, visit the Dietrich College General Education (http://www.hss.cmu.edu/gened) website.

4. Deciding: Social Sciences and Values (18 units minimum)

The theme of this category is the exploration of cognitive, behavioral and ethical dimensions of decision-making on both individual and societal levels. Making decisions requires a broad understanding of human rationality and social interaction. Some courses examine the critical collection and analysis of data for achieving such an understanding, whereas others emphasize the historical development of policies and values which form the matrices for decision-making.

Required		Units
36-200	Reasoning with Data	9
xx-xxx	One additional "Deciding" course*	9

* For a list and descriptions of additional courses approved for this category, visit the Dietrich College General Education web site (http://www.hss.cmu.edu/gened).

5. Creating: Designs and Productions (18 units minimum)

Original artifacts emerge from creative design ideas and processes of production (e.g., a poem, a painting, a musical performance, a new technology). This general education category points students primarily toward the university’s outstanding strengths in the creative and performing arts for the experience of creative design and production. Courses may center on student creation of artifacts, but they may also analyze such creations by exploring creative processes at work within and across disciplines. Such explorations should be informed by a deep understanding of contexts of production and reception.

For courses approved for this category, visit the Dietrich College General Education (http://www.hss.cmu.edu/gened) website.

6. TWO Additional GenEd courses (18 units minimum)

These courses are selected from any GenEd category.

7. University Requirement (UR) (3 units)

99-101	Computing @ Carnegie Mellon	3

This course is a 3-unit mini-course, pass/no credit, completed by the end of the first year.

8. First-Year Seminar Requirement (FSR) (9 units)

Taught by select members of the college's faculty, these seminars maintain a student-to-teacher ratio of 1:16, are centered around topics based on grand challenges to society as well as faculty expertise, and are formatted to encourage a high level of student participation and interaction. In addition to thorough examination of seminar topics, the Dietrich College First-Year Seminar Program has several other goals, including promotion of close and lasting relationships with faculty, introducing and establishing intellectual habits that will serve students well in college, and introducing students to the intellectual resources of the university. For current seminar topics and course descriptions, visit the Dietrich College General Education (http://www.hss.cmu.edu/gened) website.

Note: The first-year seminar will not simultaneously fulfill any other requirement (i.e., in a major or minor).

College Services and Programs

The educational programs in Dietrich College are complemented by a number of services, special programs, centers, and computing facilities.

Dietrich College Academic Advisory Center

Ana Maria Ulloa-Shields, *Assistant Dean and Director*
Location: Baker Hall A57
www.cmu.edu/hss/advisory-center

The Dietrich College of Humanities and Social Sciences Academic Advisory Center (AAC) is primarily responsible for advising and monitoring the progress of students prior to declaring a major. As the “home base” for undergraduates who are new to the college, the AAC provides an accessible, welcoming environment where students can seek information, advice, and counsel about selecting courses, the college's general education program requirements, and the various majors and minors available. Just as important, advisors support students' transition to life and study in the university. The advisor-student relationship is a reciprocal one. Advisors' goals are to meet students where they are, to help them learn to successfully navigate the Carnegie Mellon environment, to become increasingly self-sufficient, and to make viable, informed and confident academic and personal decisions. This kind of relationship is vital to a student’s ability to progress, grow and thrive in a new and demanding educational environment. Additionally, the AAC serves as the office of student records for Dietrich College. Acting on behalf of the College Council, the Center Director oversees adherence to university and college academic policies and procedures.

Dietrich College Senior Honors Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*
Location: Baker Hall 154F
www.hss.cmu.edu

From its inception in 1982, the Dietrich College senior honors program (http://www.cmu.edu/dietrich/undergraduate/programs/shp) has provided outstanding undergraduate students with the opportunity to work individually with faculty members throughout the college on original research and creative projects. The honors program is a senior-year program. Admission is based on achievement of a cumulative QPA of at least 3.50 in one's major and 3.25 overall, endorsement of a thesis proposal by the faculty member who will serve as thesis advisor, and department head approval. Honors students enroll in an honors thesis course sequence for both semesters of the senior year (9 units per semester). Upon successful completion of the honors thesis, a student qualifies for graduation with Dietrich College Honors, and will have this designation as well as the thesis title noted on the final transcript.

Students have found the honors program to be a challenging and enriching experience in allowing for focused, individualized work on a sustained independent project. In the opportunity it provides to demonstrate one's capacity for independent and original work, the senior honors program experience helps significantly in developing the ability to present one’s intellectual or creative self to others, including prospective employers or graduate and professional school programs.

Honors Research Fellowship Program (http://www.cmu.edu/dietrich/undergraduate/programs/dhfp) The Dietrich College Honors Research Fellowship Program is an optional component for students who have applied and been accepted into the college’s Senior Honors Program. Fellows spend the summer before their senior year undertaking early-stage research and development of their thesis topics. Financial support through a stipend and related funds for research-related expenses allows fellows to apply themselves full-time to their projects during these summer months. This in turn enables fellows to build a strong foundation and momentum for their honors thesis as the fall semester of the senior year gets underway, and ultimately leading to completion of the project by the end of the spring semester. Students apply for this fellowship program in the spring of the junior year, simultaneous with submission of an application and thesis project proposal for the Dietrich College Senior Honors Program.

Humanities Scholars Program

Timothy Haggerty, *Director*
Location: Wean Hall 8123
www.cmu.edu/dietrich/hsp

The Humanities Scholars Program (HSP) is a rigorous, four-year undergraduate program dedicated to fostering innovative interdisciplinary study and research in the humanities. The program works with the undergraduate admission office to identify a subset of students admitted to Dietrich College who have a special interest in the humanities as these are conceptualized at Carnegie Mellon. The program that includes a shared set of courses as well as an optional residential component.

As practiced within its four departments - English, History, Philosophy and Modern Languages - the humanities at Carnegie Mellon provide broad reflective analysis of humanity and its artifacts. Scholarship may incorporate, as examples, hermeneutic, ethnographic, critical, formal, or quantitative analyses within its arguments. At Carnegie Mellon, research has yielded original themes that have become institutional strengths, including social and global perspectives on culture; science and technology; languages, literature and discourse; the arts in society; cognition and rational decision making; and ethics and public policy.

During the first two years of the program, scholars take a series of four seminars that are designed to introduce them to different fields of the humanities and their disciplinary approaches (representative HSP seminars can be viewed on the program website). In the third and fourth years, students are free to pursue their major course of study. The program complements, rather than replaces, a major or minor course of study. In addition, HSP courses help fulfill breadth requirements, including the freshman seminar requirement and selected college general education requirements.

While in the program, scholars also participate in extracurricular events on campus and in the community that include talks by visiting scholars, theater performances, conferences, and exhibits that highlight the importance of humanistic inquiry and its relevance in public discourse.

Students complete their research under the direction of a faculty advisor and meet in a research seminar headed by the director of the program in the spring of their fourth year. This seminar is designed to develop and showcase students' abilities in addressing a topic from multiple disciplinary standpoints.

Quantitative Social Science Scholars Program

Mark Patterson, *Director*
Location: Wean Hall 8112
www.cmu.edu/hss/qsss

The Quantitative Social Science Scholars Program (QSSS) offers a unique opportunity in undergraduate education at Carnegie Mellon. In recent years, advances in computing power, increasingly powerful models of human behavior, and the exponential growth of data sets recording human economic and social activity have created exciting new possibilities for entrepreneurs, policymakers, and scholars seeking insight into human social behavior. Firms throughout the economy can now use data analytics to identify new markets, avoid errors, and improve efficiency. Policymakers can use the same techniques to shape the direction and expand the impact of social policies designed to promote the public good. Social scientists can also use these techniques to create a broader and deeper scientific understanding of human behavior that serves as the foundation upon which both entrepreneurs and policymakers can build.

The QSSS program is designed to help outstanding undergraduates impact society through the use of these techniques. It does so by laying out a structured program of training in advanced quantitative techniques that can be broadly applied across a range of social science disciplines and topics. Students combine this methodological training with more traditional coursework in the social science major of their choice. The program equips students to undertake sophisticated analysis of their own, and features an integrative senior thesis project that applies their methodological training to a research question of their own choosing.

The QSSS program is not a freestanding major or a minor, per se. It is a program designed to be taken in conjunction with a social science major in Dietrich College. In addition to a freshman seminar, and a sophomore research seminar, students complete coursework in a concentration area of their choice, selecting specialization in econometrics, statistics and regression, choice modeling, quantitative policy analysis, computational modeling, or psychometrics and measurement. Concentration areas are non-overlapping with students’ primary major, and typically consist of 3-4 courses each.

The program recruits students with a range of interests across the social sciences to create a cohesive interdisciplinary learning community. Majors that could fit well with this program include (but are not limited to) economics; behavioral economics, policy and organizations; decision science; policy and management; international relations and politics; statistics; statistics and machine learning.

Special features of the QSSS program include:

- An optional residential component that allows QSSS students to live together in their first year
- An exclusive QSSS freshman seminar (this seminar fulfills the Dietrich College freshman seminar requirement)
- A required senior thesis under the supervision of a faculty advisor from the student's home department and benefitting from the QSSS thesis proseminar.

Student-Defined Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*
Location: Baker Hall 154
www.cmu.edu/dietrich/undergraduate/student-defined-majors.html

For students whose educational goals cannot be as adequately served by the curricula of existing programs, the college provides the opportunity to self-define a major or minor. The procedure for establishing such a major centers on a written proposal, submitted to the college dean's office. This proposal consists of two parts:

Program description and rationale: A description of the components of the proposed program of study; a presentation of the objectives of the program of study, why it represents a coherent and (given available faculty, courses, and other resources) viable course of study, and the reason(s) why these objectives cannot be accomplished within one or more of the college's existing programs.

The curriculum: Presentation of a complete outline of all courses that will comprise the requirements for the major or minor, categorized according to that component of the major program to which each belongs (e.g., mathematics prerequisites; research methods; theoretical perspectives; etc.), and second, a semester-by-semester outline that indicates when each course is to be taken (or, for any already taken, when taken). The minimum requirement for graduation is, as with all majors in the college, 360 units of credit.

Proposals and curricula are evaluated for clarity of focus, coherence and depth in related areas, and viability within the context of the college and university offerings. Proposals should generally be developed no later than the sophomore year, and approved majors begin their program generally no later than the junior year.

As with all other Dietrich College majors, Dietrich College student-defined primary majors must fulfill all of the college's general education requirements.

Study Abroad Scholarships

Funding support for study and travel abroad is available through several sources, many administered by the university, and many others available externally. The Office of International Education is the first place to look for information about funding opportunities for study or travel abroad.

Two programs housed in Dietrich College are part of this portfolio of study/travel abroad funding programs:

The Department of Modern Languages Undergraduate Study Abroad Scholarship Program (https://www.cmu.edu/dietrich/modlang/study-abroad) offers scholarships to undergraduate students for accredited study abroad programs, limited in some instances to students who are majoring or minoring in a modern language and in other instances to students studying a particular language. Scholarship funds can be applied to tuition, room, board, airfare to the host country and book expenses.

The Dietrich College Study/Travel Abroad Grant Program (https://www.cmu.edu/dietrich/students/undergraduate/resources/study-abroad/study-abroad-scholarships.html) provides support for both traditional study abroad programs, and for non-study abroad experiences such as service learning opportunities, internships, research, or conference travel. The program uses a rolling application schedule for its grant funds, and works closely with the University's Office of International Education in advising students about eligible programs and potential funding sources, completing applications, and preparing for the intended program abroad experience.

Dietrich College Internship Opportunity Grants

www.cmu.edu/dietrich/students/undergraduate/resources/internship-opportunity-grants.html

Dietrich College encourages students to pursue interesting and professionally relevant internship opportunities. Often, however, the very positions that provide students with the most challenging and high-quality work experiences are either unpaid or modestly paid. To help compensate students for taking on work experiences that will be invaluable in helping them define and move toward their career goals, the Dietrich College Internship Opportunity Grant Program seeks to make it more financially possible for students to take advantage of such worthwhile internship opportunities.

Undergraduates with primary majors in Dietrich College, as well as BHA students, are eligible and encouraged to apply. Current sophomores and juniors receive preference. NOTE: Graduating seniors are not eligible.

Students are expected to find their own internships. There are many resources available to help in finding internships, including the Career and Professional Development Center's internship database. Preference for grants is given to students who find positions in the public sector or non-profit agencies.

For more information, including application time line and instructions, see: www.cmu.edu/dietrich/students/undergraduate/resources/internship-opportunity-grants.html

Dietrich College Pittsburgh Summer Internship Program

www.cmu.edu/dietrich/students/undergraduate/programs/summer-internship-program.html

The Dietrich College Pittsburgh Summer Internship Program is designed for undergraduates to engage and connect with organizations (mainly non-profit) in Pittsburgh.

Pittsburgh-area companies and organizations host Dietrich College students for an 8-10 week summer internship, working between 20-30 hours per week. Students accepted into the program will be supported up to the minimum level of $2,600.

Because of the stipend provided by the college and program's strong local focus, all interns are required to work in the City of Pittsburgh during the summer, not remotely, so as to ensure that they get the most out of this experience. Participants are also required to attend professional development workshops hosted by the program, and focused on a variety of topics (such as communication, professional etiquette, giving/receiving feedback, and networking).

Carnegie Mellon University Washington Semester Program

Kiron Skinner, *Faculty Director*
kskinner@andrew.cmu.edu, Porter Hall 223E

Emily Half, *IPS Deputy Director*
ehalf@andrew.cmu.edu; 412-268-7082, Porter Hall 223H

Emily Baddock, *CMU/WSP Executive Director*
ebaddock@andrew.cmu.edu; 202-608-8316, 100 Maryland Ave NE, Suite 510, Washington, DC 20002

www.cmu.edu/ips/cmuwsp

From embassy headquarters to nongovernmental organizations, think tanks to advocacy organizations, and consulting firms to media outlets, Washington, DC, is a focal point for many international and public policy activities.

Undergraduates from any course of study who would value firsthand policy experience are invited to apply to the Carnegie Mellon University Washington Semester Program (CMU/WSP), sponsored by the university's Institute for Politics and Strategy. In this semester-long program, students live, work, and study in Washington, DC, coming into direct contact with political, business, and community leaders and learning about the most pressing policy issues of the day.

Students earn 48 units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field of interest within Washington, DC, while taking classes taught by Carnegie Mellon faculty. The Institute for Politics and Strategy sponsors events and policy-oriented opportunities in Washington for students participating in the program to further enrich their experience and enhance their understanding of how Washington functions as a hub of international and public policy decision making.

Students should contact the IPS deputy director for more information or to discuss how the CMU/WSP may fit into their curriculum. Students who participate in the CMU/WSP may qualify for a minor in Politics and Public Policy (https://www.cmu.edu/ips/undergraduate%20degrees/minors/minor-in-politics-and-public-policy.html).

Curriculum

All students enroll in the following core seminars (24 units).

Core Seminars		
84-360	CMU/WSP Internship Seminar	12
84-450	Policy Forum	6
84-450	Policy Forum	6

Students enroll in 24 units from the below list of elective seminars. Offerings vary by semester.

Elective Seminars		
84-330	The Shading of Democracy: The Influence of Race on American Politics	6
84-331	Money, Media, and the Power of Data in Decisionmaking	6
84-332	Effects of US Policy on Businesses: Perspectives of Asian Americans	6
84-333	Power and Levers for Change in Washington, DC	12
84-334	Presidential Power in a Constitutional System	6
84-336	Implementing Public Policy: From Good Idea To Reality	12
84-337	Biomedical Science Research, Policy, and Governance	6
84-340	Making Change: How Organized Interests Work in Washington	12
84-343	Language and Power: How to Understand and Use Political Speech	6
84-346	Legal Issues in Public Administration	6
84-348	Advocacy, Policy and Practice	6

Academic Standards, Regulations and Protocols

Transferring into Dietrich College

Undergraduate students in other Carnegie Mellon colleges who wish to transfer (http://www.cmu.edu/hss/advisory-center/transferring/transfer-in.html) to Dietrich College apply through the college's Academic Advisory Center (https://www.cmu.edu/dietrich/advisory-center), located in Baker Hall A57. If approved, the transfer is into the college first and then into a primary major. Decisions regarding transfer requests will be based on evidence of adequate prior academic performance and on the applicant's prospects for success in the college and intended major.

The earliest point when undergraduates are considered for transfer into Dietrich College is the second semester of the first year. Students interested in transferring to Dietrich College should begin the process well before the course registration period for the upcoming semester. Prior to submitting a transfer application, students are encouraged to meet with representatives in the department where they are hoping to pursue a primary major.

Academic Actions

In order to maintain good academic standing, Dietrich College students must attain at least minimum quality point averages for each semester (as well as cumulatively), and also make and maintain adequate progress toward completing graduation requirements. Minimum quality point averages for good academic standing are 1.75 in the first year and 2.00 thereafter. “Adequate progress towards graduation” generally means that students are successfully completing 45-50 units per semester so that at the end of eight semesters they will have accumulated the minimum of 360 units required for graduation, have a cumulative QPA of at least 2.00, and completed all college General Education and primary major course requirements.

When a student fails to meet minimum performance criteria, it normally results in an “academic action.” Depending on the circumstances, one of the following actions is taken: academic warning, academic probation, continued probation, suspension, or drop. These academic actions are recommended by the college's departments based on the guidelines described below. However, the sequence of the academic actions is not automatic in all cases. Decisions may be based on unique individual student performance and circumstances, and are not determined purely on the basis of grades and quality point averages.

ACADEMIC WARNING

A student may receive an academic warning when they meet any of the following criteria: not passing two or more P/NC courses; repeatedly failing required courses, or repeatedly failing to attain minimum-level passing grades in prerequisite courses; earning a QPA between a 1.75 and a 1.99 in the first year; failing to complete the “first-year 5” courses by the end of the student’s fourth semester; falling off pace to graduate in 10 semesters; or failing to make sufficient progress through their declared primary major. The term of academic warning is one semester, and serves to alert the student that he or she is failing to make satisfactory progress toward completing degree completion despite meeting the college’s minimum QPA threshold to maintain good standing. A student’s academic warning is removed when the issue(s) that led to the warning have been resolved and no new issues around satisfactory academic progress have surfaced. A student can continue on an academic warning or move to academic probation if warranted by additional issues.

Academic Probation

A student is placed on academic probation when performance either for the semester or cumulatively fails to meet the minimum standard. The term of academic probation is one semester, and signifies to the student the college's insistence that academic performance return to at least the minimum acceptable level, and concern that a student has failed to do so. A student is removed from academic probation and returned to good academic standing when both the semester and cumulative quality point averages meet at least the stated minimum, and when adequate progress toward completing graduation requirements is being made. A student who has had one semester on probation and is not yet meeting minimum requirements but is making significant progress in this regard may be continued on academic probation.

Academic Suspension

Academic suspension is the usual action taken when a student fails to meet the minimum semester or cumulative requirements for two consecutive semesters. In general, a first-year student will be suspended if the semester and overall QPAs are below 1.75; for sophomores, juniors, and seniors, if these are below 2.00. Failure to maintain adequate progress toward graduation may also be a contributing factor in such decisions.

The minimum period of academic suspension is normally two semesters, during which a student on academic suspension is expected to reflect on the circumstances leading up to the suspension, identify the issues that prevented him or her from achieving academic success, and take actions that address these issues and demonstrate sufficient readiness to return to the university and successfully resume his or her studies. These actions could include a work or internship experience, a limited amount of approved academic course work at another college or university, and — if relevant — appropriate medical care.

Midway through the semester before a suspended student is eligible to return to the university, he or she will be notified by the Academic Advisory Center Director with detailed instructions about the process for requesting approval to return and re-enroll.

Once cleared to return from academic suspension, the Enrollment Services office will be notified and the student will be eligible to enroll. While on academic suspension, students are considered to be on a mandatory “leave of absence,” and are governed by college and university policies concerning such leaves of absence. See subsequent discussions of “Leave of Absence and Withdrawal from the College.” Students returning from academic suspension do so on final academic probation.

Academic Drop

The most severe academic action occurs when a student is dropped for academic reasons from the college and the university, and is not permitted to re-enroll. This normally results when a student, already on final academic probation, continues to perform at levels below the minimum set by the college for good academic standing, and shows no indication of being able to reach an acceptable level of performance or maintain steady progress toward completing graduation requirements. It is also an option when, in unusual cases, a student has performed poorly, and has been unresponsive to outreach efforts by college and/or university offices seeking to offer help and support.

Dietrich College Dean's Honor List

Each semester the college recognizes those students who have attained outstanding semester quality point averages by naming them to the Dietrich College dean’s honor list.

Students who complete at least 45 factorable units and attain a semester QPA from 3.50 through 3.74 are named to the Dean’s List, with Honors; if the semester QPA is 3.75 or higher, students are named to the Dean’s List, with High Honors.

Students who complete at least 36 or up to 44 factorable units and attain a semester QPA of 3.75 or higher are named to the Dean’s List, with Honors.

In addition, it is generally the case that students are not eligible for the dean's list who receive one or more "Incomplete" grades at the time when final semester grades are recorded.

Course Overloads

Overloading is defined as taking more than the equivalent of five full-semester courses in one semester; for Dietrich College students this usually means registering for more than 50 units in one semester.

Eligibility to overload is defined as having a QPA of at least 3.25 in the last completed semester, based on a course load of at least 45 factorable units, and a current cumulative QPA of at least 3.00. Students new to the college and university (i.e., first-year students and new external transfer students) may not overload during their first Carnegie Mellon semester.

Eligibility to overload based on QPA does not automatically allow the student to register for an overload. Rather, students must complete an overload petition, and meet with their primary academic advisor to discuss the proposed overload. If approved, the academic advisor will increase the student's unit maximum for the relevant semester.

The first opportunity to register for a course overload is after registration week for the proposed overload semester. Registration week for the spring semester is usually the third week in November; for the fall semester, it is usually the third week in April. Consult the official university academic calendar for the exact dates.

If as a result of final grades for the current semester a student approved to overload for the next semester falls below the QPA overload eligibility criteria, the academic advisor may withdraw the overload permission. Students thus affected are responsible for resolving this in consultation with their academic advisor.

Physical Education and StuCo* Courses

A maximum of nine units of credit for any combination of Physical Education (69-xxx) and StuCo (98-xxx) courses may be counted as credit toward graduation requirements. Physical Education and StuCo courses are not included when calculating a student's QPA or when calculating units to determine eligibility to carry a course overload.

*StuCo (http://www.cmu.edu/stuco) refers to "student-led courses" — i.e., courses designed by students, and approved to be offered for academic credit.

Course Failures and Course Repetitions

Students who fail a required course must repeat and pass it (or take and successfully complete another approved course that fulfills the requirement). If a failed course is a prerequisite to more advanced course work within a particular course sequence, the failed course must in general be repeated before moving on to the higher level course. **Exception:** Dietrich College students who do not successfully complete their first-year seminar will be registered for another first-year seminar if space is available. If space is not available, these students must select and successfully complete an additional course from one of the college's general education categories.

Failed courses that are repeated and passed, or courses that are passed but repeated in order to obtain a higher grade, are all included and remain on the student's record and are included in calculating the student's QPA. Students who repeat a course that they have already passed will not be able to apply the second set of units for the course toward graduation requirements.

Internships-for-Credit

An internship-for-credit is a supervised, professional work experience with clear links to a student's academic program, performed primarily or totally outside of a regular course structure, and for which a student earns academic credit. Students doing an internship for academic credit must be registered through the academic department of the faculty member supervising the internship, and must register for the internship course during the term (including the summer) when the internship work is being performed. There is no additional tuition charge for credit-bearing internships that are taken during the academic year. Students registered for internships during the summer will be billed for tuition at the per-unit rate set by the university.

To receive academic credit, the internship:

- must conform to the criteria for internships-for-credit (https://www.naceweb.org/about-us/advocacy/position-statements/position-statement-us-internships) set by the National Association of Colleges and Employers and the U.S. Department of Labor
- requires the involvement of a Carnegie Mellon faculty sponsor and an on-site supervisor in the design, oversight and evaluation of the internship;
- must include regular or periodic meetings between the student, the faculty sponsor, and/or the internship site supervisor to monitor progress and offer feedback on student performance;
- requires an end-product for submission to the faculty sponsor. This usually takes the form of a paper, but may also include a presentation, or some other approved form;
- may be taken for a regular letter grade or pass/no credit as per the policy of the department through which the internship course is taken by registering for the internship course through the sponsoring department. With department approval, the internship may be counted toward program requirements.
- can vary from 3-18 units in any one semester, and is limited only by the college rule of a maximum of 27 units of internship credit that can be applied to graduation requirements.

Additional policies and practices regarding internships-for-credit vary among the college's academic departments. Departments are not obligated to allow internship credit for its majors, and are free to determine whether an internship may be used to fulfill requirements or serve only as an elective. An internship-for-credit is a graded experience. Each department will determine appropriate criteria for the grade if an internship is approved for credit.

Credits for internships are generally earned according to the following scale:

- 9 units = the equivalent of 1 day (9-12 hours) per week during a full semester
- 18 units = the equivalent of 2 days (12-20 hours) per week during a full semester

A Dietrich College student may not earn more than 18 units of internship credit during a single semester or count more than 27 units of internship credit toward fulfillment of graduation requirements.

In instances when the internship sponsor requires that a student receive academic credit from the home institution, the student should contact the Dietrich College Associate Dean for Undergraduate Studies for information and advice about available options.

Dietrich College Credit Policy for Non-Carnegie Mellon Courses

The following policies govern the practice of Dietrich College undergraduates taking courses elsewhere and requesting that credits for these courses transfer to their Carnegie Mellon University academic record. Courses taken elsewhere will be considered for transfer credit if the institution offering them is fully accredited, and if the courses in question are judged to be acceptable for the purposes proposed by the student.

Approval

Dietrich College undergraduates who wish to take courses at another institution and request that credits for these courses transfer to their Carnegie Mellon University record should familiarize themselves with Dietrich's transfer credit policies found at www.cmu.edu/dietrich/advisory-center/transferring/cmu-course-credit.html. Students must receive approval before taking any courses at another institution in order to guarantee that they will receive transfer credit upon successful completion of the course(s).

Limits

Once a student enrolls in the university as a degree candidate, he or she may take a maximum of five courses (or their rough unit equivalent) elsewhere and transfer these back for credit toward the Carnegie Mellon degree.

No courses may be transferred and be substituted for the following general education requirements:

- 76-101 Interpretation and Argument or courses that fulfill the University First-Year Writing Program requirements
- 79-104 Global Histories
- 36-200 Reasoning with Data
- 99-101 Computing @ Carnegie Mellon
- First-Year Seminar requirement

Exceptions

These limits do not apply to courses and credits approved through Advanced Placement examinations, International Baccalaureate examinations, Cambridge International A-Level examinations, cross-registration through the Pittsburgh Consortium for Higher Education (PCHE), Washington Semester Program, and approved study abroad or exchange programs. Exceptions to these restrictions may be made only by way of written petition to the Dietrich College Council (c/o the Dietrich College Academic Advisory Center).

Grades

Courses taken elsewhere must be taken for a regular letter grade (not pass/no credit or pass/fail) in order to be granted transfer credit. As a matter of college policy, Dietrich College students must earn a final grade of at least "C" in order for the credit to transfer. A “C-” grade is not transferable when its equivalency is below a 2.00 on a 4.00 scale, or 70%. In cases when courses proposed for transfer credit are to apply to requirements in a Dietrich major or minor program, the program's department may set a higher minimum final grade in order for credit to transfer. Only units, not grades, transfer for courses taken elsewhere, and thus do not affect a student's Carnegie Mellon QPA. Courses offered elsewhere only on a "pass/fail" or “pass/no credit” basis are not eligible for CMU transfer credit. Students should consult their academic advisor before taking courses at another institution for which they want to receive transfer credit.

External Transfer Students

For students entering Carnegie Mellon and Dietrich College as external transfers, the same five-course limit applies after they become Carnegie Mellon degree candidates, unless their transfer credits reach the 180-unit limit for transfer credit stipulated by university policy. A candidate for the bachelor's degree must complete a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework at Carnegie Mellon. If a degree has already been obtained at another institution, courses that count toward that degree may not be used again as transfer credit toward a Carnegie Mellon University undergraduate degree.

Internal Transfer Students

This policy applies retroactively to students who enter Dietrich College through internal transfer. Courses previously approved for transfer credit may be re-evaluated for consistency with relevant Dietrich College or program policies and standards.

Students on Academic Suspension

Subject to the college's policy limiting transfer course credit, students on academic suspension from Dietrich College will be permitted to receive transfer credit for no more than three non-CMU courses per semester, and no more than a total of five non-CMU courses, while on suspension. Approval to take these courses for transfer credit is to be obtained in advance.

While on academic suspension, students are considered to be on a mandatory "leave of absence" and are governed by College and University policies concerning leaves of absence (https://www.cmu.edu/policies/student-and-student-life/student-leave.html).

Double-Counting Courses

Double-counting refers to instances when a course taken to fulfill one requirement counts simultaneously toward a requirement in another major or minor program. While the college encourages study in complementary areas where majors and minors frequently share requirements in common, it also wants to keep clear the meaning and integrity of the labels “major” and “minor.” To preserve the integrity of these definitions, double-counting is permitted in Dietrich College on a very limited basis, and only in those instances when the course(s) in question represent only a small portion of the second program.

The college and its departments have developed program-specific guidelines for this practice that appear throughout the Dietrich College section of this catalog, and particularly in the case of major and minor programs that students frequently pursue in combination.

Graduation Requirements

Eligibility for graduation in Dietrich College requires that a student:

1. complete all Dietrich College general education requirements,
2. complete all course requirements in a Dietrich College primary major,
3. achieve a cumulative quality point average of at least 2.00 for all courses taken (or, alternatively, for all courses taken after the 1st year),
4. earn at least 360 units with a minimum of 180 units taken at Carnegie Mellon University,
5. be recommended (certified) for graduation by the faculty of the student's primary major department,
6. meet all financial obligations to the university, and
7. qualify for graduation within eight years prior to the date on which the degree is granted.

The college reserves the right to modify these academic standards, regulations, and protocols.

Graduation with University Honors

Dietrich College students who achieve an overall QPA of at least 3.50 will be recommended for graduation with University Honors.

Graduation with College Honors

Students who successfully complete a senior honors thesis under the auspices of the Dietrich College Senior Honors Program qualify for graduation with Dietrich College Honors.

Undergraduate Economics Program

Chris Telmer, Head of Economics

Carol B. Goldburg, Executive Director of Undergraduate Economics (Tepper Quad 2406)

Kathleen Conway, Senior Academic Advisor and Program Manager (Tepper Quad 2407)

Location: Tepper Quad, Suite 2400
Email: econprog@andrew.cmu.edu
Advising Appointment Online Scheduler: http://meetme.so/CMUEconomics
tepper.cmu.edu/prospective-students/undergraduate/economics

At its most fundamental level, economics is the study of how scarce resources are allocated. What will be produced and consumed, how much, and by whom? These questions are central to the well-being of people throughout the world. Economists identify, model, and analyze problems with the objective of developing practical and efficient solutions to challenges confronting society. Economists are also active participants in the processes and institutions through which economic policies are implemented. In the public arena sphere, economists contribute to design of programs and incentive systems to foster efficient implementation of policies. In the private sector, economists bring modeling and data-analytic skill to bear, both in identifying ways to enhance productive efficiency within the firm and in developing strategies to enhance effectiveness of the firm as it competes in the global marketplace. Increasingly, economists are taking advantage of advances in technology to design new exchange systems in applications as diverse as global electronic markets, kidney exchanges, pollution control, and school choice mechanisms.

Carnegie Mellon University enjoys a rich history of innovative research in the field of economics. The university has a distinctive culture that fosters collaborative, problem-oriented, theoretically rigorous, and empirically tested research. The success of this distinctive approach is manifest in the international recognition accorded past and present faculty, including nine Nobel Prizes in Economics. In the classroom, faculty bring the same rigorous, innovative approach to help develop the tremendous intellectual potential and analytic skills of students who are drawn to study economics at Carnegie Mellon. Project courses and hands-on applications in classes enable our students to gain valuable practical experience in honing their skills in economic reasoning, modeling, and data analysis.

The Undergraduate Economics Program has a unique position at Carnegie Mellon University. It is the sole undergraduate program that is a joint program of the Tepper School of Business and the Dietrich College of Humanities and Social Sciences. The combination of research strength (Tepper has been home to nine Nobel Laureates in Economics) and commitment to liberal arts and interdisciplinary studies (Dietrich has "the most creative general education program of any American university" – New York Times) provides our undergraduates with a world-class economics program.

Economics majors are considered members of both colleges and enjoy the full support and services of both. Undergraduate economics students should consult the program's website for details about applicable Tepper and Dietrich academic policies and procedures.

Educational Objectives

The Undergraduate Economics Program offers a range of degrees in economics designed to develop strong analytical skills and a solid foundation in the discipline of economics. More specifically, measurable objectives for our economics curriculum are the following:

- Students should be able to identify, explain, and use economic concepts, theories, models, and data-analytic techniques.
- Students should acquire and use knowledge of economics, mathematics, statistics, and computing flexibly in a variety of contexts, providing the foundation for success in graduate studies and careers in the public and private sectors.
- Students should be able to apply their economic tools to formulate positions on a wide range of social and economic problems and engage effectively in policy debates.
- Students should use the investigative skills necessary for conducting original economic research and participating effectively in project teams.
- Students should be able to deliver effective presentations in which they combine visual communication design with oral arguments and/or the written word.

Academic Standards and Policies

Undergraduate economics students are in the unique position of belonging to two CMU colleges, Marianna Brown Dietrich College of Humanities and Social Sciences and the Tepper School of Business. To find a detailed description of the college and program policies governing economics students, please visit the program website (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum).

Advising

The Undergraduate Economics Program is committed to providing students with the opportunity to have meaningful and informative discussions about their academic, intellectual, and career interests with a wide range of advisors and mentors. Advising meetings are extended discussions which may address both immediate and long-term interests, concerns, and desires/needs. Students pursuing a degree in economics are assigned an economics advisor who meets with them on a regular basis. Any CMU undergraduate student interested in taking an economics courses is invited to meet with an economics advisor. To facilitate scheduling advising meetings, please use the online appointment scheduler (https://meetme.so/CMUEconomics).

The economics curriculum is cumulative; higher-level courses build upon the foundations learned in the core courses. This results in students needing to be aware of course-sequencing and the schedule of classes. Students are encouraged to meet frequently with their Undergraduate Economics Program academic advisor to ensure that their courses fulfill the requirements towards their degree and are appropriately sequenced. Successful students check-in with their advisor frequently and seek the advice of their academic advisor in selecting courses, pursuing additional degrees, and planning ahead for study abroad.

First-Year Advising

First-year students who major in economics enter Carnegie Mellon University as Dietrich College students, and are assigned a Dietrich College Academic Advisory Center (http://www.cmu.edu/hss/advisory-center) (AAC) advisor. While the AAC advisors are the advisors of record until students formally declare their majors, students who are considering majoring in economics are encouraged to contact the Undergraduate Economics Program academic advisor so that they will have access to program resources; program-level advising; and the community of faculty, staff, and students.

First–year students are **not** expected to know which degree option they wish to pursue. For this reason, the first–year curricula are quite similar for the four primary degrees awarded by the program. As students become involved in their course work, participate in the extra– and co–curricular activities sponsored by the Undergraduate Economics Program, and have discussions with faculty and economics advisors, the decision of which degree to pursue becomes evident.

Study Abroad

The Undergraduate Economics Program encourages students to consider enriching their undergraduate experience by studying abroad at some point during their undergraduate tenure. Studying abroad is widely defined as either study, work, internship, volunteer, or research opportunities abroad during your college career. Studying abroad provides students with not only more awareness of cultural literacies, but it further enhances their education by providing them with the opportunity to compare and contrast different economies and regimes. Many students consider their study abroad experience to be a watershed moment in their studies. With a bit of careful planning, study abroad can be worked into most any economics student's 4-year schedule.

Preparation for Professional School Programs

Many economics students will attend professional graduate school programs (e.g., DDS, JD, MBA, MD, MPP, M.Sc. Finance, etc.) immediately after graduation or within the first five years of earning their undergraduate degree. Students who are considering applying to professional graduate schools are encouraged to discuss their interests with an economics advisor early in their career at CMU. The economics advisors can provide structure and information that are invaluable during a student's intellectual and career exploration. Knowing that the choice of courses, student achievement, extra- and co-curricular activities, professional school entrance exam test scores (e.g., GMAT, LSAT, MCAT, etc), and faculty recommendations are key determinants of acceptance into these varied programs, the economics advisors will help you plan your time at CMU.

Preparation for Ph.D. Programs in Economics

The Undergraduate Economics Program has been successful in preparing students for admission into the nation's most competitive doctoral programs. The life of a researcher (whether in academia or in the private research sector) requires a set of skills that undergraduate students will begin to acquire through course work, research, and focused conversations with faculty and advisors. Doctoral programs in economics are looking for specific analytical skills. Key determinants of acceptance into these programs are the choice of courses, student achievement, research experience, graduate school entrance exam test scores (specifically the GRE), and faculty recommendations. Students who are considering pursuing a higher academic degree are encouraged to discuss their interests with an economics advisor early in their career at CMU. Interested students are encouraged to consider the B.S. in Economics and Mathematical Sciences curriculum.

Curriculum

In order to accommodate students' wide variety of goals, five primary degree programs are available: Bachelor of Arts in Economics, Bachelor of Science in Economics, Bachelor of Science in Economics and Mathematical Sciences (jointly administered by the Department of Mathematics and the Undergraduate Economics Program), Bachelor of Science in Economics and Statistics (jointly administered by the Department of Statistics and Data Science and the Undergraduate Economics Program), and Bachelor of Science in Economics and Politics (jointly administered by the Institute for Politics and Strategy and the Undergraduate Economics Program).

The five major degree programs have been designed to provide students with a solid understanding of the central theories and analytical tools of the field of economics, while maintaining the flexibility necessary to meet the needs of a diversity of career paths. The five degrees produce strong analytical thinkers who are able to model and analyze complex problems. Graduates of the Undergraduate Economics Program gain employment as economic analysts in both the private and public sectors; pursue advanced professional degrees in business, law, and public policy; as well as enter into Ph.D. programs in economics, statistics, finance, and related fields.

For students who major in other academic fields, additional major programs in Economics, Economics and Statistics, and Economics and Politics and a minor degree program in Economics are available.

Concentrations

The Undergraduate Economics Program offers six concentration areas which allow students to specialize in:

- Advanced Quantitative Economic Methods: For students considering a career in a field that requires expertise in both data analytics and economics, or those considering a graduate degree in economics.
- Strategy and Markets: Gain a more comprehensive perspective on the economics of modern business for a career path in consulting or industry.
- Global Markets and Finance: Essential for students interested in a career in international finance, central banking or macroeconomic consulting, this area explores the causes of financial crises, the role of the Federal Reserve in the economy, and the determination of exchange and interest rates.
- Policy and Social Impact: Understand the role of economics in healthcare, taxation, regulation, law, and education as a foundation for a career in government or industries impacted by policy making.
- Global Change and Disruption: Gain an understanding of the key trends reshaping the world economy — such as globalization and technological change — as an essential foundation for a career in strategic consulting, public policy or international organizations such as the IMF or World Bank.
- Market Design and the Digital Economy: For tech firms, consultancies, and many areas of business and public policy, market design — the new frontier of economics — is the key to success. Here, you'll explore why market arrangements succeed or fail, and how markets might be better designed.

Concentrations consist of groups of mutually reinforcing economics electives that build off the economics core curriculum. These focused sets of electives allow a student to explore a group of allied topics, and/or develop a specialized and advanced skill set appropriate for a desired career. Students are not required to complete a concentration in order to earn a degree. See the program website (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum) for more details.

Major Degree Requirements and Sample Schedules

In addition to completing a minimum 360 units and fulfilling both the Dietrich General Education requirements and all University requirements, recipients of an undergraduate degree in economics must complete courses in mathematics, probability and statistics, writing, economic theory, and economic analysis, as well as a set of advanced electives and other specialized courses. It is important for students to realize that degree requirements are actually the "minimum" set of degree requirements. In fact, most economics students take more courses in their major than is strictly required.

Following the list of requirements for each degree are sample four-year course schedules for a student pursuing an undergraduate degree in economics. As there are many different ways of completing the requirements, students are strongly encouraged to meet with an economics advisor to tailor their courses to their own particular needs. Students are responsible for ensuring that they understand all of the program requirements and that they meet the necessary conditions for graduation. When planning course schedules, students must give consideration to all prerequisite and co-requisite requirements.

In addition to meeting university and college graduation requirements, the Undergraduate Economics Program has the additional requirement: Economics courses counting towards any economics primary degree, additional major, or minor must be completed with a grade of "C" or higher.

B.A. in Economics

The B.A. in Economics provides a strong foundation in economic analysis and quantitative methods. The curriculum's breadth incorporates the study of political, historical, and social institutions so that students may use the economic toolkit to address the current challenges humanity faces. Built into the degree is the opportunity to study political, historical, cultural, and social institutions from other CMU departments; these courses are referred to as "Special Electives". The capstone of the curriculum is the Senior Project course where students use their qualitative and quantitative skills to contribute to the body of knowledge in empirical, experimental, and/or theoretical studies. Students pursuing this degree will be well-equipped to pursue graduate work (professional and academic), enter directly into the business world, or pursue public service.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

B.A. in Economics Curriculum

Total Number of Units for the Major:	**157/166**

Mathematics Prerequisites (19 units)

Courses		Units
21-120	Differential and Integral Calculus Passing the MCS assessment test is an acceptable alternative to completing 21-120.	10
21-256	Multivariate Analysis	9

Sophomore Economics Colloquium (3 units)

		Units
73-210	Economics Colloquium I	3

Writing Requirement (9 units)

		Units
73-270	Professional Communication for Economists	9

Economic Theory Requirements (36 units)

		Units
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

Quantitative Analysis Requirements (27 Units)

		Units
36-200	Reasoning with Data	9
or 36-207	Probability and Statistics for Business Applications	
or 70-207	Probability and Statistics for Business Applications	
73-265	Economics and Data Science	9
73-274	Econometrics I	9

Advanced Economics Electives (36 Units)

Students must take four advanced elective courses. Advanced elective courses are those numbered 73-300 through 73-495. Students have the option of earning a concentration (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Special Electives (18 Units)

Students must take two special elective courses in the humanities and social sciences. Students should consult the degree audit system for courses that satisfy the special electives requirement. The list below is a sample of the courses that qualify as special electives; this is not a full list of qualifying courses. Students should consult an academic advisor when choosing special electives.

Course List

Sample List of Special Elective Courses		Units
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-421	Emerging Energy Policies	9
19-424	Energy and the Environment	9
19-443	Climate Change Science and Adaptation	9
19-425	Sustainable Energy for the Developing World	9
66-221	Topics of Law: Introduction to Intellectual Property Law	9
79-245	Capitalism and Individualism in American Culture	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-266	Russian History and Revolutionary Socialism	9
79-280	Coffee and Capitalism	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-300	Guns in American History: Culture, Violence, and Politics	9
79-305	Moneyball Nation: Data in American Life	9
79-310	Modern U. S. Business History: 1870 to the Present	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-320	Women, Politics, and Protest	9
79-343	Education, Democracy, and Civil Rights	9
79-383	The History of Capitalism	9
79-386	Entrepreneurs in Africa, Past, Present and Future	9
80-136	Social Structure, Public Policy & Ethics	9
80-249	AI, Society, and Humanity	9
80-305	Choices, Decisions, and Games	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
84-310	International Political Economy	9
84-318	Politics of Developing Nations	9
84-362	Diplomacy and Statecraft	9
84-414	International and Subnational Security	9
84-387	Technology and Policy of Cyber War	9
88-411	Rise of the Asian Economies	9

Senior Work (9 Units; 18 Units for students working on an honors thesis in economics)

		Units
73-497	Senior Project	9
or 73-500 & 73-501	Tepper College Honors Thesis I and Tepper College Honors Thesis II	
or 66-501 & 66-502	H&SS Senior Honors Thesis I and H&SS Senior Honors Thesis II	

Sample Schedule for B.A. in Economics

The sample schedule below is an illustration of how students might plan their four-year schedules. This schedule has been designed to highlight the following characteristics of the degree program: 1) the work load is roughly 45-50 units per semester, hence there is no need for course overloading; and 2) room has been built into the schedule that would allow students to pursue additional degrees and/or study abroad. It is important for students to realize that degree requirements are the actually the "minimum" set of degree requirements. In fact, most economics students take more courses in their major than is strictly required.

Freshman		Sophomore	
Fall	Spring	Fall	Spring
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	73-240 Intermediate Macroeconomics
21-120 Differential and Integral Calculus	73-103 Principles of Macroeconomics	73-210 Economics Colloquium I	73-274 Econometrics I
73-102 Principles of Microeconomics	-----	73-265 Economics and Data Science	Economics Elective
73-060 Economics: BaseCamp	-----	"Special Elective"	-----
-----*	-----	-----	-----
-----		-----	

Junior		Senior	
Fall	Spring	Fall	Spring
73-270 Professional Communication for Economists	Economics Elective	73-497 Senior Project	Economics Elective
"Special Elective"	-----	Economics Elective	-----
-----	-----	-----	-----
-----	-----	-----	-----
-----	-----	-----	-----

*In each semester, ----- represents courses that are not directly required for the major.

B.S. in Economics

The B.S. in Economics provides a strong foundation in economic theory and advanced quantitative analysis. The curriculum focuses on using "real-world" data to forecast behavior and to investigate the relationships between observed phenomenon and economic models. Combining these sophisticated economic modeling data analytic skills with our wide range of upper-level economic electives provides students with a rigorous analytical foundation that will allow them to pursue any career that interests them. The capstone of the curriculum is the Senior Project course where students use their qualitative and quantitative skills to contribute to the body of knowledge in empirical, experimental, and/or theoretical studies. Students completing this degree will be well-equipped to pursue graduate work (professional and academic) or enter directly into the business world or public service.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

B.S. in Economics Curriculum

Total Number of Units for the Major	**167/176**

Mathematics Requirement (29 Units)

		Units
21-120	Differential and Integral Calculus Passing the MCS assessment test is an acceptable alternative to completing 21-120.	10
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	

Sophomore Colloquium (3 Units)

		Units
73-210	Economics Colloquium I	3

Quantitative Analysis Requirements (27 Units)

		Units
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9

Writing Requirement (9 Units)

		Units
73-270	Professional Communication for Economists	9

Economic Theory Requirements (36 Units)

		Units
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

Advanced Economics Electives (54 Units)

Students must take six advanced elective courses. Advanced elective courses are those numbered 73-300 through 73-495 (excluding 73-374 Econometrics II). Students have the option of earning a concentration (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Senior Work (9 Units; 18 Units for students working on an honors thesis in economics)

		Units
73-497	Senior Project	9
or 73-500 & 73-501	Tepper College Honors Thesis I and Tepper College Honors Thesis II	
or 66-501 & 66-502	H&SS Senior Honors Thesis I and H&SS Senior Honors Thesis II	

Sample Course Schedule for the B.S. in Economics

The sample schedule below is an illustration of how students might plan their four-year schedules. This schedule has been designed to highlight the following characteristics of the degree program: 1) the work load is roughly 45-50 units per semester, hence there is no need for course overloading; and 2) room has been built into the schedule that would allow students to pursue additional degrees and/or study abroad. It is important for students to realize that degree requirements are the actually the "minimum" set of degree requirements. In fact, most economics students take more courses in their major than is strictly required.

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-265 Economics and Data Science	73-240 Intermediate Macroeconomics
21-120 Differential and Integral Calculus	73-103 Principles of Macroeconomics	73-230 Intermediate Microeconomics	73-274 Econometrics I
73-102 Principles of Microeconomics	-----	73-210 Economics Colloquium I	Economics Elective
73-060 Economics: BaseCamp	-----	21-240 Matrix Algebra with Applications	-----
-----*	-----	-----	-----

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
73-270 Professional Communication for Economists	Economics Elective	73-497 Senior Project	Economics Elective
73-374 Econometrics II	Economics Elective	Economics Elective	-----
Economics Elective	-----	-----	-----
-----	-----	-----	-----
-----	-----	-----	-----

*In each semester, ----- represents courses not directly required for the major.

B.S. in Economics and Mathematical Sciences

The B.S. in Economics and Mathematical Sciences is a collaborative effort between the Department of Mathematical Sciences and the Undergraduate Economics Program. Combining advanced mathematics with advanced economic theory is the hallmark of this curriculum. The curriculum provides students with courses that complement and develop depth of understanding of economic theory, applied economics, and applied mathematics. This degree offers an integrated curriculum, guiding students through a program of coursework that exploits and builds upon the synergies between mathematics and economics. This degree program equips students with the mathematical tools that are essential for success in Ph.D. programs in economics; mathematics; and key functional areas of business including finance, accounting, marketing, and information systems. Students pursuing this degree will be well prepared for the beginning of their research careers in academia, government, and industry. There are a limited number of student openings in this program; interested students may apply as early as their sophomore year. Acceptance into the degree program is based on academic performance, rigor of coursework, and initiative while at Carnegie Mellon. In order to graduate with the B.S. in Economics and Mathematical Sciences, students must maintain a cumulative Q.P.A. of 3.33.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

B.S. in Economics and Mathematical Sciences Curriculum

Total Number of Units for the Major	**239**

Economic Theory Requirements (36 Units)

		Units
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

Quantitative Analysis Requirements (45 Units)

		Units
36-225	Introduction to Probability Theory	9
or 36-217	Probability Theory and Random Processes	
or 21-325	Probability	
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9

73-274	Econometrics I	9
73-374	Econometrics II	9

Mathematical Sciences Requirements (85 Units)

		Units
21-120	Differential and Integral Calculus Passing the MCS assessment test is an acceptable alternative to completing 21-120.	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	10
21-259	Calculus in Three Dimensions	9-10
or 21-256	Multivariate Analysis	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
21-355	Principles of Real Analysis I	9
21-356	Principles of Real Analysis II	9

Programming Requirement (10 Units)

		Units
15-110	Principles of Computing	10

Writing Requirement (9 Units)

		Units
73-270	Professional Communication for Economists	9

Advanced Economic Electives (27 Units)

Students must take three advanced economics elective courses. Advanced Elective courses are those courses numbered 73-300 through 73-495, (excluding 73-374 Econometrics II). Students are encouraged to work with their advisors to structure a set of courses which meet these requirements based on their particular interests, subject to course availability. Students have the option of earning a concentration (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Recommended Advanced Economics Electives:

73-315	Market Design	9
73-338	Financial Crises and Risk	9
73-347	Game Theory for Economists	9
73-365	Firms, Market Structures, and Strategy	9
73-421	Emerging Markets	9

Mathematical Science Depth Electives (27 Units)

Students must take three advanced mathematics depth courses. Students are encouraged to work with their advisors to structure a set of courses which meet these requirements based on their particular interests, subject to course availability.

Recommended Mathematical Science Depth Electives:

21-292	Operations Research I	9
21-329	Set Theory	9
21-365	Projects in Applied Mathematics	9
21-366	Topics in Applied Mathematics	9
21-371	Functions of a Complex Variable	9
21-374	Field Theory	9
21-441	Number Theory	9
21-484	Graph Theory	9
21-499	Undergraduate Research Topic	9

Note: Only one of the following three courses may count towards the required Mathematical Sciences Depth Electives: 21-365, 21-366, or 21-499.

Sample Course Schedule for the B.S. in Economics and Mathematical Sciences

The sample schedule below is an illustration of how students might plan their four-year schedules. This schedule has been designed to highlight the following characteristics of the degree program: 1) the work load is roughly 45-50 units per semester, hence there is no need for course overloading; 2) room has built into the schedule that would allow students to pursue additional degrees and/or study abroad; and 3) the demands of this degree require students to carefully plan their degree program while keeping in mind the college-level and university-level graduation requirements. It is important for students to realize that degree requirements are the actually the "minimum" set of degree requirements. In fact, most economics students take more courses in their major than is strictly required.

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	15-110 Principles of Computing	21-122 Integration and Approximation	21-241 Matrices and Linear Transformations
73-102 Principles of Microeconomics	21-256 Multivariate Analysis	21-127 Concepts of Mathematics	36-226 Introduction to Statistical Inference
36-200 Reasoning with Data	73-103 Principles of Macroeconomics	73-230 Intermediate Microeconomics	73-240 Intermediate Macroeconomics
73-060 Economics: BaseCamp	-----	36-225 Introduction to Probability Theory	73-274 Econometrics I
-----*	-----	-----	Economics Elective

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
21-260 Differential Equations	21-355 Principles of Real Analysis I	21-228 Discrete Mathematics	21-356 Principles of Real Analysis II
73-374 Econometrics II	Economics Elective	36-401 Modern Regression	-----
73-270 Professional Communication for Economists	Mathematics Elective	Mathematics Elective	-----
Economics Elective	-----	-----	-----
Mathematics Elective	-----	-----	-----

*In each semester, ----- represents courses not directly required for the major. Please note that students pursuing the B.S. in Mathematical Sciences and Economics must fulfill the Mellon College General Education requirements and not the Dietrich College General Education requirements.

Bachelor of Science in Economics and Politics

Politics and economics are deeply interconnected. Political institutions and decision-making impact economic growth, income distribution, and many other aspects of economic life. Both fiscal and monetary policies affect the economy, but these policies are often employed with political considerations in mind and can influence political activity. Conversely, economic outcomes shape political preferences and policy choices. The overlap between these two disciplines is endless. For example, while the United Nations is often thought of in purely political terms, the Security Council can and does impose sanctions on countries- an example of an economic policy used for political change.

The Economics and Politics major is offered jointly between the Undergraduate Economics Program (https://www.cmu.edu/tepper/programs/undergraduate-economics) (UEP) and the Institute for Politics and Strategy (https://www.cmu.edu/ips) (IPS). Students are equal members of both academic units and receive advising from both units. The major will appeal to any student interested in the design, evaluation, and political implementation of policy. It will be especially attractive to students considering careers in politics, government agencies, political and business consulting, lobbying, or the law.

The B.S. in Economics and Politics is an interdisciplinary major. The major will develop the political context and underpinnings of economic policy making. It will explore how political institutions resolve the tradeoffs and disagreements associated with policymaking and how they can facilitate or impede desirable economic outcomes.

IPS strengths lie in topics like national security, grand strategy, and globalization. Economic policy is just one facet of grand strategy, through which an administration pursues domestic and international goals. This major will also address key issues such as the complementarity between the multilateral economic institutions such as the IMF and World Bank and the use of economic coercion, and enable students to understand economic statecraft more broadly. Whether coercion is successful depends not just on the levers of power but on also on variations in authoritarian regime structure, and complex linkages in the international economy. This is also important for our understanding of the relationship between international economics on human rights practices, extending even to how treaty commitments can facilitate compliance with a global initiative to combat climate change. And, not least important, there is broad recognition that the viability of the "Euro Zone" depends on whether the political-economic agreements necessary to mitigate institutional weaknesses are politically feasible or destined to failure.

Economics and Politics is available as both a primary and additional major.

Curriculum

Students must earn a grade of "C" or better in all courses taken in the Department of Economics (73-xxx).

Prerequisites

Students must complete all of the following courses.

21-120	Differential and Integral Calculus	10
or 21-112	Integral Calculus	
36-200	Reasoning with Data	9

Foundations (48 units)

Students must complete all of the following courses.

21-256	Multivariate Analysis	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-275	Comparative Politics	9
73-210	Economics Colloquium I	3

Core (63 units)

Students must complete all of the following courses.

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9
84-265	Political Science Research Methods	9
84-326	Theories of International Relations	9
84-310	International Political Economy	9

Communication (9 units)

Students must complete one course from the following list.

73-270	Professional Communication for Economists	9
84-250	Writing for Political Science and Policy	9

Electives (27 units)

Majors are required to take 27 units (three courses) from the elective lists below. At least one course (9 units) must be taken from Economics (73-xxx) and at least one course (9 units) must be taken from the Institute for Politics and Strategy (84-xxx). Students may complete electives through coursework in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/ips/cmuwsp) Politics and Public Policy elective sequence.

Economics Electives

73-328	Health Economics	12
73-332	Political Economy	9
73-338	Financial Crises and Risk	9
73-352	Public Economics	9
73-353	Economic Foundations of Regulation: Applications to Financial Markets	9
73-359	Benefit-Cost Analysis	9
73-365	Firms, Market Structures, and Strategy	9
73-367	Technology Jobs and the Future of Work	9
73-372	International Money and Finance	9
73-415	Data Driven Business and Public Policy Decision Making	9
73-421	Emerging Markets	9
73-427	Sustainability, Energy, and Environmental Economcs	9

Politics and Strategy Electives

84-308	Political Economy of Latin America	9
84-309	Political Behavior	9
84-311	International Development: Theory and Praxis	9
84-313	International Organizations and Law	9
84-318	Politics of Developing Nations	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	6
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-363	Comparative Legal Systems	9
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-366	The American Presidency	9
84-369	Decision Science for International Relations	9
84-370	Global Nuclear Politics	9
84-372	Space and National Security	9
84-373	Emerging Technologies and the Law	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6
84-405	The Future of Warfare	9
84-414	International and Subnational Security	9

CMU/WSP Politics and Public Policy Electives

84-330	The Shading of Democracy: The Influence of Race on American Politics	6
84-331	Money, Media, and the Power of Data in Decisionmaking	6
84-332	Effects of US Policy on Businesses: Perspectives of Asian Americans	6
84-333	Power and Levers for Change in Washington, DC	12
84-334	Presidential Power in a Constitutional System	6
84-336	Implementing Public Policy: From Good Idea To Reality	12
84-337	Biomedical Science Research, Policy, and Governance	6
84-340	Making Change: How Organized Interests Work in Washington	12
84-343	Language and Power: How to Understand and Use Political Speech	6
84-346	Legal Issues in Public Administration	6
84-348	Advocacy, Policy and Practice	6

Additional Electives

19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-425	Sustainable Energy for the Developing World	9
70-365	International Trade and International Law	9
70-430	International Management	9
79-280	Coffee and Capitalism	9
79-318	Sustainable Social Change: History and Practice	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-321	Causation, Law, and Social Policy	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
88-366	Behavioral Economics of Poverty and Development	9

88-419	International Negotiation	9
88-444	Public Policy and Regulation	9

CAPSTONE (15-21 units)

Students must complete all of the following courses.

84-450	Policy Forum 12 units if taken during CMU/WSP, 6 units if taken in Pittsburgh	6
73-497	Senior Project or Senior Honors Thesis	9

SAMPLE Four Year Plan

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	73-210 Economics Colloquium I	73-240 Intermediate Macroeconomics
36-200 Reasoning with Data	73-103 Principles of Macroeconomics	73-230 Intermediate Microeconomics	Communication Course (84-250 or 73-270)
73-102 Principles of Microeconomics	84-275 Comparative Politics	73-265 Economics and Data Science	84-265 Political Science Research Methods
84-104 Decision Processes in American Political Institutions	Freshman Seminar	84-310 International Political Economy	73-274 Econometrics I
76-101 Interpretation and Argument	79-104 Global Histories	84-326 Theories of International Relations	Economics & Politics Elective 1
99-101 Computing @ Carnegie Mellon		Open 1	

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
Economics & Politics Elective 2	Open 5	73-497 Senior Project or Senior Honors Thesis	84-450 Policy Forum May also be taken during the CMU/WSP
Economics & Politics Elective 3	Open 6	Open 10	Open 14
Open 2	Open 7	Open 11	Open 15
Open 3	Open 8	Open 12	Open 16
Open 4	Open 9	Open 13	Open 17

Economics and Politics students are highly encouraged to participate in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/ips/cmuwsp) during the junior year. Study abroad is also encouraged.

B.S. in Economics and Statistics

Samantha Nielsen, *Statistics & Data Science Lead Academic Advisor*
Kathleen Conway, *Economics Senior Academic Advisor*
Rebecca Nugent and Edward Kennedy, *Faculty Advisors*
Carol Goldburg, Executive Director, *Undergraduate Economics Program*

Statistics & Data Science Location: Baker Hall 132
statadvising@stat.cmu.edu

Economics Location: Tepper 2400
econprog@andrew.cmu.edu

The B.S. in Economics and Statistics is jointly advised by the Department of Statistics and Data Science and the Undergraduate Economics Program.

The Major in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. With joint curriculum from the Department of Statistics and Data Science and the Undergraduate Economics Program, the major provides students with a solid foundation in the theories and methods of both fields. Students in this major are trained to advance the understanding of economic issues through the analysis, synthesis and reporting of data using the advanced empirical research methods of statistics and econometrics. Graduates are well positioned for admission to competitive graduate programs, including those in statistics, economics and management, as well as for employment in positions requiring strong analytic and conceptual skills - especially those in economics, finance, education, and public policy.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

The requirements for the B.S. in Economics and Statistics are the following:

I. Prerequisites 38-39 units

1. Mathematical Foundations 38-39 units

Calculus

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Note: Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Note: Taking/having credit for both 21-111 and 21-112 is equivalent to 21-120. The Mathematical Foundations total is then 48-49 units. The Economics and Statistics major would then total 201-211 units.

Linear Algebra

One of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	10
21-242	Matrix Theory	10

Note: 21-241 and 21-242 are intended only for students with a very strong mathematical background.

II. Foundations 18-36 units

2. Economics Foundations 18 units

73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9

3. Statistical Foundations 9-18 units

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data	9
36/70-207	Probability and Statistics for Business Applications	9
36-220	Engineering Statistics and Quality Control	9
36-247	Statistics for Lab Sciences	9

Note: Students who enter the program with 36-225 or 36-226 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for the Economics and Statistics Major may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

36-202	Statistics & Data Science Methods **	9
36-208	Regression Analysis	9
36-290	Introduction to Statistical Research Methodology	9
36-309	Experimental Design for Behavioral & Social Sciences	9

* Or extra data analysis course in Statistics

** Must take prior to 36-401 Modern Regression.

Advanced
Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9

36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Sequence 2 (For students beginning later in their college career)

Advanced
Choose *three* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

III. Disciplinary Core 126 units

1. Economics Core 45 units

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-270	Professional Communication for Economists	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9

2. Statistics Core 36 units

36-225	Introduction to Probability Theory *#	9

and *one* of the following two courses:

36-226	Introduction to Statistical Inference *	9
36-326	Mathematical Statistics (Honors) *	9

and *both* of the following two courses:

36-401	Modern Regression *	9
36-402	Advanced Methods for Data Analysis	9

*In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-225 (or equivalents), 36-226 or 36-326 and 36-401.

#It is possible to substitute 36-217, 36-218, or 21-325 for 36-225 36-225 36-22536-225. (36-225 36-225 36-22536-225 is the standard introduction to probability, 36-217 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 21-325 21-32521-325 is a rigorous Probability Theory course offered by the Department of Mathematics.)

3. Computing 9 units

36-350	Statistical Computing *	9

*In rare circumstances, a higher level *Statistical* Computing course, approved by your Statistics advisor, may be used as a substitute.

4. Advanced Electives 36 units

Students must take two advanced Economics elective courses (numbered 73-300 through 73-495, excluding 73-374) and two (or three - depending on previous coursework, see Section 3) advanced Statistics elective courses (numbered 36-303, 36-311, 36-315, 36-46x, 36-490, or 36-497).

Students pursuing a degree in Economics and Statistics also have the option of earning a concentration area (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Total number of units for the major	**191-201 units**
Total number of units for the degree	**360 units**

Professional Development

Students are strongly encouraged to take advantage of professional development opportunities and/or coursework. One option is 73-210 Economics Colloquium I, a fall-only course that provides information about careers in Economics, job search strategies, and research opportunities. The Department of Statistics and Data Science also offers a series of workshops pertaining to resume preparation, graduate school applications, careers in the field, among other topics. Students should also take advantage of the Career and Professional Development Center.

Additional Major in Economics and Statistics

Students who elect Economics and Statistics as a second or third major must fulfill all Economics and Statistics degree requirements. Majors in many other programs would naturally complement an Economics and Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least six courses (three Economics and three Statistics) that do not count for their primary major. If students do not have at least six, they typically take additional advanced data analysis or economics electives, depending on where the double counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Economics and Statistics.

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Economics and Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Economics and Statistics.

Sample Program

The following sample program illustrates one way to satisfy the requirements of the Economics and Statistics Major. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule).

Freshman		**Sophomore**	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	36-202 Statistics & Data Science Methods	36-225 Introduction to Probability Theory	21-240 Matrix Algebra with Applications
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	36-226 Introduction to Statistical Inference
73-102 Principles of Microeconomics	73-103 Principles of Macroeconomics	73-210 Economics Colloquium I *not required	73-240 Intermediate Macroeconomics
73-060 Economics: BaseCamp *not required	-----		73-274 Econometrics I
-----	-----	73-265 Economics and Data Science	-----

Junior		Senior	
Fall	Spring	Fall	Spring
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	Statistics Elective	Economics Elective
36-401 Modern Regression	73-270 Professional Communication for Economists	Economics Elective	Statistics Elective
73-374 Econometrics II	-----	-----	-----
-----	-----	-----	-----
-----		-----	-----

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Prospective PhD students might add 21-127 fall of sophomore year, replace 21-240 with 21-241, add 21-260 in spring of junior year and 21-355 in fall of senior year.

Supplemental Programs

Honors Program in Economics

Outstanding students are eligible for the honors programs in both the Tepper School of Business and the Dietrich College of Humanities and Social Sciences. For more information, consult the Dietrich Honors Program website (http://www.cmu.edu/dietrich/undergraduate/programs/shp).

The Tepper Senior Honors Program in Economics (http://tepper.cmu.edu/prospective-students/undergraduate/economics/curriculum/research/senior-honors-program) provides qualified students with the opportunity to engage in original research during their senior year at Carnegie Mellon. The primary rewards of participating in the Honors Program in Economics are three-fold. First comes the satisfaction of undertaking and completing an original piece of research. Working independently or with a faculty member to identify a research question and claim ownership of its discovery process is a rewarding experience. Second is the opportunity to challenge oneself intellectually. The third advantage is the opportunity to graduate with Tepper Honors. For many, this process of intellectual inquiry and knowledge creation is the highlight and culmination of their undergraduate academic experience.

Students are invited into the Tepper Senior Honors Program in Economics during their junior year. Invitation is based on academic achievement at Carnegie Mellon University, ability to work independently, and tenacity of spirit.

Accelerated Master’s Degree Programs

Accelerated Master’s Degree programs enable exceptional students to earn both an undergraduate degree and a masters degree by remaining one additional year at Carnegie Mellon. The Heinz College of Information Systems and Public Policy offers seven professional accelerated masters degree options for CMU undergraduates: a Master of Science in Arts Management (https://www.heinz.cmu.edu/programs/arts-management-master), Master of Entertainment Industry Management (https://www.heinz.cmu.edu/programs/entertainment-industry-management-master), Master of Science in Health Care Analytics and IT (https://www.heinz.cmu.edu/programs/health-care-analytics-master), Master of Information Systems Management (https://www.heinz.cmu.edu/programs/information-systems-management-master), and Master of Science in Health Care Policy and Management (https://www.heinz.cmu.edu/programs/health-care-policy-management-master), Master of Science in Information Security Policy and Management (https://www.heinz.cmu.edu/programs/information-security-policy-management-master), and Master of Science in Public Policy and Management (https://www.heinz.cmu.edu/programs/public-policy-management-master). The Tepper School of Business offers one accelerated professional degree, a Master in Business Administration.

Dual Degree in Economics

A student pursuing a primary degree outside of the department may obtain a dual degree by completing all of the requirements for the B.S. in Economics or the B.S. in Economics and Statistics along with the Dietrich College general education requirements. In addition, the student’s total units completed must be at least 90 units in excess of the requirement for the student’s other degree(s) or at least 450 units, whichever is greater. Interested students should meet with an economics advisor.

Additional Major in Economics Curriculum

All university students are eligible to pursue an additional major in economics in conjunction with a major in any department in the university other than economics. The requirements for the Additional Major in Economics are the same as those for the B.S. in Economics, except that the Dietrich College General Education requirements are waived. In order to avoid “double counting” issues, students are encouraged to meet with an economics advisor. When courses are shared across degrees, students pursuing an Additional Major in Economics are asked to take additional advanced economics electives.

Additional Major in Economics and Statistics Curriculum

All university students are eligible to pursue a major in economics and statistics in conjunction with a major in any department in the university other than statistics or economics. The requirements for the Additional Major in Economics in Statistics are the same as those for the B.S. in Economics and Statistics, except that the Dietrich College General Education requirements are waived. In order to avoid “double counting” issues, students are encouraged to meet with an economics or statistics advisor. When courses are shared across degrees, students pursuing an Additional Major in Economics and Statistics are asked to take additional advanced economics or statistics electives.

Additional Major in Economics and Politics Curriculum

All university students are eligible to pursue a major in economics and politics in conjunction with a major in any department in the university other than economics or the Institute for Politics and Strategy. The requirements for the Additional Major in Economics in Politics are the same as those for the B.S. in Economics and Politics, except that the Dietrich College General Education requirements are waived. In order to avoid “double counting” issues, students are encouraged to meet with an economics or Institute for Politics and Strategy advisor. When courses are shared across degrees, students pursuing an Additional Major in Economics and Politics are asked to take additional electives.

Minor in Economics

In addition to preparing students to be better informed global citizens and consumers, the Minor in Economics provides students with the economic and data analytical toolkit that is the foundation of business/organizational decision-making.

All university students are eligible to pursue the Minor in Economics in conjunction with a major in any other department in the university. In order to avoid “double counting” issues, students are encouraged to meet with an economics advisor. When courses are shared across degrees, students pursuing a minor in Economics are asked to take additional advanced economics electives.

All economics courses counting towards the minor must be completed with a grade of "C" or higher.

Minor in Economics (Total Number of Units for the Minor: 82)

Mathematics Requirements (10 Units)

		Units
21-120	Differential and Integral Calculus	10

Economic Theory Requirements (27 Units)

		Units
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-160	Foundations of Microeconomics: Applications and Theory *	9

*Students may choose to replace 73-160 with 73-230 Intermediate Microeconomics or 73-240 Intermediate Macroeconomics. Most of the advanced economics electives require 73-230 and/or 73-240. Please note that 21-256 is a pre-requisite for 73-230.

Quantitative Analysis Requirements (18 Units)

The quantitative analysis path is often determined by the major requirements. The sequence is designed to give students an understanding of probability theory, regression analysis, and quantitative economic analysis. Students are encouraged to talk with an economics advisor to determine which requirements best complement their primary fields of study.

Option One		Units
36-200	Reasoning with Data	9
or 36-207	Probability and Statistics for Business Applications	
or 70-207	Probability and Statistics for Business Applications	
73-265	Economics and Data Science	9

Option Two		
36-220	Engineering Statistics and Quality Control	9
73-265	Economics and Data Science	9

Option Three		
36-217	Probability Theory and Random Processes	9
or 36-225	Introduction to Probability Theory	
73-265	Economics and Data Science	9

Advanced Economics Electives (27 Units)

Students must take three advanced elective courses. Advanced elective courses are those numbered 73-3xx through 73-49x. Students are encouraged to work with their economics advisor to structure a set of courses to meet these requirements based on their particular interests, subject to course availability.

Faculty

LAURENCE ALES, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2008–

JAMES A. BEST, Assistant Professor of Economics – Ph.D., University of Edinburgh; Carnegie Mellon, 2018–

AISLINN BOHREN, Associate Professor of Economics – Ph.D., University of California, San Diego; Carnegie Mellon, 2018–

DAVID CHILDERS, Assistant Professor of Economics – Ph.D., Yale University; Carnegie Mellon, 2016–

KAREN B. CLAY, Professor of Economics and Public Policy, H. J. Heinz III College – Ph.D., Stanford University; Carnegie Mellon, 1998–

ROBERT M. DAMMON, Dean; Professor of Financial Economics – Ph.D., University of Wisconsin; Carnegie Mellon, 1984–

TIMOTHY P. DERDENGER, Associate Professor of Marketing and Strategy – Ph.D., University of Southern California; Carnegie Mellon, 2009–

KENNETH B. DUNN, Professor of Financial Economics, Emeritus – Ph.D., Purdue University; Carnegie Mellon, 1979–

DENNIS N. EPPLE, Thomas Lord University Professor of Economics – Ph.D., Princeton University; Carnegie Mellon, 1974–

SELMAN EROL, Assistant Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2016–

CHRISTINA FONG, Senior Research Scientist in Social and Decision Sciences, Dietrich College of Humanities and Social Sciences – Ph.D., University of Massachusetts; Carnegie Mellon, 2001–

JOHN GASPER, Associate Teaching Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2010–

MARTIN GAYNOR, E.J. Barone University Professor of Economics and Health Policy, H. J. Heinz III College – Ph.D., Northwestern University; Carnegie Mellon, 1995–

MARVIN GOODFRIEND, Friends of Allan Meltzer Professorship; Professor of Economics – Ph.D., Brown University; Carnegie Mellon, 2005–

BURTON HOLLIFIELD, Head, B.S. in Business Administration Program; PNC Professor of Finance; Professor of Financial Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1999–

KARAM KANG, Assistant Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2012–

ONUR KESTEN, Associate Professor of Economics – Ph.D., University of Rochester; Carnegie Mellon, 2005–

ALEXEY KUSHNIR, Assistant Professor of Economics – Ph.D., Pennsylvania State University; Carnegie Mellon, 2014–

FINN KYDLAND, The Richard P. Simons Distinguished Professorship; University Professor of Economics; Nobel Laureate (2004) – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1977–

REBECCA LESSEM, Assistant Professor of Economics – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2011–

BENNETT T. MCCALLUM, H. J. Heinz Professor of Economics, Emeritus – Ph.D., Rice University; Carnegie Mellon, 1981–

ROBERT A. MILLER, Richard M. Cyert and Morris DeGroot Professor of Economics and Statistics – Ph.D., University of Chicago; Carnegie Mellon, 1982–

NICHOLAS MULLER, Associate Professor of Economics, Engineering, and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2017–

ANH NGUYEN, Assistant Professor of Economics – Ph.D., Columbia University; Carnegie Mellon, 2018–

JOHN R. O'BRIEN, Associate Dean, Carnegie Mellon University-Qatar; Associate Professor of Accounting and Experimental Economics – Ph.D., University of Minnesota; Carnegie Mellon, 1984–

MARYAM SAEEDI, Assistant Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2016–

ALI SHOURIDEH, Assistant Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2016–

CHRISTOPHER SLEET, Head, Economics Programs; Professor of Economics – Ph.D., Stanford University; Carnegie Mellon, 2005–

FALLAW B. SOWELL, Associate Professor of Economics – Ph.D., Duke University; Carnegie Mellon, 1988–

CHESTER S. SPATT, Pamela R. and Kenneth B. Dunn Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 1979–

STEPHEN E. SPEAR, Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 1982–

V. EMILY STARK, Assistant Teaching Professor of Business Communications – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2013–

CHRISTOPHER I. TELMER, Associate Professor of Financial Economics – Ph.D., Queen’s University (Canada); Carnegie Mellon, 1992–

SHU LIN WEE, Assistant Professor of Economics – Ph.D., University of Maryland; Carnegie Mellon, 2014–

SEVIN YELTEKIN, Senior Associate Dean, Education; Professor of Economics – Ph.D., Stanford University; Carnegie Mellon, 2005–

ARIEL ZETLIN-JONES, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2012–

Visiting Faculty

CHARLES ZHENG, Visiting Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2019–

Adjunct Faculty

CAROL B. GOLDBURG, Executive Director, Undergraduate Economics Program; Adjunct Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

MARGARITA PORTNYKH, Adjunct Professor of Economics – Ph.D., Clemson University; Carnegie Mellon, 2018–

Undergraduate Economics Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

73-060 Economics: BaseCamp
Fall: 3 units
This short course will launch you into the economics intellectual space and get you thinking like an economist. Through a series of presentations by some of CMU's great economics thinkers you will learn how economic reasoning harnessed to data can lead to better policy design and better business decision making. Presentations may cover the economics of bitcoin and crypto-currency, online market design, financial crises, the future of work, how to become involved in economics research, healthcare, the environment, and other topics. The presentations will be curated by one of CMU's research economists and there will be plenty of opportunities for discussion and debate. The course will also introduce you to the CMU approach to economics and map out the CMU economics major landscape.

73-102 Principles of Microeconomics
Fall and Spring: 9 units
A one-semester course that teaches the fundamentals of microeconomics. Students will learn how microeconomic analysis can explain market successes, market failures, and how government intervention might improve outcomes. In addition to an investigation of firm behavior and consumer behavior, attention will be paid to: Game Theory, Behavioral Economics, Economics of Time and Risk, Economics of Information, Experimental Economics, and Auctions and Market Design. Students will also learn how to integrate basic data analysis and statistics. Not open to students who have received credit for 73-100. (Lecture, 2 hours; Recitation, 1 hour).

73-103 Principles of Macroeconomics
All Semesters: 9 units
A one-semester course that teaches the fundamentals of macroeconomics. Students will learn how macroeconomic analysis can explain national economic activity and how government intervention might stabilize an economy. Topics include: defining and measuring national wealth, economic growth, credit markets, unemployment, interest rates, inflation, and the monetary system. Additional emphasis will be paid to: long-term economic development, political economy, financial crises and topics that are central to contemporary macroeconomic debates such as the impact of technological change, migration, and trade on the macroeconomy. Students will access macroeconomic databases, and then use basic statistics to describe and isolate empirical patterns in macro-data. Not open to students who have received credit for 73-100. (Lecture, 2 hours; Recitation, 1 hour).
Prerequisite: 73-102 Min. grade C

73-111 Internship I
All Semesters
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, and Economics and Statistics majors.

73-112 Internship II
All Semesters: 3 units
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, and Economics and Statistics majors.

73-113 Internship III
All Semesters: 3 units
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, and Economics and Statistics majors.

73-160 Foundations of Microeconomics: Applications and Theory
Spring: 9 units
Intermediate level microeconomics stresses individual economic decision making in the context of consumer behavior, and firm behavior, and examines in detail how these behaviors interact in competitive market settings to answer the fundamental economic questions of what gets produced, how it gets produced, and who gets the output. These component theories of economic behavior are the building blocks of higher level economic analysis, as well as the basis for examining empirically-motivated deviations from classical economic predictions. As such, most of the course will be methodological in its focus, although many of the problems in the weekly assignments will involve everyday personal and business applications. The experiments we do will also give students hands-on experience with the phenomena that economic theories try to explain. (Lecture, 3 hours: Recitation: 1 hour). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-102 Min. grade C or 73-100 Min. grade C)

73-210 Economics Colloquium I
Fall: 3 units
Economics majors meet weekly for discussions about current research by faculty or students, presentations on economics from economists outside academia, and expository talks on selected economics topics not part of the usual curricula. The colloquium provides students with opportunities to grow personally and intellectually by introducing them to campus resources (including special interest to undergraduates such as preparation for graduate school) and using the economic toolbox to examine current economic topics in the press. It is recommended that students take this course during the sophomore year so that economics majors realize the range of resources that exist on campus. (Colloquium, 1 hour)

73-230 Intermediate Microeconomics
Fall and Spring: 9 units
This course is a calculus-based study of microeconomics. Topics in partial equilibrium analysis include supply and demand, consumer theory, theory of the firm, profit maximizing behavior, monopoly theory, and perfect competition. The course concludes with an introduction to general equilibrium analysis and the welfare laws. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics pre-requisite courses. Not open to first year student during S18.
Prerequisites: (21-268 or 21-269 or 21-256 or 21-259) and (73-100 Min. grade C or 73-102 Min. grade C)

73-240 Intermediate Macroeconomics
Fall and Spring: 9 units
Through macroeconomic models built upon microeconomic foundations, insights are developed into economic growth processes and business cycles. Topics include aggregation and measurement, national income, business cycle measurement, economic welfare theorems and social inefficiencies, the effect of government fiscal policy upon employment and productivity, and the relationship between investment, interest rates and economic growth. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 and 73-100 Min. grade C) or (21-256 and 73-102 Min. grade C and 73-103 Min. grade C) or (73-100 Min. grade C and 21-259) or (21-259 and 73-103 Min. grade C and 73-102 Min. grade C)

73-255 Independent Study in Economics
Fall and Spring
The Independent Study course in economics allows students to pursue their own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor; the project proposal must be approved by an Undergraduate Economics Program staff member. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and 73-160 Min. grade C

73-258 Developing Blockchain Use Case
Intermittent: 6 units
Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token—-CMU Coin—-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. http://tinyurl.com/cmucoincourse The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended.

73-265 Economics and Data Science
Fall: 9 units
This course is at the intersection of economic analysis, computing and statistics. It develops foundational skills in these areas and provides students with hands-on experience in identifying, analyzing and solving real-world data challenges in economics and business. Students will learn the basics of database and data manipulation, how to visualize, present and interpret data related to economic and business activity by employing statistics and statistical analysis, machine learning, visualization techniques. Students will also be taught a programming language suitable for data science/analysis. Databases will include leading economic indicators; emerging market country indicators; bond and equity returns; exchange rates; stock options; education and income by zip code; sales data; innovation diffusion; experimental and survey data and many others. Applications will include analyzing the effectiveness of different Internet pricing strategies on firm sales, the impact of taking online classes on a worker's earnings, the relationship between regional employment and trade policies; constructing investment risk indices for emerging markets; predicting employee productivity with machine learning tools; assessing health (sleep and exercise) improvements associated with wearable technologies (e.g. FitBit). Additionally, the course will provide students with communication skills to effectively describe their findings for technical and non-technical audiences. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (36-200 Min. grade C or 36-201 Min. grade C) and (73-100 Min. grade C or 73-102 Min. grade C)

73-270 Professional Communication for Economists
Fall and Spring: 9 units
A writing course specifically designed for third-year Economics majors and additional majors. Students gain experience with technical writing techniques and skills needed for both their senior thesis and their eventual professional careers. The course emphasizes both individual and group projects. (Seminar, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 76-101 and (73-230 Min. grade C or 73-240 Min. grade C)

73-274 Econometrics I
Spring: 9 units
This course will provide an introduction to the analysis of economic field data. The first part of the course will discuss how data is generated and how this affects the inferences we can make. In particular, we will look at the difficulties of working with field data and learn how non-random sampling leads to poor inferences. We will then move on to some simple statistical techniques, in particular OLS and its extensions as well as Maximum Likelihood Estimators. We will also learn about the large sample properties of these estimators. At the end of the course, students should be able to understand what inferences can be made with field data and some basic statistical techniques that can be used to uncover patterns in the data. (Lecture, 3 hours; Recitation, 1 hour). Pre-reqs for those entering Fall 2018 and later: (21256 or 21259 or 21268 or 21269) and (73265) and (73230 or 73240). Students pursuing the ECOMTH or MTHECO degrees may enroll in 73-274 after the completion of 36-225. Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-265 Min. grade C and (73-240 Min. grade C or 73-230 Min. grade C)

73-315 Market Design
Spring: 9 units
The market design class is going to cover three main subjects: matching, auctions, and, time allowing, marketplaces. Matching topics may include: Two-Sided Matching and Medical Residents House Allocation and Kidney Exchange School Choice Law Clerks and College Early Admission Auction/ Marketplace topics may include: Designing Optimal Auctions Common Value Auctions Multi-Unit Auctions and Treasury Auctions Multi-Item Auctions and The Assignment Model Sponsored Search Auctions The FCC and Simultaneous Ascending Auctions Package Auctions and Radio Spectrum Introduction to the Economics of Platforms Internet Platforms: e-Commerce Internet Markets: Advertising (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-257 or 21-269 or 21-256 or 21-268) and 73-230 Min. grade C

73-327 Advanced Topics In Macroeconomics And Real Business Cycles
Intermittent: 9 units
For analysts and decision makers in a variety of positions, such as business managers and government policy makers, a thorough understanding of the economy as a whole helps to make well-informed decisions. Examples of important knowledge about the economy are its sources of growth, the main impulses that cause the economy to fluctuate over time and enter into booms and recessions, the way in which these impulses propagate over time, and the state of the economy in general. The main objective of this course is to lay the foundation for such an understanding and present a framework within which we can (and will) evaluate a variety of aggregate phenomena. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-256 or 21-259) and 73-240 Min. grade C

73-328 Health Economics
Fall: 12 units
This course will teach the student to use economic analysis to understand critical issues in health care and and health policy. We will address issues such as the following: 1. What factors best explain the level and rate of growth of U.S. health expenditures? 2. Does the recent high rate of growth of U.S. health care expenditures make U.S. firms less competitive in international markets? 3. What are some of the likely consequences (intended and unintended) of the proposed reforms to Medicare? 4. Can physicians induce demand for their services? 5. What are the impacts of managed care on the health care system? 6. Do strong affiliations between physicians and health plans hurt competition? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Junior standing required.
Prerequisites: 21-120 and (73-230 Min. grade C or 73-160 Min. grade C)

73-332 Political Economy
Spring: 9 units
The Political Economy course looks at how groups within society organize for self-governance. The course will begin with an overview of the ways groups of individuals organize for collective action by examining different types of political institutions, the role these institutions play in different contexts, and the economic and strategic micro-foundations that give rise to these institutions. We will then examine the empirical evidence supporting this taxonomy, leading to a more detailed consideration of institutions that moderate social conflicts. The next part of the course examines basic results in social choice theory: the Condorcet paradox, Arrow's Impossibility Theorem, majority rule, median voter theories, and modern treatments of probabilistic voting models that allow for strategic behavior, misrepresentation of preferences, and policy manipulation. From this basis for understanding collective choice mechanisms, we will then examine how institutions foster cooperation, looking in detail at problems of public goods allocation, redistribution of income, the organization of clubs - interest groups and lobbying associations —in the private sector, and the organization of legislative activities in the public sector. In our examination of voting and electoral mechanisms, we will look at practical applications of the theory to problems of gerrymandering, voter suppression, and propaganda that feature prominently in contemporary political discourse.
Prerequisites: 73-230 Min. grade C and (84-275 Min. grade C or 84-104 Min. grade C)

73-338 Financial Crises and Risk
Fall: 9 units
This course provides an in-depth examination of the causes of financial crises as well as what governments can do to prevent them or at least reduce their cost. The course is designed to provide an understanding of individual attitudes towards risk and individual decision making about savings and investment under uncertainty, and to use this understanding to evaluate the various economic roles played by financial institutions in helping individuals manage risk, especially those roles which may lead to economic instability and crises. In addition, the course may cover bubbles and swindles, especially when these spillover to the broader macroeconomy; the role of information in banking in normal times and in bank runs; crisis resolution techniques; and the extensive history of attempts to improve regulation so as to reduce the frequency and cost of crises. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C and 73-240 Min. grade C

73-341 Within the Firm: Managing through Incentives
Spring: 9 units
We are living in an exciting age of information and knowledge when inspiring employees with a firm becomes increasingly more important Aligning the objectives of workers, managers, and owners by providing them with appropriate incentives becomes an emerging paradigm in the modern business world. In this course we learn how to reason about incentives both between managers and employees, managers and owners, and within a team of co-workers. We cover a broad range of topics including principle-agent problem, moral hazard, asymmetry of information, incentive in teams, collective decision making, and repeated interactions. These theoretical underpinnings will be illustrated with actual business experience and case studies. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-259 or 21-269 or 21-256) and (36-225 or 36-220 or 36-200 or 36-217) and 73-230 Min. grade C

73-347 Game Theory for Economists
Fall: 9 units
An introduction to the theory of non-cooperative games with an emphasis on economic applications. After an initial examination of two-person, zero-sum games, the notion of a Nash equilibrium in an n-person, non-cooperative game is considered. Existence of and refinements to the equilibrium concept are discussed in the context of both normal and extensive form games. Economic applications may include various topics, including Cournot and Bertrand oligopoly models, general competitive exchange equilibrium, and free rider problems. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C

73-348 Behavioral Economics
Spring: 9 units
This course introduces students to behavioral economics which is a subfield of economics that incorporates insights from other social sciences, such as psychology, into economic models and aims to explain the anomalies challenging some of the classical economic models. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-230 Min. grade C

73-352 Public Economics
Fall: 9 units
In this course, students analyze the role of governments in market economies and their impact on the behavior and welfare of citizens. Reasons for government intervention in markets are examined in light of some of the economic challenges faced by modern societies in an increasingly globalized marketplace. Topics include: taxation and expenditure policies, externalities and market failure, social security, public assistance and income redistribution programs. There will also be some coverage of the role of local governments in the economy with respect to such issues as crime, urban development and education. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C

73-353 Economic Foundations of Regulation: Applications to Financial Markets
Spring: 9 units
The financial crisis has focused attention on the role of regulation for our financial system and the broader economy. The course will address the foundations of regulation (?why regulate??) from various perspectives within the context of a market economy, highlighting the sources of "market failure" (such as externalities, adverse selection, and natural monopoly) and potential remedies (such as taxes and fees, disclosure, price regulation, guarantees). The conflicting goals among regulators (and why we have multiple regulators) and their impact on the meaning of regulation will be considered along with regulatory competition/arbitrage. Portions of the course will tackle relatively broad questions such as: Why regulate? What is the law of unintended consequences? What is the objective of a policy advocate? Are regulators and regulatory policies a systemic risk? Are our markets rigged? How can regulators enhance the predictability and credibility of their policies? How costly were government guarantees during the financial crisis? Should we bar insider trading? Should regulations be determined and motivated based upon cost-benefit analysis? How can we evaluate the success or failure of particular regulations and whether they have achieved their objectives? How does the Dodd-Frank Act promote financial stability? What basic aspects of the financial crisis did Dodd-Frank not address? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C

73-359 Benefit-Cost Analysis
Intermittent: 9 units
The evaluation of public private sector projects. The theory of benefit-cost analysis and related techniques, such as cost-effectiveness analysis. Attention is given to such issues as valuing goods and services that are not normally traded in the marketplace (e.g., the value of an individuals life) and the social rate of discount. Applications are considered in detail. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-256 or 21-259 or 21-269) and 73-230 Min. grade C

73-365 Firms, Market Structures, and Strategy
Fall: 9 units
This course is concerned with the economic analysis of industrial markets that are not perfectly competitive. The effects of imperfect competition on firms' decisions (pricing, location, advertising, research and development, among others) are reviewed. Implications of these effects in terms of public policy are also discussed from a variety of perspectives. Finally, applications to actual markets are considered. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-269 or 21-268) and 73-230 Min. grade C

73-366 Designing the Digital Economy
Spring: 9 units
This class analyzes the economics of e-commerce and technology. It will identify the critical features that differentiate the technology firms from traditional industries, and examine the implications for business strategy. The class will discuss topics such as network effects, switching costs, and platform markets. To complement the economic theory, we will also consider a case study of a firm each week. These have three aims: to provide applications for the concepts developed in the lectures; to inform you about different industries; and to help develop your written, rhetorical and presentation skills. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-259 or 21-269 or 21-268 or 21-256) and 73-230 Min. grade C and (70-208 or 73-265 Min. grade C or 73-274 Min. grade C or 73-374 Min. grade C or 73-407 Min. grade C or 36-202 or 36-208 or 36-220 or 36-226)

73-367 Technology Jobs and the Future of Work
Spring: 9 units
The aim of this course to provide students with an in-depth analysis of the US labor market and what role technology has in shaping labor market outcomes. This course will look at the factors influencing wage returns, the outcomes of job-search and also require students to undertake a hands-on analysis of data. Topics of interest are as follows: 1. What affects wage outcomes of workers? 2. What's happening to the labor share and what are the reasons for its decline? 3. What is the role of comparative advantage and how has increasing automation changed the returns to job-search for some individuals? 4. What is job polarization and what are the factors affecting the mobility of workers between occupations and jobs? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-259 or 21-256 or 21-269) and 73-230 Min. grade C and 73-240 Min. grade C

73-372 International Money and Finance
Spring: 9 units
The course introduces students to a micro-founded model of the global monetary system. The model is employed to assess the roles of money, banking, and central banking in the management of inflation, employment, and financial stability. Interest rates, the international exchange rate, the trade balance, and international capital flows are explored in terms of the model. The model is used to address controversial issues in international trade and financial relations, as well as current macroeconomic stabilization problems in China, the Euro area, the United States, and elsewhere. Theoretical points are illustrated with references to historical central bank practices from around the world in recent decades. The course concludes with student briefings on current central bank policies from around the world. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-256 or 21-259) and 73-240 Min. grade C

73-374 Econometrics II
Fall: 9 units
The material covered in this course extends from the material covered in Econometrics I (73-274). The course will include both the theory behind the methods and a hands-on analysis of actual data, providing students the tools for both research and industry jobs. Theories and methodologies covered will include: nonlinear regression models, qualitative response regression models, panel data estimators, simultaneous-equation models, and time series. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-256 or 21-259) and 73-230 Min. grade C and 73-274 Min. grade C

73-395 Independent Study in Economics
Fall and Spring
The Independent Study course in economics allows the student to pursue his or her own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor; the project proposal must be approved by an Undergraduate Economics Program staff member. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-259 or 21-256 or 21-269) and (73-240 Min. grade C or 73-230 Min. grade C)

73-408 Law and Economics
Intermittent: 9 units
This course will provide a broad overview of the scholarly field known as "law and economics." The focus will be on how legal rules and institutions can correct market failures. We will discuss the economic function of contracts and, when contracts fail or are not feasible, the role of legal remedies to resolve disputes. We will also discuss at some length the choice between encouraging private parties to initiate legal actions to correct externalities and governmental actors, such aas regulatory authorities. Extensive attention will be given to the economics of litigation, and to how private incentives to bring lawsuits differ from the social value of litigation. The economic motive to commit crimes, and the optimal governmental response to crime, will be studied in depth. Specific topics within the preceding broad themes include: the Coase Theorem; the tradeoff between the certainty and severity of punishment; the choice between ex ante and ex post sanctions; negligence versus strict liability; property rules; remedies for breach of contract; and the American rule versus the English rule for allocating litigation costs. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-230 Min. grade C or 73-160 Min. grade C)

73-415 Data Driven Business and Public Policy Decision Making
Intermittent: 9 units
In this course students will learn to leverage data to inform business and policy decisions. The course will teach students various methods for data description, including techniques of data visualization and statistical techniques. Students will learn how to assess the precision of estimation techniques. The final part of the course covers examples taken from epidemiology, economics, business and public policy. (Lecture, 3 hours: Recitation: 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-259 or 21-269 or 21-256 or 21-268) and 73-230 Min. grade C and 73-265 Min. grade C

73-421 Emerging Markets
Fall: 9 units
The goal of the course is to study the economic and institutional forces that spur or hinder business activity and growth in emerging economies. The course is designed to provide both quantitative and theoretical foundations for the study of emerging markets. On the quantitative side, the course will introduce students to the empirical analysis of the growth forces and obstacles facing emerging markets by providing numerous hands-on opportunities using real-world data. On the theory side, the course will provide an overview of fiscal, trade and exchange rate policies adopted in emerging economies. The course will focus on successful emerging economies such as India, China, S. Korea and Ireland with broader lessons and comparisons drawn from developed countries. The course will also look at distressed economies, such as North Korea and Venezuela analyzing the challenges and opportunities faced by these developing nations today. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-240 Min. grade C

73-423 Forecasting for Economics and Business
Spring: 9 units
Governments forecast economic indicators (e.g., GDP, job growth, etc.); businesses forecast sales; portfolio managers forecast asset return; the list goes on. Accurate forecasts are critical to robust organizational decision-making. This course will introduce students to modern methods for forecasting in economic and business applications. Topics covered include Bayesian, statistical, and online learning approaches to forecast construction and assessment, univariate and multivariate time series models and algorithms, and principled combination of multiple methods and data sources along with subject matter expertise to improve performance. Methods will be motivated by applications in macroeconomics, technology, marketing, and finance, with cases drawn from forecasting processes in a variety of business and government organizations. Students will implement forecasting methods in R, including in a real data forecasting competition.
Prerequisites: (21-269 or 21-268 or 21-259 or 21-256) and (73-230 Min. grade C or 73-240 Min. grade C or 73-274 Min. grade C)

73-427 Sustainability, Energy, and Environmental Economcs
Fall: 9 units
Topics related to sustainability and the environment are increasingly important to businesses, policymakers, and the general public. This course applies the tools of economic analysis to the problems of environmental protection, natural resource management, and energy production and use. The course will begin by introducing students to how an economist approaches problems of market failure commonly found in environmental contexts. Next, we will explore models that characterize solutions to such environmental issues. We will then address questions regarding measurement, policy design, and, finally, we will apply the tools that we have developed during the semester to the problems of climate change, and the optimal management of non-renewable resources. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-230 Min. grade C

73-469 Global Electronic Markets: Economics and the Internet
Fall: 9 units
The information revolution brought about by the Internet is having a dramatic impact on the organization of economic activity. Long-term contractual relationships that once governed corporate procurement are being dismantled as manufacturers use the Internet to market directly to the public. New transportation networks that used to simply move goods from point A to point B are evolving into dynamic inventory pipelines that allow manufacturers to track and even reroute shipments in real time. At the same time, individuals are making use of sophisticated search engines to comparison shop at a scale that would have been physically exhausting even five years ago. We will use the basic tools of economic analysis to understand how and why the changes in information technology are reshaping the economic landscape. (Lecture, 3 hours). Minimum grade standard of "C" applies only to economics courses.
Prerequisites: (21-259 or 21-256 or 21-269 or 21-268) and (73-160 Min. grade C or 73-230 Min. grade C)

73-476 American Economic History
Fall: 9 units
The study of economic history provides important perspective on current economic institutions and policies. A failure to understand the historical evolution of economic institutions or the variety of past economic experience is perhaps the worst shortcoming of many economists. The study of economic history provides an opportunity to test currently fashionable theories against data different from those used in their construction. In fact, this is a course in applied economics. The theories developed in the intermediate courses will be applied to episodes from the past in ways that increase understanding both of the specific historical episodes considered and the economic theories employed. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-230 Min. grade C or 73-160 Min. grade C)

73-497 Senior Project
Fall: 9 units
A fourth-year project course, open only to Economics primary and additional majors with Senior standing. The senior project is a capstone course in economics. The purpose of the course is to showcase the analytical and quantitative skills that you have acquired as an undergraduate at Carnegie Mellon. The course project should reflect some independent applied research that is genuinely your own work. Thus a "book report" or a "literature review" are not sufficient exercises to satisfy this requirement. The following research approaches are acceptable for the research project: an empirical study based on a data set that you put together, an experimental study based on an experiment that you conducted, an analysis of survey data based on a survey that you conducted, a theoretical analysis based on a model that you have developed, based on your own algorithm. Students who write an honor thesis are exempted from this class. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-269 or 21-256 or 21-259 or 21-268) and (73-374 Min. grade C or 73-407 Min. grade C or 73-265 Min. grade C or 36-226 or 36-303 or 73-274 Min. grade C) and 73-230 Min. grade C and 73-240 Min. grade C

73-500 Tepper College Honors Thesis I
Fall and Spring
Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and (73-265 Min. grade C or 73-274 Min. grade C or 36-226 Min. grade C) and 73-230 Min. grade C and 73-240 Min. grade C

73-501 Tepper College Honors Thesis II
Fall and Spring
Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites include: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses, and a minimum grade of "B" required in Tepper College Honors Thesis I.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-230 Min. grade C and 73-240 Min. grade C and 73-500 Min. grade B and (73-265 Min. grade C or 73-374 Min. grade C)

Department of English

Andreea Ritivoi, Department Head
Location: Baker Hall 259
english.cmu.edu

The Department of English at Carnegie Mellon engages students in the important study of reading and writing as intellectual activities embedded in historical, cultural, professional, technological, and literary practices. Working with experts in their areas, students become effective writers and analysts of various kinds of texts in a range of media, from traditional print documents to film, multimedia, and on-line texts. Faculty use distinctive methods of studying texts, but all share a deep commitment to working in small and intense workshops and seminars to help students learn to become experts in analyzing existing texts, and in producing original and distinctive work of their own.

The English Department offers the following degree programs:

- B.A. in Creative Writing
- B.A. in Film & Visual Media
- B.A. in Literature & Culture
- B.A. in Professional Writing
- B.S. in Technical Writing and Communication.

All five majors are structured to allow students to balance liberal and professional interests. Students in the **Creative Writing program** focus on analyzing and learning to produce poetic and narrative forms. Students in the **Film & Visual Media program** focus on cultural analysis, writing, production, and digital media. Students in the **Literature & Culture program** focus on the production and interpretation of print texts and other media in their social and cultural contexts. Students in the **Professional Writing program** focus on analyzing and producing non-fiction for a variety of professional contexts. Students in the **Technical Writing & Communication program** focus on integrating writing with technical expertise in a chosen area of concentration (*Technical Communication* or *Science & Medical Communication*). In addition to the five majors, we offer six minors departmental minors as well as two interdisciplinary minors, and we strongly encourage non-majors in the campus community to join us in English courses, beginning with offerings at the 200-level.

Students also get involved in a range of complementary activities, including a reading series of distinguished writers of poetry, fiction, and non-fiction; publishing, editing, and marketing through involvement with *The Oakland Review* and The Carnegie Mellon University Press; writing and editorial positions on the student newspaper, *The Tartan*, and other campus publications. We also offer a strong internship program that places student writers in media, non-profit, arts, corporate, and technical internships before they graduate. The end of every year culminates in a gala event to celebrate our students and their writing achievements in literary, academic, and professional writing. For this event, known as the Pauline Adamson Awards, we invite a well-known writer to do a public reading and then present and celebrate student writing awards in over a dozen categories, all judged anonymously by writing professionals from outside the university.

Majoring in English: The Five English Degree Options

The department of English offers students five degree options:

- The B.A. in Creative Writing
- The B.A. in Film & Visual Media
- The B.A. in Literature & Culture
- The B.A. in Professional Writing
- The B.S. in Technical Writing & Communication

Students who wish to broaden their experience with English courses may do so by taking more than the minimum requirements for each major or by combining two of the majors within the department for an additional major in English. Common combinations include, but are not limited to, a B.A. in Professional Writing with an additional major in Creative Writing; a B.A. in Creative Writing with an additional major in Literature & Culture; or a B.A. in Literature & Culture with an additional major in Professional Writing. Due to significant course overlap, students are not permitted to major in both Professional Writing and Technical Writing & Communication together. Consult the English Department and the section on "Completing an Additional Major in English" (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/departmentofenglish/#additionalmajorsminorstext) for further detail.

All of the English majors may be combined with majors and minors from other Carnegie Mellon departments and colleges. The English Department advisor can help you explore the available options and choose a major or combination of programs that is appropriate for your interests and goals.

How the Curriculum is Structured

In addition to Dietrich College requirements, English majors complete 11 to 13 courses (99 to 117 units) specifically related to their chosen major within English and structured as indicated below. Please note that courses between majors/minors in the Department of English may not double count, with the exception of the Film & Visual Media major, due to its courses being pulled from multiple programs within English. A maximum of two courses may double count between Film & Visual Media and programs inside the Department of English. A maximum of two courses may double count for programs outside of the Department of English.

Core Requirements for the Specific Major (7 to 10 courses, 63 to 84 units)

Complete seven to ten courses.

The Core Requirements differ for each major and are designed explicitly to provide both breadth and depth within the specific major the student has chosen.

English Electives (3 to 4 courses, 27 to 36 units)

Complete three to four elective courses.

Elective Courses for the majors are designed to add breadth to each student's study within English and to provide experience with the range of approaches to reading and writing available within the department. Students in all English majors are encouraged to sample widely from the Department's offerings.

The B.A. in Creative Writing

Carnegie Mellon is one of a small number of English departments in the country where undergraduates can major in Creative Writing (CW). In the CW major, students develop their talents in writing fiction, poetry, screenwriting, and creative nonfiction. While studying with faculty members who are writers, CW majors read widely in literature, explore the resources of their imaginations, sharpen their critical and verbal skills, and develop a professional attitude toward their writing. The extracurricular writing activities and a variety of writing internships available on and off campus provide Creative Writing majors with valuable experiences for planning their future. After graduation, many Creative Writing majors go on to graduate writing programs and to careers in teaching, publishing, public relations, advertising, TV and film, or freelance writing and editing.

Students in the CW major are required to take two of the introductory Survey of Forms courses, ideally in their sophomore year. Choices include:76-260 Survey of Forms: Fiction, 76-261 Survey of Forms: Creative Nonfiction, 76-262 Survey of Forms: Nonfiction, 76-265 Survey of Forms: Poetry, and 76-269 Survey of Forms: Screenwriting. In order to proceed into the upper-level courses, students must do well in these introductory courses (receive a grade of A or B). In their junior and senior years, Creative Writing majors take four workshops in fiction, poetry, screenwriting, or nonfiction where the students' work is critiqued and evaluated by peers and the faculty.

Opportunities

During their senior year, students may write a Senior Project or Honors Thesis (if they qualify for Dietrich College honors) under the supervision of a faculty member.

Carnegie Mellon also offers CW majors various extracurricular opportunities for professional development, including internships both on- and off-campus. For example, they may work as interns with the Carnegie Mellon University Press, which is housed in the English Department. The Press publishes scholarly works, as well as books of poetry and short stories by both new and established American writers.

Students may help edit and submit their work for publication to *The Oakland Review*, a Carnegie Mellon University-sponsored annual journal.

Students also have opportunities to read their works in a series of readings by student writers held in the Gladys Schmitt Creative Writing Center and to hear nationally known authors as part of the Carnegie Mellon Visiting Writers series. Additionally, the English Department offers prizes for students each year in the writing of fiction, non-fiction, poetry and screenwriting.

Curriculum

In addition to satisfying all of the Dietrich College degree requirements for B.A. candidates, Creative Writing majors must complete 11 courses in the following areas:

Creative Writing Core (7 courses, 63 units)

Survey of Forms Courses (2 courses, 18 units):

		Units
76-260	Survey of Forms: Fiction *	9
76-261	Survey of Forms: Creative Nonfiction *	9
76-262	Survey of Forms: Nonfiction	9
76-265	Survey of Forms: Poetry *	9
76-269	Survey of Forms: Screenwriting *	9

* A student must receive a grade of A or B in the Survey of Forms class in a specific genre in order to be eligible to enroll in a workshop of that genre. A student who receives a grade of C in a Survey of Forms course may enroll in a related workshop only with the permission of the workshop professor. A student who receives a D or R in Survey of Forms may not take a workshop in that genre.

Reading in Forms (1 course, 9 units):

		Units
76-363	Reading in Forms: Poetry: Intro to Literary Translation	9
76-364	Reading in Forms: Fiction	9

Four Creative Writing Workshops (4 courses, 36 units)

Complete four Creative Writing workshops, at least two in a single genre. Workshops in all genres may be taken more than once for credit, except for Literary Journalism and Magazine Writing.

		Units
76-360	Literary Journalism Workshop	9
76-365	Beginning Poetry Workshop	9
76-366	Essay Writing Workshop	9
76-375	Magazine Writing	9
76-460	Beginning Fiction Workshop	9
76-462	Advanced Fiction Workshop	9
76-465	Advanced Poetry Workshop	9
76-464	Creative Nonfiction Workshop: Magazines and Journals	9
76-469	Screenwriting Workshop: Screenwriting/ Television Writing	9

English Electives (4 courses, 36 units)

Complete four additional courses from the English Department's offerings. Two of the four English Electives must be courses that are designated as fulfilling the literature requirement and focus on close reading of literary texts. Please consult the list of courses published each semester by the Department for current offerings. English Electives may include any course offered by the Department, with the exception of 76-222 Creative Writing Matters. Additionally, English Electives can include no more than one course at the 200 level. The remaining English Electives must be at the 300 or 400 level. In choosing Electives, students are encouraged to sample courses from across the Department.

Transfer Courses

Students may transfer up to two courses from other programs toward the major in Creative Writing or the BHA in Creative Writing. Students may transfer one course from another program toward the minor in Creative Writing.

Creative Writing B.A. Sample Curriculum

This plan is presented as a two-year (junior-senior) plan for completing major requirements. Its purpose is to show that this program can be completed in as few as two years, not that it should or must be. In fact, as a department, we recommend beginning the major in the sophomore year if possible. Students in Dietrich College may declare a major as early as mid-semester of the spring of their first year and begin major requirements the following fall.

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
76-26x Survey of Forms	76-26x Survey of Forms	76-3xx/4xx Creative Writing Workshop	76-3xx/4xx Creative Writing Workshop
76-36x Reading in Forms	76-3xx/4xx Creative Writing Workshop	76-3xx/4xx Creative Writing Workshop	76-3xx/4xx English Elective
76-2xx/3xx/4xx English Elective	76-3xx/4xx English Elective	76-3xx/4xx English Elective	Free Elective
Free Elective	Free Elective	Free Elective	Free Elective
Free Elective	Free Elective	Free Elective	Free Elective

The B.A. in Film & Visual Media

The Film & Visual Media major trains students through a combination of coursework in:

- visual media,
- film history and analysis,
- screenwriting,
- and production of film and other visual media.

The major offers a comprehensive education in film and visual media, from theoretical framing and historical-cultural contextualization to training skills in both creating and analyzing film, and developing a complex blend of creative, professional, and technical competencies.

CMU's Department of English is an ideal home for the Film & Visual Media major due to the department's combination of creative writers, film and media studies scholars, film makers, digital humanities and visual communication researchers.

Curriculum

In additional to satisfying all of the Dietrich College degree requirements for B.A. candidates, Film & Visual Media majors must complete 12 courses in the following areas:

Required introductory courses (2 courses, 18 units)

Course		Units
76-239	Introduction to Film Studies	9
76-259	Introduction to Film History	9

Production Courses (2 courses, 18-21 units)

Required Course		Units
76-292	Film Production *	9

* * Students who have completed 76-239 Introduction to Film Studies and/or 76-269 Survey of Forms: Screenwriting will be given registration preference.

Additional Production Course (options include but are not limited to:)		Units
54-487	Dramaturgy: Production II	12
54-401	Through the Lens : Storytelling with the Camera	9
60-415	Advanced ETB: Animation Studio	10
60-416	Advanced ETB: Documentary Storytelling	10
76-374	IDeATe - Dietrich College Cuban Interactive Documentary Project	9
76-481	Introduction to Multimedia Design	12

Screenwriting Courses (2 courses, 18 units)

Required Courses		Units
76-269	Survey of Forms: Screenwriting	9
76-469	Screenwriting Workshop: Screenwriting/ Television Writing	9

Digital Media Courses (2 courses, 18-20 units)

Options include but are not limited to:		Units
15-104	Introduction to Computing for Creative Practice	10
60-141	Black and White Photography I	10
60-142	Digital Photography I	10
60-241	Black and White Photography II	10
60-242	Digital Photography II	10
60-245	Portrait Photography	10
60-353	Critical Studies: Media Performance - History, Theory, and Contemporary Practice	9
60-376	Large Format Photography: The Antiquarian Avant-Garde	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
76-314	Data Stories	9
76-388	Coding for Humanists	9
76-419	Media in a Digital Age	9
76-429	Digital Humanities: Politics and Early Modern Drama	9
76-472	Topics in Journalism: Storytelling in a Digital Age	9

Literature & Cultural Studies Courses (2 courses, 18 units)

Course options include but are not limited to the following:

Course		Units
76-203	Pirates and Prostitutes in the 18th Century	9
76-205	Jane Austen	9
76-210	Banned Books	9
76-221	Books You Should Have Read by Now: 16th & 17th C. Pop Culture	9
76-232	Introduction to Black Literature	9
76-245	Shakespeare: Tragedies and Histories	9
76-247	Shakespeare: Comedies and Romances	9
76-281	Modern American Drama	9
76-310	Advanced Studies in Film and Media	9
76-313	19th Century British: Victorian Sensations	9
76-314	Data Stories	9
76-321	History of the British Novel	9
76-323	God: A Literary and Cultural History	9
76-329	Unruly Women in Early Modern Drama	9
76-333	Race and Controversy in the Arts	9
76-334	Literature of Wall Street	9
76-337	Representations of Islam in Early Modern England	9
76-353	Transnational Feminisms: Fiction and Film	9
76-361	Corpus Rhetorical Analysis	9
76-377	Shakespeare and Film	9
76-381	Mad-Men, Television, and the History of Advertising	9
76-410	The Long Eighteenth Century	Var.
76-412	Performance and 18th Century Theatrical Culture	9
76-414	Politics, Media, and Romantic Literature 1789-1830	9
76-419	Media in a Digital Age	9
76-429	Digital Humanities: Politics and Early Modern Drama	9
76-435	Politics and Popular Culture	9
76-439	Seminar in Film and Media Studies: Class, Race, & Gender in Film	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
76-443	Shakespeare and Theory	9
76-444	History of Books and Reading	9
76-448	Shakespeare on Film	9

Topics in Film & Visual Media Studies Courses (2 courses, 18 units)

Course		Units
76-312	Crime and Justice in American Film	9
76-338	The American Cinema	9
76-339	Topics in Film and Media: Hollywood vs. the World Can be taken more than once.	9
76-353	Transnational Feminisms: Fiction and Film	9
76-367	Fact Into Film: Translating History into Cinema	9
76-377	Shakespeare and Film	9
76-438	The Wire: Crime, Realism, and Long-Form TV	9
76-439	Seminar in Film and Media Studies: Class, Race, & Gender in Film	9
76-448	Shakespeare on Film	9
76-449	Race and Media	9
79-214	Paris in Revolt: History, Literature, Film	6
79-225	West African History in Film	9
79-306	Fact into Film: Translating History into Cinema	9
79-308	Crime and Justice in American Film	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-326	German History through Film	9
79-339	Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)	6
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6
79-341	The Cold War in Documents and Film	9
82-215	Arab Culture Through Film & Literature	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-296	A Century of Russian Film	9
82-355	Tpcs in Hispanic Std: Beyond the Film Screen: The Hispanic World Through Film	9

Transfer Courses

Students may transfer up to two courses from other programs toward the major in Film & Visual Media Studies.

B.A. in Film & Visual Media Sample Curriculum

Please note that this sample curriculum is only a guide and that, in close consultation with the Department of English academic advisor, students may adjust their course plan.

Freshman	Sophomore	
Spring	**Fall**	**Spring**
76-269 Survey of Forms: Screenwriting	76-239 Introduction to Film Studies	76-259 Introduction to Film History
		Digital Media Course

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
76-292 Film Production	Production Course	Literature & Cultural Studies Course	Topics in Film & Visual Media Studies Course
Digital Media Course	76-469 Screenwriting Workshop: Screenwriting/Television Writing	Topics in Film & Visual Media Studies Course	Literature & Cultural Studies Course

The B.A. in Literature & Culture

The Literature & Culture Major teaches students how to read, interpret and write persuasively about novels, poems, plays and other imaginative works across a variety of genres and media forms. Along with teaching students the analytical skills and methodological tools to interpret these works, this major teaches the importance of understanding imaginative works within their cultural and historical contexts. In addition, the major is designed to train students in strong professional and academic skills like critical thinking, inductive reasoning and persuasive argumentation that are applicable to other fields of study and a variety of career paths.

Curriculum

In additional to satisfying all of the Dietrich College degree requirements for B.A. candidates, Literature & Culture majors must complete 13 courses in the following areas:

Requirements

13 courses, 117.0 units total

Required Introductory Courses (3 courses, 27 units)

Course		Units
76-26x	Survey of Forms (Fiction, Creative Nonfiction, Poetry, or Screenwriting)	9
76-245	Shakespeare: Tragedies and Histories	9
or 76-247	Shakespeare: Comedies and Romances	
76-275	Critical Writing Workshop	9

200-Level Literature & Culture Courses (2 courses, 18 units)

Course options include but are not limited to the following:

Course		Units
76-203	Pirates and Prostitutes in the 18th Century	9
76-205	Jane Austen	9
76-210	Banned Books	9
76-217	Contempory American Literary & Cultural Studies	9
76-218	Special Topics in Literature: Medieval Romance & Arthurian Legends	9
76-221	Books You Should Have Read by Now: 16th & 17th C. Pop Culture	9
76-232	Introduction to Black Literature	9
76-238	What Was the Hip-Hop Generation?	9
76-245	Shakespeare: Tragedies and Histories	9
76-247	Shakespeare: Comedies and Romances	9
76-281	Modern American Drama	9

300-Level Literature & Culture Courses (2 Courses, 18 units)

Course options include but are not limited to the following:

Course		Units
76-310	Advanced Studies in Film and Media	9
76-313	19th Century British: Victorian Sensations	9
76-314	Data Stories	9
76-321	History of the British Novel	9
76-323	God: A Literary and Cultural History	9
76-329	Unruly Women in Early Modern Drama	9
76-333	Race and Controversy in the Arts	9
76-334	Literature of Wall Street	9
76-337	Representations of Islam in Early Modern England	9
76-341	Gender and Sexuality in Performance	9
76-343	Rise of the American Novel	9
76-344	Censored Texts	9
76-353	Transnational Feminisms: Fiction and Film	9
76-361	Corpus Rhetorical Analysis	9
76-367	Fact Into Film: Translating History into Cinema	9
76-377	Shakespeare and Film	9
76-381	Mad-Men, Television, and the History of Advertising	9

Theory Course (1 course, 9 units)

Course options include but are not limited to the following:

Course		Units
76-350	Theory from Classics to Contemporary	9

Rhetoric Course (1 course, 9 units)

Course options include but are not limited to the following:

Course		Units
76-319	Environmental Rhetoric	9
76-328	Visual Verbal Communication	9
76-355	Leadership, Dialogue, and Change	9
76-359	User Experience Methods for Documents	9
76-384	Race, Nation, and the Enemy	9
76-386	Language & Culture	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-396	Non-Profit Message Creation	9
76-415	Mediated Power and Propaganda	9
76-419	Media in a Digital Age	9
76-457	Rhetorical Invention	9
76-486	Argument Theory	9
76-492	Rhetoric of Public Policy	9

400-Level Capstone Seminar Course (1 course, 9 units)

Course options include but are not limited to the following:

Course		Units
76-410	The Long Eighteenth Century	Var.
76-412	Performance and 18th Century Theatrical Culture	9
76-414	Politics, Media, and Romantic Literature 1789-1830	9
76-419	Media in a Digital Age	9
76-429	Digital Humanities: Politics and Early Modern Drama	9
76-435	Politics and Popular Culture	9
76-439	Seminar in Film and Media Studies: Class, Race, & Gender in Film	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
76-443	Shakespeare and Theory	9
76-444	History of Books and Reading	9
76-448	Shakespeare on Film	9

English Elective Courses (3 courses, 27 units)

Courses for the English Elective requirement can be fulfilled by choosing any of our 200- to 400-level courses. Students are encouraged to sample courses across our programs.

B.A. in Literature & Culture Sample Curriculum

We recommend students begin the major in the sophomore year if possible. Students in Dietrich College may declare a major as early as mid-semester of the spring of their first year and begin major requirements the following fall.

Sophomore		Junior	
Fall	**Spring**	**Fall**	**Spring**
76-275 Critical Writing Workshop	76-24x Shakespeare	76-2xx Literature & Culture course	76-2xx Literature & Culture course
76-26x Survey of Forms		76-3xx Literature & Culture course	76-3xx Literature & Culture course
		English Elective	Rhetoric course
			English Elective

Senior	
Fall	**Spring**
Theory course	76-4xx Capstone Seminar
English Elective	

The B.A. in Professional Writing

Professional Writing (PW) combines a professional education with a strong foundation in rhetorical studies. The major prepares students for successful careers as writers and communications specialists in a range of fields, including but not limited to: editing and publishing, government, law, journalism, the non-profit sector, education, public and media relations, corporate communications, advocacy writing, and the arts.

The PW major includes 13 courses: 10 PW Core Requirements + 3 English Electives. The 10 Core Requirements include foundations courses in genre studies, editing, and argument, a professional seminar, plus a cluster of advanced rhetoric and specialized writing courses, all designed to closely integrate analysis and production. Through special topics courses — journalism, web design, advocacy writing, document design for print, science writing, public relations and corporate communications, writing for multimedia — students can pursue specializations while working with faculty who are both experts and practicing professionals in these fields. The 3-unit professional seminar, 76-300 Professional Seminar, which meets weekly during the fall term, provides majors with the opportunity to meet and network with practicing professionals in a range of communications fields. PW majors also gain experience in working on team- and client-based projects and receive focused support to develop a portfolio of polished writing samples to use in applying for internships and employment. Through English Electives in Rhetoric, Creative Writing, and Literary and Cultural Studies, students gain additional practice in the careful reading, writing, and analysis of both literary and non-fictional texts and important insights into how texts function in their historical and contemporary contexts. As a capstone experience, senior PW majors have the opportunity to complete a Senior Project or, upon invitation from the college, a Senior Honors Thesis in Rhetoric or Professional Writing. PW students can also apply for research grants through the Undergraduate Research Office to work on independent research projects with faculty.

While the major appeals to students with strong professional interests, both core and elective requirements develop the broad intellectual background one expects from a university education and prepare students to either enter the workplace or pursue graduate study in fields as diverse as communications, law, business, and education. PW majors also have the opportunity to apply for the Department's accelerated MA in Professional Writing, the MAPW 4+1, which allows them to complete the degree in 2 semesters instead of the usual 3. Because the major in Professional Writing is deliberately structured as a flexible degree that allows a broad range of options, PW majors should consult closely with their English Department advisors on choosing both elective and required courses and in planning for internships and summer employment.Various opportunities for writers to gain professional experience and accumulate material for their writing portfolios are available through campus publications, department-sponsored internships for academic credit, and writing-related employment on and off campus.

PW majors also have the option of taking writing internships for academic credit during their junior or senior year and are also strongly encouraged to seek professional internships throughout their undergraduate years and during their summers. Opportunities in public and media relations, newspaper and magazine writing, healthcare communication, publishing, technical writing, public service organizations, and writing for the web and new media illustrate both internship possibilities and the kinds of employment that Professional Writing majors have taken after graduation.

Curriculum

In addition to satisfying all of the Dietrich College degree requirements for B.A. candidates, Professional Writing majors must fulfill 13 requirements in the following areas:

Professional Writing Core (10 courses, 84 units)

Complete ten courses.

Departmental core requirement (1 courses, 9 units):

76-26x	Survey of Forms (Nonfiction, Fiction, Poetry, or Screenwriting)	9

professional writing core requirements (4 courses, 30 units):

76-271	Introduction to Professional and Technical Writing	9
76-300	Professional Seminar	3
76-373	Argument	9
76-390	Style	9

Rhetoric/language studies Requirement (1 course, 9 units):

Complete one course from a set of varied offerings in Rhetoric/Language Studies as designated each term by the English Department. These courses focus explicitly on language and discourse as objects of study and emphasize the relationships of language, text structure, and meaning within specific contexts. Courses include but are not limited to the following:

Course		Units
76-301	Internship	Var.
76-359	User Experience Methods for Documents	9
76-360	Literary Journalism Workshop	9
76-384	Race, Nation, and the Enemy	9
76-386	Language & Culture	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-395	Science Writing	9
76-396	Non-Profit Message Creation	9
76-415	Mediated Power and Propaganda	9
76-419	Media in a Digital Age	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-494	Healthcare Communications	9

Advanced Writing/Rhetoric Courses (4 courses, 36-42 units):

Complete four courses from a set of varied offerings in Advanced Writing/Rhetoric as designated each term by the English Department. Options include all courses that fulfill the Rhetoric requirement, plus additional courses in specialized areas of professional writing. Students should select courses in consultation with their English Department advisor or the Director of Professional and Writing. Courses include but are not limited to the following:

		Units
76-301	Internship	Var.
76-302	Global Communication Center Practicum	6
76-359	User Experience Methods for Documents	9
76-360	Literary Journalism Workshop	9
76-372	News Writing	9
76-375	Magazine Writing	9
76-378	Literacy: Educational Theory and Community Practice	9
76-386	Language & Culture	9
76-389	Rhetorical Grammar	9
76-391	Document & Information Design	12
76-395	Science Writing	9
76-396	Non-Profit Message Creation	9
76-415	Mediated Power and Propaganda	9
76-419	Media in a Digital Age	9
76-425	Science in the Public Sphere	9
76-472	Topics in Journalism: Storytelling in a Digital Age	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-487	Web Design	12
76-491	Rhetorical Analysis	9
76-494	Healthcare Communications	9

English Electives (3 Courses, 27 Units)

Complete three courses from any of English Department’s offerings (exceptions include 76-270, which is designed for non-majors). One may be at the 200-level or above; the remaining two must be at the 300- or 400-level. Two must be courses designated as Text/Context Electives, which focus on the relationship between texts and their cultural and historical contexts.

Professional Writing B.A. Sample Curriculum

This plan is presented as a two-year (junior-senior) plan for completing major requirements. Its purpose is to show that this program can be completed in as few as two years, not that it should or must be. In fact, as a department, we recommend beginning the major in the sophomore year if possible. Students in Dietrich College may declare a major as early as mid-semester of the spring of their first year and begin major requirements the following fall.

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
76-271 Introduction to Professional and Technical Writing	76-26x Survey of Forms	76-3xx/4xx Advanced Writing/Rhetoric Course	76-3xx/4xx Advanced Writing/Rhetoric Course
76-300 Professional Seminar	76-373 Argument	76-3xx/4xx Advanced Writing/Rhetoric Course	76-3xx/4xx Advanced Writing/Rhetoric Course
76-390 Style	76-3xx/4xx Rhetoric Course	76-3xx/4xx English Elective	76-3xx/4xx English Elective
76-2xx/3xx/4xx English Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

The B.S. in Technical Writing & Communication

The B.S. in Technical Writing & Communication (TWC) is one of the oldest undergraduate technical communication degrees in the country with a history that stretches back to 1958. The degree is specifically designed to prepare students for successful careers involving scientific, technical, and computer-related communication, including writing and designing for digital media.

Today’s technical communicators have the strong backgrounds in technology, communication, and design needed to enter a broad range of information-based fields, and do work that both includes and goes well beyond writing documents for print distribution. The expanding range of options includes positions that involve organizing, managing, communicating, and facilitating the use of both technical and non-technical information in a range of fields and media.

Technical communicators develop and design web sites, explain science and technology to the public, develop print and multimedia materials, develop information management systems, design and deliver corporate training, and develop support systems for consumer products ranging from software for word processing or personal finances to complex data management systems.

The B.S. in TWC recognizes the important changes taking place in communication-based careers and includes two distinctive “tracks,” one in Technical Communication (TC) and one in Scientific and Medical Communication (SMC). Both tracks begin with a common core of foundation courses in print and on-line communication as well as a shared set of prerequisites in math, statistics, and computer programming. The two tracks differ in the set of theory/specialization courses beyond the core, with each track including a specialized set appropriate to its focus.

In both tracks, TWC students work on real projects for actual clients, learn group interaction and management skills, and develop a flexible repertoire of skills and strategies to keep up with advances in software and technology. Above all, they focus on developing structures and information strategies to solve a broad range of communication and information design problems.

TWC students are able to draw on exceptional resources on and off campus to enhance their education. Most obvious are the course offerings of Carnegie Institute of Technology, the Mellon College of Science, and the School of Computer Science. Additional course offerings in business, organizational behavior, policy and management, psychology, history, and design are also encouraged. As a capstone experience, Seniors have the opportunity to complete a Senior Project or, upon invitation from the college, a Senior Honors Thesis. TWC students can also apply for grants and fellowship through the Undergraduate Research Office to work on independent research projects with faculty.

While the major appeals to students with strong professional interests, both core and elective requirements develop the broad intellectual background one expects from a university education and prepare students to either enter the workplace upon graduation or pursue graduate study in fields as diverse as communications, business, instructional design, information design, education, and science and healthcare writing.

Various opportunities for writers to gain professional experience are available through campus publications, department-sponsored internships for academic credit, and writing-related employment on and off campus. TWC students have the option of doing internships for academic credit during their junior or senior year and are encouraged to pursue a series of internships throughout their 4 years and during their summers.

All TWC students are required to enroll in the English Department’s 3-unit course, Professional Seminar (76-300), which meets once a week during the fall term and provides majors with the opportunity to meet and network with practicing professionals in a range of communications fields.

The Technical Communication (TC) Track

The Technical Communication track (TC) prepares students for careers in the rapidly changing areas of software and digital media. Students learn the fundamentals of visual, verbal, and on-line communication as well as the technical skills needed to design, communicate, and evaluate complex communication systems and to manage the interdisciplinary teams needed to develop them. Students become fluent in both print-based and electronic media across a variety of information genres and learn to design information for a range of specialist and non-expert audiences. The TWC/TC major can be pursued as a primary major within Dietrich College or as an additional major for students in other Colleges with an interest in combining their specialized subject matter knowledge with strong writing and communications skills. Graduates of this track are likely to follow in the footsteps of previous TWC students from Carnegie Mellon who are currently employed as web designers, information specialists, technical writers, and information consultants in a range of technology and communication-based organizations including Salesforce, IBM, Oracle, Microsoft, Apple, and HP Vertica.

The Scientific and Medical Communication (SMC) Track

The Scientific and Medical Communication track (SMC) is designed for students who seek careers that focus on communication and information design problems in health, science, and medicine. It should appeal to students with interests in the health care professions, science and public policy, patient education, scientific journalism and related fields. Like the TC track, the SMC track is designed to provide both the technical and the communication skills needed to analyze and solve complex communication problems. Students learn the fundamentals of visual, verbal, and on-line communication as well as the technical skills needed to design, communicate, and evaluate complex information systems and to manage the interdisciplinary teams needed to develop them. Students become fluent in both print-based and electronic media across a variety of information genres and learn to design information for a range of specialist and non-expert audiences The TWC/SMC major can be pursued as a primary major within Dietrich College or as a secondary major for students in other Colleges, such as MCS, with an interest in science or medicine.

Curriculum

All Technical Writing & Communication majors must satisfy the Dietrich College requirements for the B.S. degree, and a set of 3 to 4 prerequisite courses in calculus, statistics, and computer science. All prerequisites should be completed by the beginning of the fall semester, junior year. Prerequisites may double count toward Dietrich College Requirements or requirements for other majors or minors.

Mathematics Prerequisite (1 course, 10 units):

Complete one of the following:		Units
21-111	Differential Calculus	10
21-112	Integral Calculus	10
21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	10

Statistics Prerequisite (1 course, 9 units):

36-201	Statistical Reasoning and Practice	9

Computer Science Prerequisites (1 - 2 courses*, 10 - 22 units):

Students in the Technical Communication track must complete two required Computer Science courses:		Units
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12

Students in the Scientific and Medical Communication track complete one required Computer Science course:		Units
15-110	Principles of Computing	10

15-110 Principles of Computing is designed for students with little or no prior programming experience and is appropriate for students in both the SMC and TC tracks. 15-112 Fundamentals of Programming and Computer Science prepares students in the TC track for all other advanced Computer Science courses.

Beyond these prerequisites, students in both TC and SMC tracks take a common set of 5 TWC Core Requirements in writing, communication, and information design. To complement these foundations courses, TWC students take a set of 3 Theory/Specialization courses specific to either TC or SMC. In addition, students in the SMC track take a series of 3 courses in the natural sciences or engineering relevant to their areas of interest, while TC students take 3 electives in management, technology, and social issues.

DEPARTMENTAL CORE REQUIREMENT (1 COURSE, 9 UNITS):

76-26x	Survey of Forms (Nonfiction, Fiction, Poetry, or Screenwriting)	9

TWC Core Requirements (5 courses, 45 units):

76-271	Introduction to Professional and Technical Writing	9
76-300	Professional Seminar	3
76-390	Style	9
76-391	Document & Information Design *	12
76-487	Web Design **	12

* prerequisite = 76-271 Introduction to Professional and Technical Writing
**prerequisite = 76-271 Introduction to Professional and Technical Writing + 76-391 Document & Information Design

Theory/Specialization Courses (3 courses, 27 units):

Complete 3 courses to deepen your area of speciality and complement your chosen track (TC or SMC) in the major. One must be chosen from among courses designated as Recommended Options for TWC majors. Theory/ Specialization courses, including those marked as Recommended Options, are advertised by the English Department on a semester-by-semester basis. TWC students should select courses in consultation with their faculty advisor.

Recommended courses include but are not limited to the following:		Units
76-319	Environmental Rhetoric	9
76-359	User Experience Methods for Documents	9
76-361	Corpus Rhetorical Analysis	9
76-388	Coding for Humanists	9
76-395	Science Writing	9
76-419	Media in a Digital Age	9
76-425	Science in the Public Sphere	9
76-428	Visual Verbal Communication	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design *	12
76-491	Rhetorical Analysis	9
76-494	Healthcare Communications	9

Additional Options include but are not limited to the following:		Units
76-301	Internship	Var.
76-302	Global Communication Center Practicum	6
76-318	Communicating in the Global Marketplace	9
76-319	Environmental Rhetoric	9
76-325	Intertextuality	9
76-340	American English	9
76-351	Rhetorical Invention	9
76-355	Leadership, Dialogue, and Change	9
76-359	User Experience Methods for Documents	9
76-360	Literary Journalism Workshop	9
76-361	Corpus Rhetorical Analysis	9
76-372	News Writing	9
76-375	Magazine Writing	9
76-378	Literacy: Educational Theory and Community Practice	9
76-386	Language & Culture	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-391	Document & Information Design	12
76-395	Science Writing	9
76-396	Non-Profit Message Creation	9
76-419	Media in a Digital Age	9
76-420	The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process	9
76-425	Science in the Public Sphere	9
76-428	Visual Verbal Communication	9
76-472	Topics in Journalism: Storytelling in a Digital Age	9
76-474	Software Documentation	9
76-475	Law, Performance, and Identity	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-484	Discourse Analysis	9
76-487	Web Design	12
76-491	Rhetorical Analysis	9
39-605	Engineering Design Projects	12

Electives (3 courses, 27 units):

TWC majors take 3 courses outside of English to deepen their area of specialty in their track. Typcially, students in the Technical Communication (TC) track select courses that focus on management, technology, and social issues. Students in the Science and Medical Communication (SMC) track select courses in the natural sciences, engineering, statistics or (for example) healthcare-related courses in the Heinz School. Students should work with their academic advisor and the Program Director to select courses that are meaningful for their track. Courses in this category may double count with a major or minor in another department.

TWC Sample Curriculum

We strongly recommend beginning the major in the fall of the sophomore year if possible. This sample curriculum is only a guide and, in close consultation with the Department of English academic advisor, students may adjust their course plan. Please note that the below plan does not include the 3-4 prerequisite courses (see above), which should be completed by the junior year.

Sophomore		Junior	
Fall	**Spring**	**Fall**	**Spring**
76-26x Survey of Forms	76-390 Style	76-300 Professional Seminar	Theory/Specialization Course
76-271 Introduction to Professional and Technical Writing*		76-391 Document & Information Design*	TC or SMC Track Elective
		TC or SMC Track Elective	

Senior	
Fall	**Spring**
76-487 Web Design*	Theory/Specialization Course
Theory/Specialization Course	TC or SMC Track Elective

*These courses must be taken in the sequence indicated. 76-271 is offered all semesters and therefore can be taken fall or spring of sophomore year. 76-271 is a prerequisite for 76-391, and 76-271 + 76-391 are the prerequisites for 76-487. 76-391 and 76-487 are offered only in the fall semesters.

Completing an Additional Major in English

For Students with a Primary Major in the English Department

Students with a primary major in the English Department who have interests that include more than one of the department's majors have the option of completing an additional major within the department. Students may combine any of the departmental majors with one another, with the exception of Professional Writing and Technical Writing & Communication. Students may not combine these two majors because so many of the courses overlap.

Students with a primary major in the English Department and one or more additional majors in the English Department must fulfill the Core Requirements for each of those majors. The Survey of Forms requirement, common to all 5 majors, needs to be taken only once, with the exception of Creative Writing, which requires two Survey of Forms courses. For the English Department majors that require English Electives, students must complete the number of English Electives required by the major with the higher number of Electives. For example, a student with a primary major in Creative Writing and an additional major in Professional Writing would take

4 English Electives, as Creative Writing requires 4 English Electives, and Professional Writing requires only 3 English Electives.

Because students are only required to take a minimum of one Survey of Forms course, with the exception of Creative Writing, which requires two Survey of Forms courses, as well as the number of English Electives that is greater between the primary and additonal major(s), students can generally add an additional major within the English Department by completing 6 to 9 additional courses.

An example:

A student who has fulfilled all 11 departmental requirements for the B.A. in Creative Writing can complete the additional major in Professional Writing by adding 9 courses: 4 courses of the PW Core (76-271 Introduction to Professional and Technical Writing, 76-300 Professional Seminar, 76-373 Argument, 76-390 Style), one Rhetoric/Language Studies course, and 4 Advanced Writing/Rhetoric courses.

Because sequencing of courses can become an issue when doing multiple majors, students are strongly advised to consult closely with the English Department academic advisor about the sequence of their courses. The English Department academic advisor can also provide students with documents that clearly outline the requirements for additional majors based on their primary majors within the Department.

For Students with a Primary Major Outside of the English Department

Students in other departments who wish to complete an additional major in the English Department should contact the English Department's academic advisor. Additional majors in the five English programs are required to complete all requirements for the chosen major. The English Department will allow a maximum of two courses from the additional major to double count with the primary major requirements. The only exceptions to this rule are the Technical Communication Electives for the *Technical Communication* concentration in the Technical Writing & Communication major and the Natural Science and Engineering Electives for the *Science & Medical Communication* concentration in the Technical Writing & Communication major. All of those electives may double count with programs outside of the English Department. In planning schedules for an additional major, it is critically important that students consult with academic advisors in both departments in which they are majoring to be sure that all requirements for graduation can be met.

Minor in English

The English Department also offers minors in **Creative Writing, Humantities Analytics, Literature & Culture, Professional Writing,** and **Technical Writing**. The minors in English are available to all undergraduate students except English majors, who may not both major and minor in English.

For the minor, students may double count up to two courses with programs outside of the Department of English.

Courses that meet the various requirements are advertised on a semester-by-semester basis. Full descriptions are available each semester from the English Department main office.

Creative Writing Minor

Complete 6 courses and a minimum of 54 units, which includes First-Year Writing. Students may transfer one course from another program toward the Creative Writing minor.

Course		Units
First-Year Writing *		9
76-26x	One Survey of Forms Course +	9
76-xxx	Two 300/400 level Fiction, Poetry, or Screenwriting Workshop Classes	18
76-3xx	One Reading in Forms Course	9
76-2xx	One 200-level or above English Elective	9

* Course options include 76-101, 76-102, [76-106 and 76-107], [76-106 and 76-108], or [76-107 and 76-108].

\+ A student must receive a grade of A or B in the Survey of Forms class in order to be eligible to enroll in a workshop of that genre. A student who receives a grade of C in a Survey of Forms course may enroll in a related workshop only with the permission of his or her workshop professor. A student who receives a D or R in Survey of Forms may not take a workshop in that genre.

Humanities Analytics Minor

The human experience that is traditionally at the core of a humanities education is being dramatically transformed by the emergence of big data, digital platforms, computational thinking, and digital connectivity. Spurred by such developments, the minor in Humanities Analytics (HumAn), offered by the Department of English, will train students in the processes involved in analyzing, digitizing, quantifying, and visualizing different types of humanities and cultural phenomena, including printed books, manuscripts, historical records, art, music, and film. The HumAn minor trains students to work with cultural objects (like texts, film, historical records, etc.) but also to turn words and images into data; to move from one cultural object (like a Victorian novel, for instance) to a corpus consisting of tens of thousands of other novels published in the same period, and to combine close reading with distant reading (aggregating and analyzing massive amounts of data) for maximum insight and accuracy.

Students will develop a broad technical understanding of state-of-the-art computer-assisted methods for humanistic study, such as: social network analysis, text analysis and data mining, topic modeling, classification techniques, and visualization. Students will also investigate the histories and historical contexts of such methods, learning to consider their applicability in specific domains. Finally, students will learn to turn a critical eye on the corpora and infrastructures that increasingly underpin humanistic research.

The minor is open to students across multiple colleges and degree programs, and will enrich their education in distinct ways and complement their primary majors. For example, students with a primary major in a humanities or social science department will learn the foundational methods used in the computational analysis of text. Students with a primary major in a non-humanities field will use technology as a lens into cultural history and will develop skills for making humanities knowledge visible and appealing. The minor will bridge divides not only between the "digital/technological" and the "humanistic," but also between the qualitative and quantitative, between theory and applications, critiquing and making.

Specific career paths available to a student graduating with a HumAn minor might include:

- the publishing industry
- the entertainment industry
- the GLAM sector (digital curating for **g**alleries, **l**ibraries, **a**rchives, and **m**useums)
- data journalism
- digital approaches to cultural heritage
- LODLAM (**L**inked **O**pen **D**ata for **L**ibraries, **A**rchives, and **M**useums)

Curriculum

Required Courses — 6 courses, 54 units

Required Courses		Units
76-275	Critical Writing Workshop	9
76-380	Methods in Humanities Analytics	9

Two core courses from the following list:		Units
76-314	Data Stories	9
76-361	Corpus Rhetorical Analysis	9
76-388	Coding for Humanists	9
76-419	Media in a Digital Age	9
76-425	Science in the Public Sphere	9
76-429	Digital Humanities: Politics and Early Modern Drama	9
76-483	Corpus Analysis in Rhetoric	9
88-275	Bubbles: Data Science for Human Minds	9
88-300	Programming and Data Analysis for Social Scientists	9

Electives — 2 courses, 15-24 units

Note: Additional courses not on List A or List B may also be approved as electives; please speak with the English Department academic advisor.

List A: For Humanities (English, History, Modern Languages, Philosophy) majors

Two elective courses relevant to digital and analytics methods (at least 18 units)		Units
05-391	Designing Human Centered Software	12
05-434/11-344	Machine Learning in Practice	12
11-441/741	Machine Learning for Text Mining [1]	9

15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
19-713	Policies of Wireless Systems	12
36-201	Statistical Reasoning and Practice	9
36-202	Statistics & Data Science Methods	9
36-315	Statistical Graphics and Visualization [3]	9
36-350	Statistical Computing [3]	9
48-095	Spatial Concepts for Non-Majors	Var.
48-120	Digital Media I	6
51-229	Digital Photographic Imaging	9
53-451	Research Issues in Game Development: Designing for XR	12
60/62-142	Digital Photography I	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10

1 Course is very mathematical, and is therefore appropriate only to students with such a preparation.
2 Non-architecture majors require instructor permission to enroll.
3 This course has prerequisites.

List B: For Non-Humanities majors

Two elective courses relevant to broad Humanities expertise (at least 18 units)		Units
76-325	Intertextuality	9
76-373	Argument	9
76-385	Introduction to Discourse Analysis	9
76-394	Research in English	9
76-444	History of Books and Reading	9
76-472	Topics in Journalism: Storytelling in a Digital Age	9
76-476	Rhetoric of Science	9
76-491	Rhetorical Analysis	9
76-786	Language and Culture	Var.
79-200	Introduction to Historical Research & Writing	9
79-305	Moneyball Nation: Data in American Life	9
80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-381	Meaning in Language	9
80-383	Language in Use	9
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-383	Second Language Acquisition: Theories and Research	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Literature & Culture Minor

Complete 6 courses and a minimum of 54 units, including First-Year Writing as a prerequisite.

Curriculum

Required Courses — 6 courses, 54 units

Two Introductory Courses		Units
76-275	Critical Writing Workshop	9
76-26x	Survey of Forms (Fiction, Creative Nonfiction, Poetry, Screenwriting)	
		9

200-Level Literature & Culture Courses (2 courses, 18 units)

Course options include but are not limited to the following:

Courses include but are not limited to:		Units
76-203	Pirates and Prostitutes in the 18th Century	9
76-205	Jane Austen	9
76-210	Banned Books	9
76-217	Contempory American Literary & Cultural Studies	9
76-218	Special Topics in Literature: Medieval Romance & Arthurian Legends	9
76-221	Books You Should Have Read by Now: 16th & 17th C. Pop Culture	9
76-230	Literature & Culture in the 19th Century: Environmentalisms	9
76-232	Introduction to Black Literature	9
76-233	Literature and Culture in the Renaissance	9
76-238	What Was the Hip-Hop Generation?	9
76-245	Shakespeare: Tragedies and Histories	9
76-247	Shakespeare: Comedies and Romances	9
76-281	Modern American Drama	9

300- or 400-Level Literature & culture or theory Courses (2 Courses, 18 units)

Course options include but are not limited to the following:

Courses include but are not limited to:		Units
76-310	Advanced Studies in Film and Media	9
76-313	19th Century British: Victorian Sensations	9
76-314	Data Stories	9
76-321	History of the British Novel	9
76-323	God: A Literary and Cultural History	9
76-329	Unruly Women in Early Modern Drama	9
76-333	Race and Controversy in the Arts	9
76-334	Literature of Wall Street	9
76-337	Representations of Islam in Early Modern England	9
76-341	Gender and Sexuality in Performance	9
76-343	Rise of the American Novel	9
76-350	Theory from Classics to Contemporary	9
76-344	Censored Texts	9
76-353	Transnational Feminisms: Fiction and Film	9
76-361	Corpus Rhetorical Analysis	9
76-367	Fact Into Film: Translating History into Cinema	9
76-377	Shakespeare and Film	9
76-381	Mad-Men, Television, and the History of Advertising	9
76-410	The Long Eighteenth Century	Var.
76-412	Performance and 18th Century Theatrical Culture	9
76-414	Politics, Media, and Romantic Literature 1789-1830	9
76-419	Media in a Digital Age	9
76-429	Digital Humanities: Politics and Early Modern Drama	9
76-435	Politics and Popular Culture	9
76-439	Seminar in Film and Media Studies: Class, Race, & Gender in Film	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
76-443	Shakespeare and Theory	9
76-444	History of Books and Reading	9
76-448	Shakespeare on Film	9

Professional Writing Minor

Complete 6 courses and a minimum of 54 units, including First-Year Writing as a prerequisite.

Course		Units
First-Year Writing *		9
76-270	Writing for the Professions	9
or 76-271	Introduction to Professional and Technical Writing	
76-xxx	Two 200/300 level Core Writing Course **	18
76-xxx	Two 300/400 level Advanced Writing/Rhetoric Courses **	18
76-xxx	One 200-level or above English Elective	9

* Course options include 76-101, 76-102, [76-106 and 76-107], [76-106 and 76-108], or [76-107 and 76-108].

** Courses for PW minors in these areas are advertised by the English Department each semester.

Technical Writing Minor

Complete 6 courses and a minimum of 54 units, including First-Year Writing as a prerequisite.

Course		Units
First-Year Writing *		
76-270	Writing for the Professions	9
or 76-271	Introduction to Professional and Technical Writing	
76-xxx	Two 300-level Core Writing Courses **	18
76-xxx	Two 300/400 level Recommended Theory/ Specialization Courses **	18
76-xxx	One 300/400 level Technical Communication Elective +	9

* Course options include 76-101, 76-102, [76-106 and 76-107], [76-106 and 76-108], or [76-107 and 76-108].

** Courses for TW minors in these areas are advertised by the English Department each semester.

+ To fulfill this requirement, courses can come from the “additional” OR “recommended” options list of theory/specialization courses listed for Technical Writing majors in the English Department’s “What Counts for What?” document.

Senior Honors Thesis

Seniors in all five majors in the English Department who meet the necessary requirements are invited by the College of Humanities and Social Sciences (Dietrich College) to propose and complete a Senior Honors Thesis during their final year of study. The thesis may focus on research and/or original production in any of the areas offered as a major within the Department. To qualify for the Dietrich College Honors Program, students must have a cumulative Quality Point Average of at least 3.50 in their major and 3.25 overall at the end of their junior year and be invited by Dietrich College to participate. Students then choose a thesis advisor within the Department and propose and get approval from Dietrich College for a Senior Honors Thesis. The Honors Thesis is completed over the two semesters of the senior year (9 units each semester) under the direction of the chosen advisor. By successfully completing the thesis, students earn 18 units of credit and qualify for graduation with “College Honors.”

Creative Writing majors participating in the Senior Honors Thesis program may petition to have one semester of their thesis work count as one of their Workshop course requirements. Students interested in this option should contact the Director of Undergraduate Studies.

Internship Program

Qualified students in all four of the Department’s degree programs have the option of doing a professional internships for academic credit during their junior or senior years. These opportunities help students explore possible writing-related careers as well as gain workplace experience. Each internship is arranged, approved, and overseen by the Department’s Internship Coordinator. Particular attention is given to matching students to internship sites of specific interest to them. Students have interned in a wide variety of communications-related positions including placements at local radio, television, and print publications; museums, theaters, and cultural organizations; non-profit and public service organizations; public relations, advertising, and marketing firms; software and technology companies; new media organizations; and hospitals and healthcare communication organizations.

To be eligible for an internship, students must have a Quality Point Average of 3.0 or better and credit for at least one writing course (including Survey of Forms) beyond First-Year Writing. Internships generally carry 3-12 units of credit. A 9-unit internship is the standard and requires a minimum of 120-140 hours (8-10 hours per week over a 15-week term) of work at the internship site during the term. In addition, interns complete a reflective journal and a series of short research and writing assignments relevant to the specific internship. Students doing an internship for credit must be registered for the internship during the term (including summer) when they are working at the internship site. Majors in the Department may count one 9-12 unit internship for one of their degree requirements, generally an English elective.

The Accelerated MA in Professional Writing: MAPW 4+1

The MAPW 4+1 is a special program under which Carnegie Mellon students (usually majors or minors in the English department or BHA or BHS students with relevant coursework) can qualify to complete the MA in Professional Writing in 2 semesters instead of the usual 3. Students apply for admissions during their junior or senior year and, following admission and evaluation of their transcripts, may receive credit for up to four courses, or one full semester of work toward the MA requirements. The degree has a professional focus, combines intensive work in both writing and visual design, and prepares students for a range of communications careers. The coursework and career options most commonly pursued by students in the degree include

- Writing for Digital Media, including web design and information design
- Writing for Print Media, including Journalism
- Editing & Publishing
- Technical writing, including instructional design
- Science, Technology, and Healthcare Writing
- Public & Media Relations / Corporate Communications / Nonprofit Communication

Students interested in applying to the 4+1 program should consult the Director of the MAPW program early in their junior year for further details and advice on shaping undergraduate coursework to qualify for this option.

Faculty

MARIAN AGUIAR, Associate Professor of English – Ph.D., University of Massachusetts;

JANE BERNSTEIN, Professor of English – M.F.A., Columbia University;

DAVID BROWN, Associate Teaching Professor of English – Ph.D., Lancaster University;

GERALD P. COSTANZO, Professor of English – M.A., M.A.T., Johns Hopkins University;

DOUG COULSON, Assistant Professor of English – Ph.D., The University of Texas at Austin;

JAMES DANIELS, Thomas Stockham Baker University Professor of English – M.F.A., Bowling Green State University;

SHARON DILWORTH, Associate Professor of English – M.F.A., University of Michigan;

JASON ENGLAND, Assistant Professor of English – M.F.A., Iowa Writers' Workshop;

LINDA FLOWER, Professor of English – Ph.D., Rutgers University;

KEVIN GONZÁLEZ, Assistant Professor of English – M.F.A., Iowa Writers’ Workshop;

SUSAN HAGAN, Assistant Teaching Professor, Liberal & Social Sciences, Carnegie Mellon University-Qatar – Ph.D., Carnegie Mellon University;

PAUL HOPPER, Paul Mellon Distinguished Professor Emeritus of the Humanities, Rhetoric and Linguistics – Ph.D., University of Texas;

SUGURU ISHIZAKI, Professor of English – Ph.D., Massachusetts Institute of Technology;

BARBARA JOHNSTONE, Professor Emerita of English – Ph.D., University of Michigan;

DAVID S. KAUFER, Mellon Distinguished Professor of English – Ph.D., University of Wisconsin;

ALAN KENNEDY, Professor Emeritus of English – Ph.D., University of Edinburgh;

JON KLANCHER, Professor of English – Ph.D., University of California at Los Angeles;

PEGGY KNAPP, Professor Emerita of English – Ph.D., University of Pittsburgh;

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JOHN J. ODDO, Associate Professor of English – Ph.D., Kent State University;

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ANDREEA DECIU RITIVOI, Professor of English – Ph.D., University of Minnesota;

KAREN SCHNAKENBERG, Teaching Professor Emerita of English – Ph.D., Carnegie Mellon University;

LAUREN SHAPIRO , Assistant Professor of English – M.F.A., Iowa Writers' Workshop;

DAVID R. SHUMWAY, Professor of English – Ph.D., Indiana University;

KRISTINA STRAUB, Professor of English – Ph.D., Emory University;

CHRISTOPHER WARREN, Associate Professor of English – Ph.D., University of Oxford;

NECIA WERNER, Associate Teaching Professor of English – Ph.D., Carnegie Mellon University;

DANIELLE WETZEL, Teaching Professor of English – Ph.D., Carnegie Mellon University;

JEFFREY WILLIAMS, Professor of English – Ph.D., Stony Brook University;

STEPHEN WITTEK, Assistant Professor of English – Ph.D., McGill University;

JOANNA WOLFE, Teaching Professor of English – Ph.D., The University of Texas at Austin;

JAMES WYNN, Associate Professor of English – Ph.D., University of Maryland;

Department of English Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

76-100 Reading and Writing in an Academic Context
Fall and Spring: 9 units
76-100 is an academic reading and writing course for multilingual students, especially those who are not native speakers of English or who consider English to be their weaker language. The course emphasizes reading comprehension strategies for reading a variety of text types in English (e.g., journalism, textbook selections, popular press arguments, and academic journal articles). Throughout the semester, students use these sources to write summaries and short position papers. The course introduces students to readers' expectations for North American rhetorical style at the sentence, paragraph, and whole text or genre levels. Within the course we discuss explicit genre and linguistic norms for writing in academic English so that writers can connect with their readers. Students who take this course qualify through an online placement test that is administered through the university prior to the fall semester. (All sections are offered MWF). Each 76-100 course is structured by the reading and writing objectives of the course as well as a vocabulary for writing in English, but some courses present different themes (or content) in their readings.

Course Website: http://www.cmu.edu/hss/english/first_year/index.html

76-101 Interpretation and Argument
Fall and Spring: 9 units
See full course descriptions at this URL: http://www.cmu.edu/hss/english/first_year/index.html
Course Website: http://www.cmu.edu/hss/english/first_year/index.html

76-102 Advanced First Year Writing: Special Topics
All Semesters: 9 units
76-102, Advanced First-Year Writing courses are designed for students who have demonstrated an understanding of academic writing that most incoming freshmen have not. Because of the students' level of preparedness, the First-Year Writing Program provides intensive, advanced courses for students to work closely with senior faculty within the English department. Advanced courses assume that students have established strong reading and synthesizing skills, as well as a demonstrated interest in writing and communication, prior to entering Carnegie Mellon. The course topics shift each semester. Students enroll through special invitation. Class size for 76102 is capped at 19 and there are no prerequisites for the course. Advisors will be notified if their students qualify for the advanced writing courses.

Course Website: http://www.cmu.edu/dietrich/english/first_year/index.html

76-106 Writing about Literature, Art and Culture
Fall and Spring: 4.5 units
This mini course (one of two minis students can choose to fulfill their FYW requirement) uses artistic, literary, and cultural texts (e.g., poetry, short story, lyrics, video clips) to introduce students to a variety of academic reading and writing practices that enable students to engage with texts and write about them with complexity and nuance. Within the course, we will discuss texts and evidence from multiple perspectives. We will examine how literary and cultural scholars write about texts (defined broadly), how they make claims, provide reasoning, and use textual support to argue for particular ways of seeing cultural objects. Throughout the semester, students will draw upon prior strategies and develop new ones for close reading and for critical analysis in order to produce their own thesis-driven arguments about why texts matter. We will consider and write about the extent to which these reading strategies are relevant for other kinds of reading and analysis by comparing texts from a variety of different disciplinary contexts.

Course Website: https://www.cmu.edu/dietrich/english/first_year/index.html

76-107 Writing about Data
Fall and Spring: 4.5 units
Our lives are increasingly shaped by writing that involves numbers: newspapers routinely report the latest medical fads; politicians support their political agendas with both dubious and credible statistics; parents use data to decide where to buy a house and where to send their kids to school. This course (one of two minis students can choose to fulfill their FYW requirement) focuses upon interpreting and making arguments using mainly numerical data but also qualitative data. We will look at research in a range of disciplinesincluding psychology, education, medicine, engineering, and the sciencesand note how writers select and analyze the data they collect. We will also examine what happens to this research when it is picked up by the popular media. Students will also practice collecting and analyzing their own data and reporting it to suit the needs of various stakeholders. There are two primary audiences for this section. Students in data-driven majors will find the section useful preparation for communicating in their disciplines. Students in other fields will learn how to critique and respond to the many ways that numbers shape our lives. This section presumes a basic ability to calculate averages, percentages, and ratios, but no advanced mathematical or statistical preparation. Instead, this section provides a fascinating look at how numbers and words intersect to create persuasive arguments in academic, professional, and popular contexts. Students will compare and analyze texts that make arguments with data, practice rhetorical strategies for synthesizing and representing data so that by the end of the class, students will apply these strategies to write an original data-driven research proposal.

Course Website: https://www.cmu.edu/dietrich/english/first_year/index.html

76-108 Writing about Public Problems
Fall and Spring: 4.5 units
If all problems required a simple fix, we could don our Avenger costumes, pick up Thors hammer, and right the worlds wrongs. But most problems arent so simple. Most of the problems we encounter require careful investigation and research so that we might propose solutions that connect with others to make change. In this 76101 class (one of two minis students can choose to fulfill their FYW requirement), we will learn how public problems are defined and argued across a range of texts, including proposals, op-ed genres, and white papers. By analyzing a range of proposal texts, we will identify the different kinds of legwork necessary to write a successful proposal, arguably one of the most challenging aspects of writing a persuasive recommendation for change. We will examine how writers unpack problems rhetorically and use evidence to argue solutions for different stakeholders who may not share common values. We will learn strategies for evaluating and synthesizing data from existing research to use in a proposal argument. By the end of the course, students will write their own proposal that recommends a solution and a feasible plan for solving a real problem.

Course Website: https://www.cmu.edu/dietrich/english/first_year/index.html

76-120 First-Year Seminar: CSI Underground Books & Printing
Intermittent: 9 units
This is a course devoted to solving unsolved crimes (for realz!). We'll take on puzzling cases of illegal printing that have stymied investigators for hundreds of years. In working together to determine who may have been responsible for scandalous and illicit books, we'll learn about the history of censorship, the history of printing and typography, copyright and its discontents, crime syndicates, piracy, document forensics, and more. We'll get our hands dirty with rare books from the 16th and 17th centuries and also see what we can discover using modern technology and data analysis. This is a course for students who'll enjoy the thrills of creatively aggregating and assessing evidence and the challenges of real-world humanities problems that span history, literature, and technology. Students should expect to work in teams and also to expect the unexpected. Who knows what we'll find? With any luck, we'll be able to crack a few cases!

76-203 Pirates and Prostitutes in the 18th Century
Fall: 9 units
In this course, we discuss how sailors, pirates, and prostitutes changed the modern world. Blackbeard, Captain Kidd, "Black Sam" Bellamy, Calico Jack Rackham: these are just a few of the pirates who gained notoriety by terrorizing the seas in the 18th century. We explore this Golden Age of Piracy, investigating how these privateers created their own counter-culture. Equally important were the "ladies of the night" who eagerly anticipated the ships' return to port. Our course discusses how some of these women were able to amass fortunes off the pirates' plunder, and even became pirates themselves. We will examine various texts depicting sailors, pirates and their wenches, including paintings, cartoons, novels, songs about sailing, and plays. In doing so, students will be able to see how people dealt with various problems associated with privateers: sailors kidnapping loved ones, drunkenly tearing up the ports and spreading venereal disease, and enacting revenge against the Royal Navy's barbarity.

76-205 Jane Austen
Intermittent: 9 units
It is a truth universally acknowledged that Jane Austen is one of the most popular writers of the past two hundred years. In this course, students will have the opportunity to indulge in the work of this beloved author and answer: What can an exploration of Austen's time tell us about her novels and about ourselves as readers? In this course, we will read Austen's six published novels (Northanger Abbey, Pride and Prejudice, Sense and Sensibility, Emma, Mansfield Park, and Persuasion) as we consider: In what ways can we describe Austen's novels as "romantic," and how does her work fit within the parameters of the Romantic canon? With increases in literacy rates and the emergence of lending libraries, what can Austen's novels tell us about readership and popular fiction in the early nineteenth century? How do these vibrant texts engage with important issues of their (and our) time, like revolution, women's rights, race, sexuality, nationality and religion? Additionally, we will encounter excerpts from Austen's contemporaries and explore other cultural materials - like diaries, letters, periodicals, maps, music, fashion, and the visual arts - to paint a rich historical context around our reading. Finally, we will consider how cinematic adaptations of Austen's works can contribute to our interpretations of her novels.

76-208 Grammar for Everyone
Intermittent: 4.5 units
This is a mini-course in fundamental grammatical structures of English and how these structures fit into the writer's toolkit. This means you will learn a lot about English-language grammar in this course en route to understanding a lot about English language writing. This course is designed for students with no grammar background, for students with lots of grammar background, for students with no writing background, and for students with lots of writing background. The novel focus of this mini is on how grammatical knowledge can support and systematize your writing knowledge and practice.

76-210 Banned Books
Intermittent: 9 units
Freedom of expression enjoys an almost sacrosanct position in American politics, and yet there have been repeated attempts in the past century to ban, burn, censor, and suppress a number of controversial books. Students in this course will learn about the historic, institutional, and social contexts in which these censorship controversies arise, as well as the ways in which artists have responded to censorship attempts. We will ask which kinds of work are typically challenged and how attempts at censorship affect our understanding of a banned text and its significance. Readings for this class will include novels such as Toni Morrison's The Bluest Eye, Kurt Vonnegut's Slaughterhouse Five, Judy Blume's Are You There God? It's Me, Margaret, Stephen Chobsky's The Perks of Being a Wallflower, Sherman Alexie's The Absolutely True Diary of a Part-Time Indian, and Alison Bechdel's Fun Home: A Family Tragicomedy. In addition to literature, we will also consider the ways in which other forms of art, such as movies and music, have been challenged and censored. Students in this course will also celebrate the American Library Association's Banned Books Week, which will take place September 22-28.

76-213 19th Century British Literature
Intermittent: 9 units
Topics vary by semester. Spring 2012: Women writers played an essential role in the construction of Victorian literary culture. In this course we will read novels, poems, and periodical extracts by a diverse body of nineteenth-century female authors as a means of better understanding women's historic and aesthetic impact on Victorian culture. While some of our authors are well known, like the wildly popular poet Elizabeth Barrett Browning, we will also encounter the 'lost' author, journalist, and controversial anti-feminist Eliza Lynn Linton. The writing of Victorian women exemplifies important social debates from the nineteenth-century. Social taboos such as divorce, suffrage, Bloomerism, children out of wedlock, and women in the workforce were all topical in Victorian culture. As the conflicted and introspective heroine of George Eliot's The Mill on the Floss reminds readers, the role of marriage as a woman's sole profession was becoming increasingly untenable in the modern era. Victorians were forced to ask what other function were women fit to occupy. From the Pre-Raphaelite poetry of Christina Rossetti, to the gothic horror of Emily Bronte's Wuthering Heights, "the woman question" served as a lightening rod for a variety of nineteenth-century cultural anxieties. The woman as deviant and criminal which we will encounter in Mary Elizabeth Braddon's Lady Audley's Secret was an especially controversial aspect of the female-dominated genre of "Sensation Fiction." Margaret Oliphant records in an 1867 review from Blackwoods: "What is held up to us as the story of the feminine soul as it really exists underneath its conventional coverings is a very fleshy and unlovely record.(See Dept. for full desc.)

76-215 19th Century American Literature
Intermittent: 9 units
Topics vary by semester. Consult the course descriptions provided by the department for current offerings. Example, Spring 2010: In this class, we will be reading many of the major works of Edgar Allan Poe, Nathaniel Hawthorne, and Herman Melville. Often described as America's Dark Romantics, these three authors are frequently read as reacting to the current of optimism and idea of human perfectibility that characterized antebellum America and the Transcendentalist movement. We will begin by reading most of Poe's short fiction and novellas and a number of his poetic and journalistic works. We will also read Hawthorne's two major novels House of the Seven Gables and The Scarlet Letter, as well as a number of his shorter works from Twice-Told Tales. The class will also look at a number of Melville's major works beginning with his first novel Typee, his short story collection The Piazza Tales, and culminating with Moby Dick. In addition to reading these canonical authors for their artistic merit, we will also consider the ways in which their works interacted with some of the prevailing ideas of their historical moments.
Prerequisite: 76-101

76-217 Contempory American Literary & Cultural Studies
Intermittent: 9 units
Topics vary by semester. Consult the course descriptions provided by the department for current offerings. Example, Summer 2010. It has been said that the teenager is the most free and least happy of all living beings. Given America's current obsession with youth culture, it's hard to imagine a time when the word "teenager" did not exist. However, this word came into being largely as a result of the post World War II boom in consumerism when advertisers needed a new way to define an emerging demographic group with its own disposable income and spending power. Through a survey of twentieth century literature that focuses on the teenage experience, we'll explore the changing meanings of young adulthood over the last one hundred years. What is the relationship between the invention of the teenager and modernist aesthetics? What characteristics were considered markers of young adulthood in the 1920's? In the 1950's? In 2000? How are the experiences of angst, anomie and the unfulfilled American dream connected to modern Western life through the teenage subject? How do tropes of individualism, rebellion, freedom and resistance connect the literature of teen angst with other genres of American literature? How has teen angst been both an impediment to and the inspiration for cultural resistance and social change? To answer these questions, we will compare texts such as Philip Roth's Portnoy's Complaint, Anzia Yezierska's The Bread Givers, J.D. Salinger's Catcher in the Rye, Margaret Atwood's The Edible Woman, Dave Eggers' A Heartbreaking Work of Staggering Genius, and Banana Yoshimoto's Kitchen. See English Department for full description.
Prerequisite: 76-101

76-218 Special Topics in Literature: Medieval Romance & Arthurian Legends
Fall and Spring: 9 units
This course will explore the "greatest hits" of medieval literature from early Arthurian legend to the most popular of the Canterbury Tales. We will read famous medieval romances from Chaucer's Troilus and Crysede to Gottfried von Strassburg's Tristan, and the timeless letters of Abelard and Heloise. We will compare and contrast these texts across time, place, space, genre, and form, discussing medieval cultural values of chivalry, nobility, honor, quest, charity, and fealty. Students will be expected to write short responses, one close reading paper, and a comparative paper by the end of the term.

76-221 Books You Should Have Read by Now: 16th & 17th C. Pop Culture
Intermittent: 9 units
This course will explore the "greatest hits" of sixteenth and seventeenth-century English literature from Thomas More's Utopia (1551) to the political pamphlets of the English Revolution 1640. We will look at early modern travel narratives, representations of the New World, and the "get rich quick" schemes of the long sixteenth century. We will read a range of city comedies presenting realistic and satirical representations of early modern trade, crossdressing, politics, religion, and working life in London. These representations will be compared to plays set in the countryside depicting witches, the law, and coercive the transfer of money and property. The third part of this course will explore revenge tragedies and the political pamphlets of the English Revolution, asking how the new worlds, old worlds, and utopian imaginings of sixteenth century England compare to those of a century later.

Course Website: http://www.cmu.edu/hss/english/courses/index.html

76-222 Creative Writing Matters
Intermittent: 9 units
This course will explore at least two of the meanings of the word "matters"¿as in "is of importance," and as in "things, concerns." Through reading and writing in various genres, students will discover and discuss how creative writing engages with the world around us while also learning some of the important techniques of writing creatively in various genres, including scriptwriting, fiction, nonfiction, and poetry. The class will read a wide variety of books, and students will have the opportunity to interact with the authors through public readings, classroom visits, and attending a play. In addition, the class will take advantage of other literary events happening around Pittsburgh in order to further examine places where writing comes off the page and engages with the world. Revision will be required and emphasized.

76-223 Contemporary Black Literature
Spring: 9 units
This course will take a transatlantic approach to what constitutes blackness as well as black literature and expression from the turn of the 20th century until the present. We will investigate the relationship between poetic forms and expressions of social and self-representation. However, this class will primarily focus on prose works (novels, memoirs and non-fiction essays) that span a multitude of genres from mystery to literary and science fiction. Authors include: W.E.B. Dubois, Zora Neale Hurston, James Baldwin, Zadie Smith, Claude McKay, Amiri Baraka, Franz Fanon, Marlon James, Edouard Glissant, Nnedi Okorafor, Merle Collins and Jamaica Kincaid to name a few.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-225 Topics in Rhetoric: Words and Numbers
Intermittent: 9 units
Topics vary by semester. Spring 2014: For decades, communication researchers relying on stimulus-response theories associated a text with a single dominant stimulus evoking a single dominant response. This thinking widely influenced rhetorical understandings of language for decades as well. Today, rhetorical theories of language have discredited these behaviorist theories in favor of theories that see language as the constructors of situations rather than the effects of them. When speakers and writers use language, they resuscitate, enact, and perform worlds of experience from words. They create not only meanings but histories, identities, and social bids to initiate social change. This course introduces students to a theory and ontology of language study that is in keeping with language as a constructive activity. Students will learn to use software designed to analyze texts qualitatively and numerically from a constructive point of view. The software works as a microscope to help you see patterns of language use that escape the limited attention span of even the most painstaking of close readers. After learning how the software works, we will do exercises with small textual samples so that students can sharpen their powers of observing language across families of patterns. Students are encouraged to analyze the texts they love most — from literature, politics, journalism, to their favorite blog posts, tweets, and Facebook posts. (Full course description available on English department website).

76-227 Comedy
Intermittent: 9 units
We can't, of course, expect to come up with an absolutely complete definition of the comic, but for our purposes we can consider it as an embodiment of the opposite of "gravity." Comedy is characterized by its levity. This does not mean, of course, that it is any less "serious" than tragedy, even if-or especially-because it tends to favor the superficial over the profound. Indeed, if tragedy is adolescent, then the mature, adult mode is the comic, being more social and rational. A key characteristic of comedy is wit-or simply intelligence. Comedy involves a lot of pure play of the mind. It turns out that there have been a few notable attempts to help us understand just why comedy is the "social" genre beyond all others, why the comic attitude is the civilized, urbane, mature view of life. And we'll consider some of those theories while trying to understand why some things are comic and some are not. We'll consider several classical works of comic literature, beginning with Aristophanes, Shakespeare, and moving on to more recent examples, including some films.

76-230 Literature & Culture in the 19th Century: Environmentalisms
Intermittent: 9 units
In this class we'll go back in time to the Walden Pond of Thoreau's time, with a focus on the "Green Nineteen"—-writers and thinkers who considered the relationship between human civilization and the wilderness (Mary Shelley's Frankenstein, Thoreau's Walden Pond, and selected essays from Ralph Waldo Emerson). We will also think about the environment in relation to a famous slave narrative (Douglass, The Slave Narrative of Frederick Douglass) and in relation to one of the great feminist novels of the time, The Awakening. Finally we will consider the environmental consciousness of the two most important poets of the 19th century, Walt Whitman and Emily Dickinson. As for coursework, we will use the class to practice meditation, nature walks, and one project in which you will design your own environmentally conscious Utopian community.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-232 Introduction to Black Literature
Intermittent: 9 units
This course will take a transatlantic approach to what constitutes blackness as well as black literature and expression from the turn of the 20th century until the present. We will investigate the way authors and artists use literature and other mediums of expression for social and self-representation. Our primary focus will be on prose works (novels, memoirs and non-fiction essays) that span a multitude of genres from mystery to literary and science fiction. There will also be sections of the course that focus other mediums such as visual art, comics, music, film and television. We will cover figures such as: Fredrick Douglass, W.E.B. Dubois, Zora Neale Hurston, Langston Hughes, Claude McKay, Amiri Baraka, Franz Fanon, Toni Morrison, Merle Collins, Kyle Baker, Kara Walker and Beyonce to name a few.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-233 Literature and Culture in the Renaissance
Intermittent: 9 units
This course is designed to introduce students to the period of the Renaissance and its extraordinary cultural, literary, and artistic developments all across Europe. Spreading from the fifteenth to the seventeenth century, the Renaissance saw Europe transition from the medieval age to early modernity. That transition was characterized by watershed events such as the Reformation and the wars of religion, the dissemination of print, the rediscovery of classics within the humanist movement, the invention of perspective in visual culture, major scientific discoveries (Galileo, Copernicus, Descartes), the development of proto-capitalism, and the beginning of colonial enterprises with lethal implications in an age often dubbed "the Age of Discovery." In this course, we will read, interpret, and write about the literature that flourished in that rich and complex cultural context. Readings will include Thomas More's Utopia, Christopher Marlowe's Doctor Faustus, Spenser's The Faerie Queene, a selection of English poetry, as well as Machiavelli's The Prince, Erasmus's Praise of Folly, Rabelais's Pantagruel, and Cervantes's Don Quixote.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-235 20th Century American Literary and Cultural Studies
Intermittent: 9 units
Topics vary by semester. Example, Fall 2010: 20th Century American Bestsellers: In this course we will work to construct a story about the United States and its literary tastes in the twentieth century by reading a selection of bestselling American fiction from the last 100 years. The class will introduce students to concepts central to the cultural study of popular texts, as well as a number of more and less familiar authors and novels. Readings will include only novels that appeared on yearly Publisher's Weekly top-ten bestsellers lists from 1900 to 1975. Winston Churchill's A Far Country, Edith Wharton's The Age of Innocence, Margaret Mitchell's Gone with the Wind, Sloan Wilson's The Man in the Gray Flannel Suit, J. D. Salinger's Franny and Zooey, and E. L. Doctorow's Ragtime are just a few of the novels that have shown up on this list. To complete our sketch of popular contemporary fiction, students will present on a bestseller from the last three decades and its reception. Moving through the wide range of texts that became bestsellers, from Wharton to Dan Brown or Stephen King, will allow us to consider whether Daniel J. Boorstin really got the whole picture when he said, "A best-seller was a book which somehow sold well because it was selling well." Course requirements will include a midterm exam, a presentation, and a final paper based on the presentation, as well as intensive reading.
Prerequisite: 76-101

76-237 Post Colonial Literature
Intermittent: 9 units
Topics will vary by semester. Consult the course descriptions provided by the department for current offerings.

76-238 What Was the Hip-Hop Generation?
Intermittent: 9 units
This course will attempt to answer a simply stated but not so simply answered question: What is (or was) the "hip-hop" generation? Bakari Kitwana gives us a very broad but useful rubric to understand whom that generation was in his 2002 book, The Hip-Hop Generation: Young Blacks and the Crisis of African-American Culture. For Kitwana it defines the first generation of African-American youth that grew up in post-segregation America. While useful, Kitwanas definition is also quite provocative since many of the earliest practitioners (and consumers) of what would eventually be called "hip-hop" were not all African-Americans but Greeks, Puerto Ricans, Jews, Jamaicans, Germans, Trinidadians, Mexicans, etc..., many of whom lived in America but also encountered hip-hop elsewhere on the planet. In our class we will take a broad, global perspective on the question of "what is/was the hip-hop generation" through scholarly and popular works by Kitwana. Jeff Chang, Tricia Rose and many others. Given the significant media studies components of this course our class will lean heavily on musical, cinematic and televisual sources. Not only will you watch early fictional films about hip-hop like Wildstyle and Krush Groove but others like Matthieu Kassovitzs La Haine and Rick Famuyimas Brown Sugar which are influenced by hip-hop culture. We will also watch music videos as well as listen to singles and select albums like Queen Latifahs All Hail the Queen, Kendrik Lamars To Pimp A Butterfly, Die Antwoords Tension as well as read memoirs such as Jay-Zs Decoded.
Prerequisite: 76-101

76-239 Introduction to Film Studies
Fall and Spring: 9 units
This course is an introduction to the history, technology, aesthetics and ideology of film. The main focus will be on the narrative fiction film, but we will also discuss documentaries, avant-garde work and animation. At the same time, we will be attentive to the ways in which our conceptual understanding of film has impacted the development of successive waves of visual media. The central organizing principle is historical, but there are a number of recurring thematic concerns. These include an examination of the basic principles and terminology of filmmaking, the development of film technology, the definition of film as both art and business, the history of film as an object of critical and cultural study, and the importance of film as the precursor of newer formats. The course has four key goals. First, to provide students with a solid grounding in the key issues and concepts of film studies. Second, to expand their ability to knowledgeably critique individual cinematic works and the relationship of those works to the larger culture. Third to provide students with experience in expressing those critiques in verbal, written and visual forms. Lastly, to provide them with an understanding of the central role of film history and film studies in the development of newer media.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-241 Introduction to Gender Studies
Fall and Spring: 9 units
Biological sex vs. gender roles. Intersectional feminism. LGBTQIA+ rights. Consent. Masculinity and gender roles. #metoo and gender-based violence. Economic inequity. Sexual politics. This course offers students a scholarly introduction to these social and political issues. Organized thematically, with interdisciplinary readings both foundational and contemporary, the class will combine theory, literature, and film with texts like law, public policy, and media representations. We will read critically and discuss openly. Readings will include work by Virginia Woolf, Simone de Beauvoir, Judith Butler, Kimberlé Crenshaw, bell hooks, Michael Kimmel, Raewyn Connell, Chimamanda Ngozi Adichie, Roxanne Gay, James Baldwin and Margaret Atwood.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-245 Shakespeare: Tragedies and Histories
Spring: 9 units
Few authors have captured the human condition as poignantly as Shakespeare. This course uses Shakespeare's best-known tragedies and history plays to introduce students to the Bard's drama, time, and culture. Together we will read some of the most powerful plays that Shakespeare wrote throughout his career. Those gorgeous works explore with unmatched depth, craft, and lucidity the themes of power, love, loss, ambition, madness, identity, and finitude, while relentlessly asking the same question: what does it mean to be human? We will read, analyze, and discuss Titus Andronicus, Richard III, Richard II, Romeo and Juliet, Julius Caesar, Hamlet, Othello, King Lear, Macbeth, and Antony and Cleopatra. What did those plays mean in their original context? What cultural work did they perform in early modern England? What cultural work do they perform today, and, ultimately, why do we need Shakespeare now more than ever?

76-247 Shakespeare: Comedies and Romances
Fall: 9 units
In the theatrical culture of Elizabethan England, comedy was serious business. This course uses Shakespeare's best-known comedies and romances to introduce students to the Bard's drama, time, and culture. Together, we will read some of Shakespeare's queerest and most delightful comedies such as Midsummer Night's Dream and Twelfth Night in conversation with darker troubling plays that revolve around sexual violence (The Taming of the Shrew, Measure for Measure), racism (The Merchant of Venice), and colonization (The Tempest, Cymbeline). We will also wonder: what does Shakespeare's late romance plays such as The Winter's Tale, or Pericles, often described as "tragicomedies" or as "problem plays," tell us about the strengths and limits of comedy as a genre? In short, valuing those classics of the English literary canon simultaneously for the timeless craft and for the historically located cultural horizon that they evidence, we will explore what it means, as readers of Shakespeare, to take comedy seriously.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-259 Introduction to Film History
Fall and Spring: 9 units
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Prerequisite: 76-239

76-260 Survey of Forms: Fiction
Fall and Spring: 9 units
Sections A & B: This course serves as an introduction to the craft of fiction. We will read a wide array of short stories, a novella, and a novel, and study the techniques and elements of literary fiction as they are displayed in the works of established writers. I will expect you to read the assigned works carefully, giving ample time and consideration to these readings, and to come to class prepared to discuss them. You will also be expected to spend a good deal of time on your own writing, to improve upon that work throughout the term, and to provide thoughtful criticism on your classmates' work. By the end of the semester, you should have a solid understanding of the elements of successful literary fiction, be able to write meaningful critiques of such writing, and be able to write and revise a complete short story. At times, the class will be fun, but it will also entail a good deal of effort and time on your part. Overall, you should see this class as an opportunity to develop and share your creative work, and to learn skills and new ways of thinking about writing. Section C: This is an introduction to the reading and writing of fiction designed as the first in a sequence of courses for creative writing majors and also as a general course for students wanting some experience in creative writing. Writing exercises will be devoted to such aspects of fiction as description, characterization, and narration, and to the writing of scenes and stories. In the second half of the course, students write a full short story of around 10-12 pages due two weeks before the end of the term. These are distributed to the class, discussed, and revised.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-261 Survey of Forms: Creative Nonfiction
Intermittent: 9 units
The National Endowment for the Arts defines "creative nonfiction" as "factual prose that is also literary." In this survey course, students will read a wide range of work that falls into this lively genre, including memoir, travel writing, the personal essay, and nature writing. Weekly writing assignments will give students the chance to work on short pieces of their own creative nonfiction.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-262 Survey of Forms: Nonfiction
Intermittent: 9 units
According to The National Endowment for the Arts, creative nonfiction is "factual prose that is also literary." Memoir, the essay, and literary journalism are just three kinds of writing that fit into this very broad, very vital genre. While creative nonfiction often borrows techniques from fiction, such as narrative, scene, dialogue, and point of view, creative nonfiction is based on actual events, characters and places. What distinguishes creative nonfiction from journalism is that it conveys more than bare-bones facts and that language, analysis and narrative voice are integral parts of each piece. In this course, students will have the chance to read widely within the genre. Exercises and writing assignments will give students the chance to write their own pieces, so that by the end of the semester, everyone will have written four different kinds of creative nonfiction.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-263 Survey of Forms: Playwriting
Intermittent: 9 units
This course is an introduction to the craft of playwriting. Beginning with an understanding of the basic elements of dramatic action such as: character, conflict, plot, setting and dialogue, students will be given weekly writing prompts both in class and as homework assignments in order to explore each of these elements in their own writing, along with reading and analyzing examples of contemporary dramatic literature. There will be opportunities to attend local and university productions in order to appreciate how a text is transformed when staged. Student writing will be workshopped in class with the goal of learning how to give and take feedback as well as completing a short play by the end of the semester.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-265 Survey of Forms: Poetry
Fall and Spring: 9 units
Section A: This course combines the writing of poetry with the study of the techniques of poetry. It consists of three primary units focusing on Diction and Tone, Rhythm and Meter, and Imagery. Students are expected to demonstrate their knowledge through writing poems in specific poetic forms and through analyzing poems in relation to the specific techniques introduced in each unit. Section B:
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/hss/english/courses/courseshtml

76-267 The Short Story
Intermittent: 9 units
Poe defined the short story as something that could be read at one sitting. While simple enough, the definition in fact suggests a concern with concentrated form and unified artistic effect. In a sense, the short story has been around as long as people have been telling each other tales, but as a literary form it came into its own in modern times, during the 19th century, and it continues to be produced in considerable numbers. For many readers one of the great features is the one Poe pointed to, it is short. People who have never finished a novel by Henry James must be legion. So, with the short story, we can experience something with genuine literary merit, in an accessible form. Concentration, of course, can bring issues of comprehension and often short stories can seem puzzling, or incomplete to the average reader. This class will attempt to develop our abilities to read with care and attention—and feeling—in order to make us better readers of any artistic text. The challenges of the short form turn out to be excellent opportunities for learning a lot, in a little space. We?ll make use of several inexpensive anthologies, and look at one or two central writers (Hemingway and Borges) in more depth. The class will require the writing of a few short papers, engaging in online discussions on Blackboard, and three in class tests. Students can expect to develop their historical understanding of current experience and to gain an understanding of how to interpret and comment on significant pieces of fiction. They will become familiar with some key ideas about the nature of short stories in general and the interpretation of texts., and will engage in an attempt to develop a theory of the aesthetic nature of short fiction.
Prerequisite: 76-101

76-269 Survey of Forms: Screenwriting
Fall and Spring: 9 units
This is a course in screenplay narrative. The screenplay has a certain format observed by every screenwriter. It is not so difficult to learn the format. The difficulty is in developing a screen story populated by believable characters, creating an expressive and logical relationship between the scenes by manipulating screen space and screen time, knowing what to omit from the story and what to emphasize, and finally writing dialogue that sounds real, but that does not simply copy everyday speech. The class will be structured into weekly writing exercises, discussion of the narratives under consideration, presentation and discussion of student work, and a final writing project.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-270 Writing for the Professions
Fall and Spring: 9 units
Strong writing and communication skills are expected across the professions, from computer science to data science, from healthcare to engineering. This course is designed to help students in these and other professions build skills and confidence in written, oral, and team communication. Our guiding, research-based premise for the course is that readers in professional contexts are busy, actively look for the information they need, and deserve to get that information in a clear and accessible way. In this course, you will strengthen your writing and communication skills through a series of projects that put real readers and users of documents at the center your writing process. Through genres like job application packages, proposals, presentations of complex information for non-experts, and team-based technical documentation, you will practice the skills you will need as you move from student writer to professional. The course is writing intensive, and requires regular participation and attendance. This course is designed for all undergraduates pursuing majors and minors outside English, and has no pre-requisites beyond First Year Writing.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-271 Introduction to Professional and Technical Writing
Fall and Spring: 9 units
Professional and technical communicators use words and images to connect people with information. With a strong foundation in rhetoric, this course will sharpen your abilities to communicate information clearly, effectively, and responsibly to real readers, stakeholders, and decision makers. Our assignments and conversations will include a wide range of genres and rhetorical situations you can expect to encounter as a professional and technical communicator, including job application genres, narrative genres like feature articles that blend subject matter interviews with keen observation, research genres like proposals, and team writing genres like technical documentation. A high level goal for the course is to combine theory, methods, and best practices for putting real readers and users of information at the center of our communication strategies. By the end of the course, you will have a portfolio of polished work that you can use to narrate your professional strengths and interests. This course is designed for undergraduates pursuing majors and minors in a writing and communication field, and who want to explore professional and technical communication as a discipline and career area.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-272 Language in Design
Fall: 9 units
Language in design is a professional communications course for designers. During your career as a designer, you will be expected to produce written documents to supplement and accompany your design processes and solutions. In this course, you will learn the conventions associated with the types of writing that designers most often have to produce on the job, such as proposals, memos, and reports. Additionally, you will prepare a job packet (including a resume, a cover letter, and a portfolio) that you can use as you begin your job search. You will also refine your ability to talk about your projects to both expert and non-expert audiences. Ultimately, this course aims to prepare you for the professional communications situations that you will encounter in your design career.

76-273 Presenting a Public Self
Fall: 9 units
Presenting your work and ambitions in public forums is a skill that you will be expected to demonstrate as you emerge from undergraduate studies and prepare to enter the commercial sector, graduate-level academic work or professional education in business, medicine or law. While such expectations exist, practice in this genre of writing, particularly in the personal statement, is not always readily available in existing coursework. "Presenting a Public Self" will introduce methods for developing and practicing your ability to communicate individual proficiencies and aspirations in written form, while bringing you in contact with a body of published work by public intellectual figures from the U.S. and other territories whose writing demonstrates an intertwining of personal narrative and public, professional identity, to engage readers of all stripes. Throughout the term you will practice writing in the public yet personal vein through assignments like: self-portrait essay, to cultivate a first-person voice, an op-ed essay, to practice balance in argument from the position of a burgeoning expert in your disciplinary area, and a personal statement, where you will learn to combine articulation of a personal narrative and professional competency to argue why you are a strong candidate for a particular opportunity. Reading selections for the semester will include work produced by your peers, as well as published writers whose work combines personal and professional spheres, ranging from texts like Paul John Eakin's Living Autobiographically to Mary Catherine Bateson's Composing a Life to Spencer Nadler's The Language of Cells: A Doctor and his Patients, amongst others.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-275 Critical Writing Workshop
Fall: 9 units
This course will introduce you to ways of critical thinking and writing about literary and media genres: poetry, drama, fiction and film. Authors may include William Blake, Percy Shelley, Jane Austen, Herman Melville, Emily Dickinson, H. G. Wells, Charlotte Perkins Gilman, T. S. Eliot, Toni Morrison, Tom Stoppard, or Don Delillo. Film directors may include Sergei Eisenstein, Orson Welles, Alfred Hitchcock, Jean-Luc Godard, or others. Students will learn how to interpret print and visual media and how to communicate their interpretations with clarity and self-awareness. To that end, students will write four short to mid-length interpretive papers to workshop in class.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-276 Genre Studies
Intermittent: 9 units
Topics vary by semester. Consult the course descriptions provided by the department for current offerings. Fall 2012: Poe defined the short story as something that could be read at one sitting. While simple enough, the definition suggests a concern with concentrated form and unified artistic effect. in a sense, the short story has been around as long as people have been telling each other tales, to be sure, but as a literary form it came into its own in modern times, during the 19th century and it continues to be produced in considerable numbers. For many readers one of the great features is the one Poe pointed to: it is short. People who have never finished a novel by Henry James must be legion. So we can experience something with genuine literary merit, in an accessible form. Concentration, of course, can bring issues of comprehension and often short stories can seem puzzling or incomplete to the average reader. This class will attempt to develop our abilities to read with care and attention—and feeling—in order to make us better readers of any artistic text. The challenges of the short form turn out to be excellent opportunities for learning a lot, in a little space. We'll make use of several inexpensive anthologies, and look at one or two central writers (Hemingway, for example) in more depth. The class will require the writing of a few short papers, engaging in online discussions on Blackboard, and three in class tests.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-281 Modern American Drama
Intermittent: 9 units
This course will focus on major American playwrights of the 20th century, likely including S. Glaspell, ONeill, Hellman, Wilder, Hansberry, Guare, Williams, Wilson, Mamet, Miller, Albee, Shepard, Wasserstein, Kushner, and Myers. Some plays will be viewed on video or in film adaptations.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-285 Team Communication
Intermittent: 6 units
This mini will introduce you to research and theory on how to create effective teams. In it, you will learn: - leadership strategies for managing projects and getting everyone to contribute to their best capacity
- interpersonal skills for negotiating team conflict - communication strategies for working with individuals from very different professional and cultural backgrounds. - techniques for fostering trust and inspiring team innovation and creativity - how to use technology to manage teams that are geographically separated Professor Joanna Wolfe has been studying student and professional technical teams for fifteen years and is the author of multiple books and award-winning articles on team communication. This course will be hands-on with assigned readings and video cases that are discussed in class with plenty of opportunities to role-play different communication strategies and techniques.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-286 Oral Communication
Intermittent: 6 units
Oral presentations are essential to professional success. Yet many people find themselves growing weak in the knees at the thought of presenting in front of a group. They read off of notes, speak too fast, or pepper their speech with nervous filler words such as "um" or "you know." 76-286 Oral Presentations is a mini intended for students who want to boost their confidence in presenting in front of others. You will learn strategies for structuring the content of a presentation, designing effective presentation slides, and controlling your voice and body language to produce a smooth, confident-sounding oral delivery. We will begin with giving short informal presentations and gradually increase the stakes as your confidence improves. You will have weekly opportunities to practice and improve your skills. We will also find opportunities to practice in a variety of physical settings so you can envision yourself as a calm, confident speaker no matter your surroundings. Grades in the course will be based on improvement and effort to encourage students to focus on their development rather than on final outcomes.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-292 Film Production
All Semesters: 9 units
Experiencing the process of filmmaking from the script to the set and to the editing room, students will develop a personal filmic language to create a short final film, exploring audio and visual forms that will serve the content they developed in their scripts. The focus will be on understanding the various aspect of the film grammar with an emphasis on the basic visual components - using space, tone, line, shape, color, movement and rhythm- and how they are used to visually tell the story. These components are used to define characters, communicate moods, emotions, thoughts and ideas.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-294 Interpretive Practices: Introduction to Critical Reading
Fall: 9 units
This course will introduce you to foundational theories and methods that form the practice of interpreting literary, poetic, cinematic, and other artistic modes of expression. We will start with an introduction to poetics through the works of Aristotle then move our way up through specific terms and theories of language, image and narrative as a system of communication and imaginative expression from Ferdinand Saussure to Roland Barthes and Hortense Spillers. I have organized our course around specific art works that I have paired with an interpretive reading practice and/or term. We will read, watch or listen to the works of: T.S. Eliot, Beyoncé, Sergei Eisenstein, Kara Walker, Mary Shelley and Percival Everett to name a few.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-295 Topics in Russian Language & Culture: 20th Century Russian Masterpieces
Fall: 9 units
The October Revolution of 1917 had profound effects not only for Russian society, but also for literature and culture. Even before the Revolution, Vladimir Lenin stressed the importance of literature on the hearts and minds of people. After the Revolution, the new Soviet state demanded writers to become, in Stalin's words, "engineers of human souls," and proclaimed "socialist realism" as the only permissible method of creative work in literature. This course focuses on masterpieces of Russian prose and poetry of the 20th century. Readings will include the "proletarian" writings of Maxim Gorky, the "symbolism" of Alexander Blok, the "futurism" and "modernism" of Vladimir Mayakovsky, as well as works by many other authors. We will discuss such important issues for Russian cultural history as the role of the intelligentsia in the Russian Revolution; the content and method of Russian decadence; symbolism and modernism; and the experience of imprisonment, liberation, and exile that became so important for many writers and poets.

76-300 Professional Seminar
Fall: 3 units
This weekly, 3-unit seminar is designed to give professional writing majors an overview of possible career and internship options and ways to pursue their professional interests. Each session will feature guest presenters who are professionals working in diverse communications-related fields such as web design, journalism, public relations, corporate and media relations, technical writing, medical communications, and working for non-profits. The visiting professionals talk about their own and related careers, show samples of their work, and answer student questions. The course is required for first-year MAPW students and is open to all English undergraduates, who are urged to participate in their sophomore or junior years to explore options for internships and careers.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-301 Internship
Fall and Spring
This course is designed to help you explore possible writing-related careers as you gain workplace experience and earn academic credit. You'll work on- or off-campus as an entry-level professional writer for 8-10 hours per week in a field of interest to you (public relations, journalism, advertising, magazine writing, non-profit, healthcare, etc.). You are responsible for finding an internship. Most of your class time for the course will be completed at your internship site - a minimum of 120 hours (8-10 per week) over the semester for 9 units of credit. As the academic component of the course, you'll keep a reflective journal and meet periodically with the internship coordinator to discuss your internship and related professional issues. You must register for the course before the add/drop deadline of the semester in which you want to do your internship. Before you can register, you must contact the internship instructor listed above to express your interest in the course and to be cleared for registration. Credit for the internship course cannot be retroactively awarded for past internships.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-302 Global Communication Center Practicum
Fall: 6 units
This practicum is restricted to students who have applied and accepted a position as a Global Communication Center tutor. For more information on applying, contact the course instructor. Students in this six-unit mini will learn about best practices in tutoring, gain experience analyzing and responding to a wide range of academic and professional genres, and learn to adapt their tutoring style for different kinds of students. In addition, we will learn to support oral, visual, and collaborative modes of communication alongside more traditional written genres. Assessments include regular hands-on activities, reading responses, and participation in class discussions. Please note that in terms of time commitment, a 6 unit mini is equivalent in weekly workload to a 12 unit full semester course. The mini is half the credits because it requires the same workload but only for half the semester.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: https://www.cmu.edu/gcc/faqs/index.html

76-306 Editing and Publishing
Fall and Spring
Note: Registration in this course is by permission only. Students must contact Prof. Costanzo directly. In this course students will work closely with the editors of Carnegie Mellon University Press to learn many of the facets of producing books. These range from business management and marketing to the elements of editing, book design, and production.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-307 Advanced Editing and Publishing
Fall and Spring
Note: Registration in this course is by permission only. Students must contact Prof. Costanzo directly. In this course students will work closely with the editors of Carnegie Mellon University Press to learn many of the facets of producing books. These range from business management and marketing to the elements of editing, book design, and production.

76-310 Advanced Studies in Film and Media
All Semesters: 9 units
This course will focus on several key technical components of filmmaking and the ways they function within the film text, as well as the ways they can be read as an indication of the underlying ideology of a work. Individual units of the course will concentrate on performance, production design, photography, editing and music. Films will be drawn from a variety of national cinemas from around the world. A primary goal of the course will be the development of skills useful for filmmaking, film analysis and scholarship. Students will engage in focused projects designed to facilitate the pedagogical goals of each unit.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-311 Acting Out in the London Theatre
Intermittent: 9 units
More Londoners went to the theater between 1660 and 1800 than read novels or even newspapers. The theater was THE social media of this formative period in the history of an English-speaking, urban public, and this course explores the power of the theater as a means of both social control and political resistance. What audiences did and said in the theater could matter as much as the plays in the formation of public opinion. A growing print media carried public consensus or dispute from the theater into coffee shops, taverns, and private libraries. Instead of taking a traditional "survey" approach to this period in the English theater, we will study a succession of "nights at the theater," specific performances of plays that happened on particularly eventful evenings when the playwhile significantwas not the only important performance. The introduction of an actress to a king who would make her his royal mistress, the final performance of a beloved actor, and the violent riots that were frequent occurrences in theaters are examples of cultural performances that shaped public opinion. We will read plays, of course, but also print and visual documents that speak to the moment of the play; we will listen to music, and generally immerse ourselves in the social and political struggles over public opinion in a world that very much prefigures our current world of celebrity and fake news.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-312 Crime and Justice in American Film
Intermittent: 9 units
Films dealing with criminal activities and criminal justice have always been popular at the box office. From the gangsters of the Thirties and the film noir of the Fifties to the more recent vigilante avenger films of Liam Neeson, the film industry has profited from films about crime and its consequences. How those subjects are portrayed, however, tells us a great deal about larger trends in American history and society. Every imaginable type of criminal activity has been depicted on screen, as have the legal ramifications of those acts. But these films raise profound questions. What is the nature of crime? What makes a criminal? Are there circumstances in which crime is justified? How do socioeconomic conditions affect the consequences? How fair and impartial is our justice system? Perhaps most importantly, how do depictions of crime and justice in popular media influence our answers to these questions? This class will utilize a variety of films to discuss the ways in which popular media portrays the sources of crime, the nature of criminals, the court and prison systems, and particular kinds of criminal acts. Films to be screened may include such titles as The Ox-Bow Incident, Out of the Past, 12 Angry Men, Young Mr. Lincoln, Brute Force, The Equalizer, Jack Reacher and Minority Report. By thoroughly discussing these films and related readings we will be able to trace the various changes in attitude towards crime and justice in America over the last century.

76-313 19th Century British: Victorian Sensations
Intermittent: 9 units
Today if something causes a "sensation," it gives us a rush of excitement, a public uproar, a scandalous controversy, a terrifying threat, all magnified to us by electronic and global media. How should we think about, as opposed to merely reacting to, such sensations that preoccupy both public media and personal fears and fantasies? This course will show that "sensation culture" began in the 19th century and has been ever since a key part of mass culture up to the sensations of the present. At the center of very different public "sensations" there could be serial killers, astonishing scientific discoveries, daring visions of revolutionary transformation, revelations of devastating poverty and over-the-top luxury and wealth. Sensations powerfully affect the feelings, body, and imagination whether they are exploitative media concoctions or staggering revelations of the most serious social and natural secrets. We will read across this range of Victorian sensations—from Dickens? Oliver Twist and the 1% vs. the 99%, to the jolt produced by new theories of evolution (Darwin and Chambers), to alarming visions of revolution (Marx and Engels), to terrifying domestic secrets revealed in "sensation novels," to the advent of the serial killer (Jack the Ripper and Mr. Hyde), to anthropologies of disease and death. We will see all of these in relation to the new Victorian mass print media that constructed these and other "sensations" to contemporary readers. Readings in recent theory will help us raise conceptual issues about what makes a sensation and why some current cases (think epidemic, terror, climate change, vast inequality) help us grasp the history of producing and responding to painfully serious or pleasurably spectacular "sensations."
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-314 Data Stories
Intermittent: 9 units
Every dataset has a story. In the age of big data, it is vital to understand the unlikely casts of algorithms, data miners, researchers, data janitors, pirates, data brokers, financiers, etc. whose activities shape culture. This course will feature a range of "farm to table" data stories, some going back hundreds of years, and introduce students to resources and strategies for contextual research. It will explore cases such as the London cholera epidemic, Google Books, Netflix, the Oxford English Dictionary, the Strava map, and the Queen Nefertiti scan alongside several pieces of art and fiction that capture aspects of data stories typically obscured elsewhere. Research methods introduced will include book history, media archeology, history of information, infrastructure studies, ethnography, narratology, and digital forensics. Students will read scholarly articles, novels, journalism, and popular non-fiction, and they will develop and individualized long-form research and writing projects informed by contemporary developments in data studies, journalism, and art.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-315 19th Century American Literature
Summer: 9 units
These days, it's pretty easy to get to Walden Pond. It's right off route 126 South (not too far from Concord) and there is a nice little farm stand there called the Farm at Walden Woods, where you can get corn and raspberries and freshly baked bread. In this class we'll go back in time to the Walden Pond of Thoreau's time, with a focus on the Green Nineteen—-writers and thinkers who considered the relationship between human civilization and the American wilderness (Thoreau, Emerson and Hawthorne). We will think about the interrelationship between the environment and nascent capitalist industries by reading the poetry and prose by young women who worked in the Lowell Mill (The Lowell Mill Offerings). We will also think about the environment in relation to two slave narratives (Douglass, The Slave Narrative of Frederick Douglass and Harriet A. Jacobs, Incidents in the Life of a Slave Girl. Finally we will consider the environmental consciousness of the two most important poets of the 19th century, Walt Whitman and Emily Dickinson. As for coursework, we will use the class to practice meditation, natures walks, and one group project in which you will design your own environmentally conscious Utopian community.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-317 Contemporary American Fiction
Intermittent: 9 units
No one seems to know quite how to define contemporary American fiction. It's clear that fiction has changed since the 1960s and 70s, the heyday of postmodernism, but it's not clear what exactly characterizes the work that has come since. In this course, we will read a selection of American fiction from the 1980s to the present and try to get a sense of its main lines. In particular we'll look at the turn to "genre," the expansion to multicultural authors, and the return to realism. Also, we will consider how it relates to American society. Authors might include Chimamanda Ngozi Adichie, Junot Diaz, Jennifer Egan, Bret Easton Ellis, Jonathan Franzen, Chang-Rae Lee, Emily St. John Mandel, Gary Shteyngart, and Colson Whitehead.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-318 Communicating in the Global Marketplace
Intermittent: 9 units
We live in a global world, whether we like it or not. Globalization is a political, economic, and cultural phenomenon that deeply impacts how well we can communicate with others in both professional and interpersonal settings. Regardless of the language people speak and the cultures that may have shaped our beliefs and values, we are bound together by professional interests and political agendas in a community that has no choice but to function well. In the current international environment, some of the most important and rewarding employment opportunities are with multinational and international corporations. But are we prepared for the challenge of working with professionals from all over the world? Even as more people around the globe learn English, specific cultural values, beliefs, and assumptions continue to influence the way in which they communicate. More often than not there is a whole different worldview behind a foreign accent. Globalization brings along several pressing questions: How can professional communicators avoid the potential for misunderstanding and conflict that comes with cultural difference? How can professional communicators contribute to shaping a workplace discourse that can reach a wide, diverse, global audience? How can professional global communication be effectively planned, measured, and improved? This courses prepares you to address these questions by explaining the specific ways in which national culture influences professional and technical communication, the impact of globalization on business environments and communication, and the ways in which you can rely on general concepts and principles in order to communicate effectively in specific international settings and situations.
Prerequisites: 76-272 or 76-271 or 76-270

76-319 Environmental Rhetoric
Fall: 9 units
Environmental rhetoric is a place of commitment and contention in which competing discourses celebrate our relationship with the natural world, frame environmental problems, and argue for public action. As we compare the environmental rhetoric of naturalists, scientists, policy makers, and activists, we will trace an American history that has managed to combine mystical celebration with militant critique, and scientific research with public debate. Equally important, this course will prepare you to act as a rhetorical consultant and writer, learning how writers communicate the three "Rs" of environmental rhetoric: relationship with nature, the presence of risk, and the need for response.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-320 Leadership & Organizational Communication
Intermittent: 9 units
Please note: In order to register for this course, students must have had an internship with an organization prior to registration. Even as most organizations continue to change, one constant is the importance of effective communication. Upward, downward, and lateral communications are the lifeblood of organizations. If you are in a leadership position, communication become your key tool for managing teams, improving performance, and creating change. In any position, you can spearhead progress by designing effective documents and improving existing communication practices. Proficiency in written and oral communications tends to be recognized and rewarded in organizations. Combined with the ability to leverage formal organizational structures and social networks, it helps one excel, and thrive, in organizations. This course is designed as an overview to the field of organizational communication with an emphasis on leadership roles and behaviors. The content will blend the conceptual with the practical. It will focus on problems that are likely to arise in the workplace and ways to solve them through communication. The students will build a portfolio of "solutions" that will demonstrate their evolving skills of applying rhetoric in organizational contexts. Specific topics will include the attributes of great communicators (including leaders and managers as communicators), the challenges of communicating in organizations as we play particular roles (e.g., individual contributor, manager or team member), ways to build credibility and enhance internal resumes, and techniques to master communication requirements related to performance management processes, conflict situations, and changing organizational culture and design. We will also explore a myriad of organizational issues such as communicating across generations and cultures, communicating externally, and communicating through technology.

76-321 History of the British Novel
Intermittent: 9 units
Topics vary by semester. Consult the course descriptions provided by the department for current offerings. Example, Fall 2011: Poe defined the short story as something that could be read at one sitting. While simple enough, the definition suggests a concern with concentrated form and unified artistic effect. in a sense, the short story has been around as long as people have been telling each other tales, to be sure, but as a literary form it came into its own in modern times, during the 19th century and it continues to be produced in considerable numbers. For many readers one of the great features is the one Poe pointed to: it is short. People who have never finished a novel by Henry James must be legion. So we can experience something with genuine literary merit, in an accessible form. Concentration, of course, can bring issues of comprehension and often short stories can seem puzzling or incomplete to the average reader. This class will attempt to develop our abilities to read with care and attention—and feeling—in order to make us better readers of any artistic text. The challenges of the short form turn out to be excellent opportunities for learning a lot, in a little space. We'll make use of several inexpensive anthologies, and look at one or two central writers (Hemingway, for example) in more depth. The class will require the writing of a few short papers, engaging in online discussions on Blackboard, and three in class tests.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-322 Gender and Sexuality in Performance
Intermittent: 4.5 units
"Performance" describes a wide range of practices, from the everyday to the artistic. Gender and sexuality are key elements in everyday, political, and artistic performances, from the very personalhow you order a latte at Tassa D'Oro, tell a lover goodbye at the airport or comfort a crying childto the very publicperforming a Bach cello suite or an iconic King Lear, staging a demonstration against police violence or marketing a new app. This course will be co-taught by a specialist in gender and queer theory and a practitioner of performance art. We plan to bring performance art and theory into a practical partnership in the creation and critique of social and individual narratives about gender and sexuality. How does everyday performance define gender and sexual identity? How do gender and sexuality define everyday performance? How does aesthetic performanceart, theater, film, digital media, poetryintervene in the ways in which gender and sexuality are performed? Readings in theory at the intersection between gender studies and performance studies will help us explore these questions. We will also consider a variety of cultural and artistic practices. The addition of simple performance prompts and exercises for students to incorporate into their research will blur theory and studio practices. Students will be encouraged to practice their theories surrounding performance within the classroom and in public space.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-323 God: A Literary and Cultural History
Intermittent: 9 units
This course will investigate ideas about God, primarily from the Western intellectual tradition. Our readings will include selections from Hebrew and Christian scripture, Dantes Inferno, Augustines Confessions, Benedict Spinozas Theological-Political Treatise, and Carl Schmitts Political Theology, as well as more recent investigations by Pope Francis, Marilynne Robinson, and Talal Asad. Students will be responsible for a presentation and two interpretive papers.

76-324 Topics in Rhetoric: Language and Place
Intermittent: 9 units
TBD
Prerequisite: 76-101

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-325 Intertextuality
Spring: 9 units
What do we mean when we say that someone has "twisted" our words, or that our words have been "taken out of context"? Why is Martin Luther King Jr. best remembered for saying, "I have a dream," and not for saying, "War is the greatest plague that can affect humanity"? What are political "talking points" and how are they perpetuated? How does a claim (unfounded or not) become a fact? How does a fact become a myth? These are just some of the questions that we will consider. More specifically, this is a course in how meaning changes as texts created in one context and for specific purposes are repeated, cited, and used in other contexts and for other purposes, sometimes related and relevant, sometimes not. More technically, we'll be focusing on the rhetorical nature of intertextual discourse. Our goal will be to examine the ways that people of all kinds¿including politicians, journalists, and scientists¿strategically draw upon and transform the statements, arguments, and evidence of other people to promote their own viewpoints or purposes. We will begin by investigating scholarship that views language as an extended conversation in which people struggle to have their own voices heard, and other voices countered or even suppressed. Later, we will survey a number of studies that suggest how individuals and organizations recontextualize and reinterpret prior discourse for persuasive ends. More specifically, we will analyze how the micro-features of the language (for example, qualifications, evaluations, and attributions) are used to persuade audiences that certain assertions are (not) factual, that certain speakers are (not) authoritative, and that certain proposed actions are (un)desirable. Ultimately, you can conduct your own research on intertextual rhetoric on a topic of specific interest to your academic or professional goals.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-327 Influential Women Writers
Intermittent: 9 units
Since long before the first autobiographical text in the English language? Margery Kempe?s?women writers have opened new territory for prose narrative. This course will deal with some historical examples of this phenomenon: Marie de France?s short fiction, Aphra Behn?s Orinoco, and, of course, Jane Austen? novels. We will then focus on some twentieth-century writers with various kinds of influence. Virginia Woolf is known for technical experimentation, and Ursula Le Guin excelled in the male-dominated arena of science fiction. The innovative use of known forms is represented by Hilary Mantel?s historical fiction and A. S. Byatt?s remarkable Possession.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-328 Visual Verbal Communication
Spring: 9 units
People create a wide range of communicative artifacts that integrates visual and verbal elements-newsletters, product brochures, web pages, graphical novels, journal articles, resumes, software references, yellow stickies, etc. Yet, such visual-verbal discourse has only recently attracted the serious attention of research communities. Some of the relevant research questions include: Why do visual variations exist across different contexts? (e.g., Popular science looks different from Discover.) Why and how do visual styles change over time? (e.g., Magazines from the 1950s don't look like present day magazines.) Do visual elements have persuasive power? If so, what roles do they play in shaping an argument? How do people learn to communicate using visual-verbal artifacts? In this seminar, we will address these and other questions through readings and discussions on various threads of studies around the analysis of communicative artifacts that integrate visual and verbal expressions. We will review key research publications concerning visual-verbal communication from relevant disciplines, including professional & technical communication, rhetoric, argumentation, and literacy. Particular attention will be paid to descriptive methods (e.g., social-semiotic analysis, visual argument, and rhetorical structure theory) and the types of questions these methods can help us answer. Throughout the semester, students will be encouraged to explore the visual-verbal communication artifacts found around them and use those to connect class discussions to the practice of design. Required assignments include a brief bi-weekly response to the readings, several short analysis papers, and a longer term paper with a topic chosen by students based on their professional or research interests.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-329 Unruly Women in Early Modern Drama
Intermittent: 9 units
"Unsex me here" Lady MacBeth famously exclaims on her path to murder, power, and psychological collapse. The connections between sex, gender, and agency that she articulates are connections that early modern theater-makers, from Shakespeare to Aphra Behn, obsessively revisited as they created some of the most haunting characters of the canon, both tragic and comic. In this course, we will look at shrews, witches, she-devils, ranting widows, aspiring divorcees, sex workers, roaring girls, evil queens, and all sorts of nasty women that would tread the boards in early modern London. At the heart of those theatrical depictions lie strong cultural anxieties surrounding the desire and possibility to fashion, control, and discipline¿in other words, to regulate and rule over¿femininity in a time period that witnessed the invention of the "two-sex model" (Thomas Laqueur) and "the cultural production of domestic heterosexuality" (Valerie Traub). How did theatre participate in the invention of early modern femininity? How did performance relate and/or resist the discourses about women deployed in the domains of law, religion, medicine, economy, and politics? How did women of color specifically fare in early modern dramaturgy? And what changed when women were allowed to act and actresses replaced boy actors under the Restoration? To study unruly women in early modern drama, we will read plays by Shakespeare, Elizabeth Cary, Ben Jonson, John Webster, Thomas Middleton, Thomas Heywood, Thomas Dekker, John Fletcher, Aphra Behn, and others in conversation with contextual materials and theoretical texts from the field of Women's, Gender, and Sexuality studies.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-331 Dissenters and Believers: Romanticism, Revolution, and Religions
Intermittent: 9 units
We usually think of the American and French revolutions as primarily political, but they also confronted dominant religious beliefs and generated alternatives ranging from enthusiasm and pantheism to atheism. We will explore the literary and political meanings of religious belief and dissent in major writers like Samuel Coleridge, Thomas Paine, Edmund Burke, William Wordsworth, Matthew Lewis and others who grappled with Protestantism, Catholicism, Dissent, and such interesting extreme alternatives as evangelicalism, enthusiasm, pantheism, and atheism. Two interpretive papers and in-class presentations will be required.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-108 and 76-106)

76-332 African American Literature: The African American Crime Novel
Intermittent: 9 units
Topics will vary by semester. Spring 2014: The hard-boiled crime novel, developed in the 1920s, 30s, and 40s, depicts a world full of corruption and exploitation, where law does not necessarily equal justice. But while early hard-boiled crime fiction was typically written by white authors and focused on white protagonists, African Americans soon found the genre particularly appropriate to depict their long experience with systemic racism and economic exploitation in the U.S. In this class, we will explore how African-American authors like Richard Wright, Chester Himes, Walter Mosely, and Paula Woods appropriated the hard-boiled crime novel over the 20th Century to represent the effects of racism and economic inequality on the black community and American society and, in doing so, developed the genre into a unique expression of African-American history and identity. We will also examine how the African-American crime novel is taken up by other cultural mediums like film and, more recently, the graphic novel to create new ways of expressing the genre.
Prerequisite: 76-101

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-333 Race and Controversy in the Arts
Intermittent: 9 units
In the last three years, social media platforms have given artists and consumers of art an unprecedented platform to engage with the commercial art world as both activists and critics. 2017's trending hashtag #oscarssowhite remarked on long-standing issues of inclusion within commercial filmmaking in the United States. Twitter also spread news from art worlds that were not always in the limelight; like Dana Schultz's painting "Open Casket" at the Whitney Biennial or Kenneth Goldsmith found poem "The Body of Michael Brown", read at an obscure conference at Brown University. Our course will put these and other controversies surrounding the politics of representation in the arts into broader historical and artistic contexts. We will approach the topic through particular case studies - from The Merchant of Venice to 2 Live Crew's obscenity trial - that highlight the confluence of social, political and artistic forces that frame these controversial works.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-106 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-334 Literature of Wall Street
Intermittent: 9 units
It started with a financial panic that closed the New York Stock Exchange for ten days. One quarter of the nation's transportation companies went bankrupt, as did nearly 20,000 businesses. Unemployment reached 14%. Four years later it was officially declared a "depression." When did all of this happen? Was it 2009? Or the 1930s? No, it was the depression triggered by the financial panic of 1873. Out of this period, also known as the "Gilded Age," came a unique strain of American literature. Frank Norris's grisly tale of an overbearing dentist and his miserly wife, McTeague, Andrew Carnegie's autobiography, Upton Sinclair's iconic The Jungle, Edith Wharton's tragic love story House of Mirth, Charlotte Perkins Gilman's feminist utopian novel, Herland, William Dean Howell's capitalist satire, The Rise of Silas Lapham, Theodor Drieser's mournful Sister Carrie-all of these writings react to, and try to shape, the economy of a century ago. These novels, which were often critical of corporate capitalism, give us a rich and detailed picture of the last time in the US that Americans suffered under the kind of gap we have today between rich and poor. In the US today the top 1% controls 42% of the country's wealth, while the bottom 80% controls a mere 7% of the country's wealth. What can we learn about the present by reading the fictions of financial crisis and inequality in the past?
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-335 20th and 21st Century American Fiction
Intermittent: 9 units
This course will examine American fiction from 1900 to the present. It will cover the movement from modernism, through midcentury realism and postmodernism, to the contemporary. We will look at scholarly definitions of those modes, as well as some of the cultural context that has informed American literature. Some of the authors will include modernists like Stein and Faulkner; midcentury writers and postmodernists like Ellison, McCarthy, and Pynchon; and contemporary writers like Diaz, Lahiri, and Franzen.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-337 Representations of Islam in Early Modern England
Intermittent: 9 units
This seminar explores the representation of Islam and Islamic cultures in early modern English literature, from the late Middle Ages to the beginning of the eighteenth century. In the early modern period, England had a complex multifaceted relation to the Islamic world. Since the Crusades, England had thought of the Islamic world as a deadly religious enemy to annihilate, but at the end of the sixteenth century, the Islamic world was also a key diplomatic ally against the Spanish archenemy, a fabulously rich trading partner in the world emporium of the Mediterranean sea, and an efficient model of empire to emulate in the Atlantic world. As a result, the Islamic world came to occupy a central place in English national imagination and maintained that place throughout the seventeenth century. What fantasies about the Islamic world does early modern English literature reveal? How do religion, race, gender, and sexuality intersect in the formation of those cultural fantasies? Do authors reinforce those fantasies or pressure them? How do specifically English social, political, and cultural issues inform literary representations of Islam? What image of England emerges when English authors use Islam as a mirror for the nation? In other words, what do texts about Islam tell us about early modern England? To answer those questions, we will read across genres, comparing romances, epic poems, plays, travel writing, pamphlets, and essays, and we will set canonical authors such as Chaucer, Spenser, Marlowe, Shakespeare, and Milton in conversation with other illuminating early modern writers such as Richard Knolles, George Sandys, Robert Daborne, Henry Stubbe, and Mary Pix.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-338 The American Cinema
Intermittent: 9 units
This course will look at major works and major directors of sound-era American Cinema in the context of the history of the film industry and the larger society. It will do so through lens of Hollywood 50 years ago, 1967, which has been called the annus mirabilis (miracle year) of American cinema. Most weeks we will watch a film from 1967 paired with one made before or since. The focus will on major stylistic and thematic continuities and developments. We will look at the work of major directors, such as Hawks, Hitchcock, Coppola, and Polanski, major genres, such as screwball comedy, crime dramas, and Westerns, and major styles, such as film noir.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-339 Topics in Film and Media: Hollywood vs. the World
Fall and Spring: 9 units
For almost a century the American film industry has dominated popular media worldwide. Anywhere in the world, American stars, American films, and American modes of storytelling are never far away. Why and how was that dominance achieved, and how have other cultures and industries challenged it? Film and television account for billions of dollars of U.S. exports and provide one of the key sources of global "soft power" and cultural influence. Understanding how that dominance works is therefore crucial to the question of America's economic, political and cultural place in the world. This course will examine ways in which other national cinemas have fought, or are currently fighting, against the hegemony of American popular film culture. We will discuss a variety of national cinemas including those of France, Mexico, India and China (among others). Students will be expected to watch at least two films a week outside of class, in addition to readings and written assignments.
Prerequisites: 76-101 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-340 American English
Spring: 9 units
Ever since the development of radio in the early 20th century, Americans have expected that we would soon all talk alike. The conviction that the media would make us all sound the same revived with the widespread adoption of television, starting in the 1940s, and the development of the internet in the 1990s led to worry about how soon we'd all be writing the same. But fears of the homogenizing effects of the mass media on American English have proven to be exaggerated: Americans still talk and write in many different ways. In this course we explore why this should be. Why don't we all speak alike? Why do we need variation in language? We will explore how regional and social dialects and varieties come to be and what their functions are, and you will learn how to hear, see, and describe varieties of language. We will also touch on American languages other than English. Documentary films and online materials about language will be the basis for another strand of the course, as we work together to explore how linguistic variety can best be represented and explained in non-technical ways, and in a variety of media, for the general public. Reading will be mainly in two books: American English, by Walt Wolfram and Natalie Schilling-Estes (2nd. edition), and Language in the USA: Themes for the Twenty-First Century, edited by Edward Finegan and John R. Rickford. There will be regular homework assignments, a midterm exam, and a final project.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-341 Gender and Sexuality in Performance
Intermittent: 9 units
"Performance" describes a wide range of practices, from the everyday to the artistic. Gender and sexuality are key elements in everyday, political, and artistic performances, from the very personalhow you order a latte at Tassa D'Oro, tell a lover goodbye at the airport or comfort a crying childto the very publicperforming a Bach cello suite or an iconic King Lear, staging a demonstration against police violence or marketing a new app. How does everyday performance define gender and sexual identity? How do gender and sexuality define everyday performance? How does aesthetic performanceart, theater, film, digital media, poetryintervene in the ways in which gender and sexuality are performed? Readings in theory at the intersection between gender studies and performance studies will help us explore these questions. We will read Judith Butler's work on gender as performative, Joseph Roach's work on the history of celebrity, Marvin Carlson's work on theater, and important essays in queer and transgender theory. We will also read and view a wide variety of cultural and artistic practices, from the British 17th century up to the recent work of feminist and queer performance artists. Your written and spoken contributions to the class will, besides regular postings on the course materials and participation in class discussions, entail the investigation of an everyday, cultural, or aesthetic performance of your choosing.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-343 Rise of the American Novel
Intermittent: 9 units
This course will survey American fiction from the beginning of the nation through the first half of the twentieth century. We will look at early fiction, like Washington Irving's "Rip Van Winkle" and mid-1800s classics like Hawthorne's Scarlet Letter, up to twentieth-century works like The Great Gatsby and perhaps some contemporary novels. Through the term, we will ask how the fiction represents the special character of American experience. Alongside readings, you will write several short papers and present some of your research to the class.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-344 Censored Texts
Intermittent: 9 units
Censorship? Banned books? Book burnings? Could it happen here? Over the last century some of the most important films and books have book banned, censored, protested and withdrawn from high schools and in rare cases, college courses or public libraries. But artists don't like to be silenced, and many of them have found ways to tell their stories, regardless of the consequences. In this course we will read a handful of books that have all been challenged by parents, school boards, and/or library patrons. This year is a special Sci-Fi/Fantasy version of the course! We will read texts including Shirley Jackson's The Lottery and Other Stories, J.D. Madeleine L'Engle A Wrinkle in Time, J.K Rowling, Harry Potter and the Sorcerer's Stone, Salman Rushdie's Satanic Verses, Margaret Atwood's The Handmaiden's Tale, Octavia Butler's Kindred, and Chuck Palahniuk's, Fight Club. We will also celebrate the American Library Association's banned book week, which is September 25th to October 1.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-345 Parchment to Pixels: History of Books
Intermittent: 4.5 units
This course surveys the evolution of the physical book through the history of writing materials, manuscript production, printing presses, type design, illustration, bookbinding, and book formats from the earliest times to the present. The best part: examining and experiencing real books from the 14th through 21st centuries in the Fine & Rare Book Room of Hunt Library. The course objective is to enable you to analyze and appreciate the purposes and attributes of books and related technologies. Some themes that help organize the 3,000 years of history of the book: types of content; information and communication; organization, storage, retrieval and transmission of knowledge; economic aspects; readers and community; parts of the book; effect of societal changes on the book; future of the book. Keep asking who or what enabled the next development. To flourish in the course, you will need to be curious, finding patterns and inter-relationships. Your evaluation will be based on class discussion, a journal, two quizzes, two short papers, and a take-home final exam to synthesize ideas.The class includes in-class, non-graded exercises on calligraphy, illuminating, binding, & 3-D printing.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-346 Angels and Diplomats -- Renaissance Poetry from Wyatt to Milton
Intermittent: 9 units
The starting point for this course is a question at the nexus of theology, politics, and art that no less central to the age of Shakespeare and Milton than it is today: how should power be represented? Biographically, many canonical poets of the sixteenth and seventeenth centuries worked as ambassadors, representing power abroad (Wyatt, Sidney, Donne, Marvell). Many more poets including Shakespeare and Milton thematized diplomacy, in both its divine and more worldly forms. What, then, can structures of mediation like diplomacy and angelic intervention tell us about works like Sidney's sonnet sequence Astrophil and Stella, Shakespeare's Hamlet, or Milton's Paradise Lost? And what can Renaissance poetry tell us about topics such as sovereignty, immunity, license, fidelity, automation, and accommodation? The course will include introductory and contextual readings from Genesis, Pseudo-Dionysius, John Calvin, Thomas Hobbes, Alberico Gentili, and George Puttenham. Assignments and class discussions will be occasions to practice historically-informed criticism; to compare conceptual structures within seemingly distinct domains of history and thought; and to articulate major fissures and changes in Renaissance angelology, diplomatic practice, and literary craft.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-347 Recent American Fiction
Intermittent: 9 units
We will read very recent American fiction, from about 1990 to the present. Authors might include Chimamanda Adichie, Michael Chabon, Junot Diaz, Jennifer Egan, Bret Easton Ellis, Jonathan Lethem, and Colson Whitehead. We will try to gather trends or tendencies that distinguish it from previous fiction. Does it suggest a different moment in fiction from postmodernism? And does it have a comment about American culture and its relation to the contemporary world?
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-106 and 76-108)

76-349 20th Century American: The Lost Generation
Intermittent: 9 units
Before the Beat Generation there was the Lost Generation. Both moments of literary history have an important relevance for our time, and both produced many major literary works. The 20s, like the 50s and 60s, were marked by the effects of World War. Gertrude Stein seems to have started the whole generation naming fad with her comment to Hemingway, "You are the lost generation." Paul Fussell identifies the cultural effect of WWI as the production of 'irony' as the central quality of modern identity (Some Beat writers make a similar claim for the effects of WWII). This class is neither a prequel nor a sequel to the Beat writers class; it is related in theme but focused on different writers and texts. Students might consider taking this class as a point of entry to 'The Beat,' or might consider this class as a follow-on to 'The Beat' in order to understand more fully some of the central literary and historical issues of our time. In both cases we focus on the intersection between cultural change and major war. The Lost Generation class might include, for example, work by Stein, Hemingway, W.B. Yeats, Ezra Pound, T.S. Eliot, the major War Poets, F. Scott Fitzgerald, Robert Graves, Vera Brittain, and Evelyn Waugh.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-350 Theory from Classics to Contemporary
Fall: 9 units
In this class, we will survey classic literary theories from Plato's exiling the poets from his ideal republic, through the philosopher Immanuel Kant's reflections on beauty, up to contemporary theories of deconstruction, Marxism, feminism, sexuality, and labor. (Our primary text will be The Norton Anthology of Theory and Criticism.) The class will give you a sense of the concepts and concerns critics have used to talk not only about literature but about culture and society.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-351 Rhetorical Invention
Intermittent: 9 units
Rhetorical invention refers to the discursive process of inquiry, discovery, and problem solving, or how we decide what to say, what arguments to advance, and what means of persuasion to use. Although invention is centrally important to rhetoric-without which it becomes a superficial and marginalized study of clarity, style, and arrangement-from the Scientific Revolution and Enlightenment through the mid-twentieth century invention all but disappeared as a topic of rhetorical study under the pressure of the view that invention should be exclusively directed by deductive logic and the empirical method rather than rhetorical considerations such as audience or language. This view of invention fundamentally shaped modern thought and continues to influence the ways we think and communicate today. In this course, we'll begin by examining the repudiation of rhetorical invention in the development of modern thought before focusing on efforts to recover a rhetorical understanding of invention from the mid-twentieth century forward, surveying a variety of contemporary theories of rhetorical invention including those promoted by postmodern, posthuman, and digital rhetorics. The course is designed to explore the central importance of invention to contemporary rhetorical theory through a pairing of historical and contemporary readings.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-353 Transnational Feminisms: Fiction and Film
Intermittent: 9 units
How do controversial practices related to women become touchstones that draw women together across cultures or, conversely, push them into separate cultural and political spheres? This introductory-level course familiarizes students with the challenges transnational feminism has posed to Western notions of feminism. To explore these contestations, we will look at a series of controversies. We will read these controversies through novels, drama, short stories and films, with some secondary theoretical readings. This course will take six case studies concerning cultural practices that have generated global debates about the status of women and issues like consent, freedom, and equality. Beginning with several works about regional/Islamic practices of veiling, we will look specifically at the close connections made between womens practices and elements of tradition, including religion. With an eye toward historicizing feminist interventions, we will look at 19th century debates on sati, commonly called widow burning, in India, to see how certain issues became loci for global intervention during colonial periods and, later, for global feminist movements. Within the contemporary period, we will turn to cultural, economic and political practices like female genital cutting, transnational domestic labor, global sex trade, and transnational forced marriage.
For each of these controversies, we will be reading a range of positions represented in different types of writing across genre, with a focus on literary and filmic depictions.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-108 and 76-106)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-354 South Asian Literature
Intermittent: 9 units
Topics vary by semester. Spring 2014: This course focuses on twentieth-century literature written in English from India, Pakistan and other parts of South Asia, as well as by people of South Asian origin. The course will begin by looking at literary representations that portray the struggle for decolonization and the trauma of partition. As we move forward to the contemporary period, we will examine the competing aesthetics of social and magical realism. We will then look back at India from the perspective of the diaspora, considering themes of identity, immigration and globalization from the perspective of South Asians writing in Britain and the United States. Texts might include works by Mulk Raj Anand, Bapsi Sidhwa, Amitav Ghosh, Salman Rushdie, Romesh Gunesekera, Arundhati Roy, Aravind Adiga, and Jhumpa Lahiri.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-355 Leadership, Dialogue, and Change
Fall: 9 units
This is a course about the tradition and strategies of leadership based on dialogue and how this powerful counter-rhetoric organizes people to work together on complex problems through problem-posing, pragmatic inquiry, and the inclusion of marginalized perspectives. By studying contemporary leadership theory and the American tradition of prophetic pragmatism, we explore ways everyday people can act on commitments and create change. Students will work as rhetorical consultants, learning methods for intercultural rhetorical research and developing a Community Think Tank on a current issue.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-106 and 76-108)

76-357 Linguistic & Social Aspects of Immigration
Intermittent: 9 units
This course introduces students to the linguistic and social aspects of immigration in today's global society. Immigration will be studied as a socio-political construct with an emphasis on the linguistic, socio-cultural, and political challenges and opportunities that migration creates for the individual and society. Throughout the course we will explore one key question: What challenges and opportunities do different aspects of migration posses for multilingual societies and individuals? A great deal of the course focuses on the linguistic challenges that migration creates for the individual and society, with a special emphasis on the development of bilingualism and the education of immigrant children. From a larger socio-political perspective, the course focuses on various case studies of immigrant populations throughout the world in order to obtain a better understanding of the characteristics, opportunities, and challenges faced by immigrant populations internationally.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-359 User Experience Methods for Documents
Intermittent: 9 units
This course will be useful for any student who is interested in learning more about user experience methods that are widely used in professions such as designing/writing for new media, technical writing, science and healthcare communication, public media relations, policy and non-profit communication. You will deepen your mastery of the following research skills associated with planning and testing documents: interviewing in context, retrospective interviewing, focus groups, surveys, and think-aloud usability testing of documents. In addition to specific research methods and skills, we will cover issues that pertain to all research methods: How many people do I need to include in my study? How should I select them? Are my results valid? Is what I think I'm finding out reliable? What are the ethical issues in my study? We will use a combination of lecture, discussion, exercises and projects to achieve these objectives.
Prerequisites: 76-270 or 76-271 or 76-272 or 76-390

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-360 Literary Journalism Workshop
Spring: 9 units
The class will help you tell true stories about the world you inhabit. Literary Journalism is a genre that reports on the world through stories that have been put through the lens of an individual writer's sympathetic imagination. Literary Journalism is always about the revelation of people and events, as influenced by social structures and ideas in a particular time and place. And again, unlike traditional journalism, the point of view of the writer is not supposedly "neutral". What makes this kind of non-fiction engaging often comes down to point of view. A writer is telling us a story they know well, either through observation or personal experience. Writers telling stories in this genre are opinionated, and often full of personality and voice. The obligation of the writer is to connect what might be merely "personal" to a wide audience, and usually, to connect what's personal to broader context, situating stories in the historical and political moment.
Prerequisites: 76-265 or 76-262 or 76-472 or 76-372 or 76-271 or 76-270 or 76-260 or 76-261

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-361 Corpus Rhetorical Analysis
Intermittent: 9 units
The Digital Humanities is a huge and growing field spanning many disciplines and skill sets. The focus of this course is on tools and methods that allow students to analyze textual corpora as purveyors of stories, information, and arguments that seek to influence cultural thinking, reveal existing cultural mindsets, and often both in tandem, either synchronically or diachronically. This is the point of view often taken by analysts who work for universities, think tanks and intelligence agencies who seek to understand cultural trends and mindsets from volumes of digital texts. For such analysts, close reading is an indispensable part of their work and computing tools help focus their reading while reading helps refine their understanding of the computer output. The course will give students intensive practice with methods and tools for analyzing corpora of text at the word, phrase, and sentence level, and with working with large scalable dictionaries and multivariate statistics.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-362 Reading in Forms: Fiction
Intermittent: 9 units
This course will give students a general introduction to the Gothic tradition in literature. The course aims to encourage creative writing students to engage critically and creatively with the tradition of Gothic fiction, and in particular with the trope of the house in the Gothic tradition. We will read six short novels in the genre, and we will also look briefly at some core theorizations. Students will use this critical understanding to develop further, and reflect upon, their own creative practice.
Prerequisite: 76-101

76-363 Reading in Forms: Poetry: Intro to Literary Translation
Intermittent: 9 units
This course will serve as an introduction to the theory and practice of literary translation. We will examine the concepts of fidelity to the original, authorial intention, the nuance of tone and style, and the politics of translation. Texts will include essays on theory and a variety of literary works (primarily fiction and poetry) in translation. We will look at multiple translations of the same work, and there will be the option for students to pursue their own project in literary translation. Working knowledge of a language other than English is helpful but is not required for this course.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-364 Reading in Forms: Fiction
Fall and Spring: 9 units
In this class we'll explore fiction about urban life and sub-culture primarily through critically acclaimed HBO series The Wire, supplemented by novels set in urban environments that subvert stereotype and tackle the complicated relationships between individuals, institutions, social conditions, and constricted opportunities. How can an author write about ordinary people making sense of their world while defying simplistic moral distinctions? How can an author successfully weave together the broad range of forces that shape the lives of those who are consigned to cyclical existences marked more my limitations than opportunity? How do you capture an authentic voice in such an environment? How do you avoid cliche? Whose story is it to tell?
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-365 Beginning Poetry Workshop
Fall and Spring: 9 units
This course is designed first and foremost as a workshop, meaning that a large percentage of class time will be devoted to critiquing your and your classmates' creative work. I will expect you to become strong editors and contributors to class discussion, and to accept and learn from criticism. You will be composing individual poems as well as working on a series or longer work. I will also assign a fair amount of reading, mainly contemporary poetry (individual poems and collections) published in the last few years. You will finish the semester by compiling a portfolio of creative work.
Prerequisites: (76-102 or 76-101 or 76-108 or 76-107 or 76-106) and (76-265 Min. grade B or 76-222 Min. grade B)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-366 Essay Writing Workshop
Intermittent: 9 units
In this course we will analyze the different types of narrative structure, narrative suspense, voice, metaphor, and point of view that make for effective non-fiction writing. We will also examine the difference between good writers and good work, the functions of objective distance from and intimate investment in a subject, as well as the philosophical questions spurred by non-fiction writing. What is the non-fiction writer's role, and how does it differ from that of the fiction writer? Where do the two genres overlap? What gives non-fiction writing integrity? What does the term creative non-fiction mean? How have the form and aims of non-fiction writing - from memoir to essays to long-form journalism - evolved for better and for worse? We will scrutinize the writing of Eula Bliss, Kate Fagan, Joan Didion, James Baldwin, Jo An Bear, Gary Younge, David Foster Wallace, Umberto Eco, and many others. In addition to critical writing assignments, students will have several opportunities to write their own non-fiction pieces.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-367 Fact Into Film: Translating History into Cinema
Intermittent: 9 units
From the very beginning, film has provided a window into the past. But how useful are the images we see through that window? For every person who reads a work of history, thousands will see a film on the same subject. But who will learn more? Can written history and filmed history perform the same tasks? Should we expect them to do so? How are these two historical forms related? How can they complement each other? This course will draw examples from across the history of film in order to examine how the medium of film impacts our understanding of facts and events, the ways that film transfers those facts to the screen, and how that process affects the creation of historical discourse. Films may include such titles as The Fall of the Roman Empire, The Gunfight at the O.K. Corral, Saving Private Ryan, World Trade Center, Enemy at the Gates, Lagaan and Hero.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-368 Role Playing Game Writing Workshop
Fall: 12 units
Role-playing games (RPGs) are a vibrant and viable popular medium for interactive storytelling. A generation of novelists, screenwriters, playwrights and TV writers came of age playing RPGs. They learned how to tell stories with their friends. Later on, they developed those skills and have won Pulitzers, Emmys, Tonys and Oscars. This workshop builds upon a thesis that interactive games share a large portion of dramatic theory DNA with plays, TV, and film. Play is performance. The skills developed when creating any time-bound media transfer well to games but must be seen through a different lens - the lens of the player. To do so, we first examine and dissect both RPG story and game design (using pencil and paper examples) seeking an understanding of both system as well as narrative best practices. Once we lay the groundwork, students are divided into three-to-five-person writing teams. Teams use an existing pen-and-paper RPG system to create a set of a campaign-style story for that system and that story world. The final product is a hard copy story bible of portfolio-quality. I emphasized this is a writing course, not an RPG design course. Any level of writing experience is welcome, as I provide support and instruction to scaffold in experienced students. More advanced students often find the unique authorial POV of games to be a very different challenge. Experience with and passion for RPGs is a must in this class.
Prerequisites: 76-269 Min. grade C or 76-260 Min. grade C

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-371 Innovation in Teamwork
Intermittent: 9 units
Academic teams, campus organizations, workplaces are all dynamic activity systems, organized and driven by institutional habits and rules, by roles, status and power, and by the material and conceptual tools we draw on. Yet as we have all observed, these Rules, Roles and Tools often operate in contradictory ways, even in conflict with one another. Effective team leaders are able to recognize these contradictions and draw a writing group, a project team, a social organization or a workplace into what is called an "expansive transformation." That is, to innovate new ways of working together. In this course, you will learn how to become more effective not only as a team member, but also a project leader, and even group consultant in your college work and workplace. Looking at films, case studies, research, and your own experience, we will learn how to analyze how teams of all sorts are working, to communicate more effectively across different expectations and values, and to collaboratively innovate new ways of working together. Your final project will let you document your ability to be a knowledgeable team leader and effective collaborator.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108)

76-372 News Writing
Fall: 9 units
In this course, we will study and learn the fundamental skills of journalistic writing. We will start with the basics - the importance of accuracy, clarity and fairness, writing for audience, striving for objectivity, judging newsworthiness, meeting deadlines. But the key to learning how to write in a journalistic style is to practice those skills so the core class work (and most of your grade) will be based on seven writing assignments due approximately every two weeks throughout the semester. Expect to do some writing each class period. We will learn how to write a story lede (yes, that's how journalists spell it), how to structure a story and how to write different kinds of news stories, from crime news to features to editorials and commentary. We also will learn how to research a news story, conduct an interview and sort through mountains of information to discern what's important so we can write about it in a clear, concise manner.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-373 Argument
Fall and Spring: 9 units
The purpose of this course is to give you extensive practice in analyzing and producing effective arguments. For us, an "argument" will involve the conveying of a reasoned position on an issue of controversy, and this conveying may take a variety of generic forms (op-ed pieces, political ads, websites, blogs, essays, grant proposals, prose fiction, films, images, and even everyday conversation). The course will introduce you to the fundamentals of argumentation theory and consider a variety of principles that concern the production, analysis and evaluation of verbal (and to a lesser extent, visual) arguments. You will apply the principles through discussion in class to various cases, through a series of written responses to readings, and by producing several written arguments.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-374 IDeATe - Dietrich College Cuban Interactive Documentary Project
Intermittent: 9 units
As diplomatic US-Cuban relations evolve, the possibilities of an enriching dialogue involving cultural, artistic, technical and economic areas of collaboration, between both nations, has become crucial. In this context, the idea of an academic course involving Carnegie Mellon University students and faculty visiting the city of Camagüey, Cuba under the umbrella of a holistic cultural experience of knowledge and discovery has been an inspiring learning option where participants can explore and research diverse areas of study within a socio-cultural environment known for the resourcefulness and creativity of its people, the diversity of its culture and a unique historical-geopolitical situation. The Carnegie Mellon University Cuban Media Production Class was created as an educational experience that considers the production of individual, multidisciplinary, media projects in, about, and inspired by contemporary Cuba. The concentration of this media class is open to the creative areas of video production, sound, photography, interactive media, writing, data visualization, media performance, etc. The main media production aspect of this class will take place during the Spring Break of 2019 (March 10-17). The individual projects will be done under the guidance of faculty, artists, filmmakers and media professionals from educational and cultural institutions in both countries. Student registration for this class is open and requires a letter of presentation + intention with the designated faculty in charge.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

76-375 Magazine Writing
Fall: 9 units
In this course we'll be reading lots of great nonfiction, some of which has appeared in magazines during the past few years. We'll look at how excellent nonfiction for magazines has to employ a strong narrative voice, and the techniques of storytelling. Students will be asked to research and write their own articles, based on a variety of assignments. The class will be conducted as a discussion, and demands participation from each class member.
Prerequisites: 76-372 or 76-272 or 76-260 or 76-262 or 76-271 or 76-270

Course Website: http://www.cmu.edu/hss/english/

76-377 Shakespeare and Film
Intermittent: 9 units
The dramatic works of William Shakespeare have inspired an extraordinarily rich and varied cinematic legacy that began in the era of silent films and now boasts masterpieces by directors such as Akira Kurosawa, Roman Polanski, Peter Greenaway, and Orson Welles, not to mention history-making performances by icons including Marlon Brando, Elizabeth Taylor, Laurence Olivier, Al Pacino, Leonardo DiCaprio, and Ian McKellen (among many others). This course will consider a selection of key Shakespeare films alongside critical readings centered on questions of adaptation and performance. As we watch and read together, we will work toward a broader understanding of what Shakespearean drama means in a 21st century context, and how film has helped to shape the author's massive cultural impact.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-378 Literacy: Educational Theory and Community Practice
Spring: 9 units
Literacy has been called the engine of economic development, the road to social advancement, and the prerequisite for critical abstract thought. But is it? And what should count as literacy: using the discourse of an educated elite or laying down a rap? This course combines theory, debate, and hands-on community engagement. Competing theories of what counts as "literacy"¿and how to teach it¿shape educational policy and workplace training. However, they may ignore some remarkable ways literacy is also used by people in non-elite communities to speak and act for themselves. In this introduction to the interdisciplinary study of literacy¿its history, theory, and problems¿we will first explore competing theories of what literacy allows you to do, how people learn to carry off different literate practices, and what schools should teach. Then we will turn ideas into action in a hands-on, community literacy project, helping urban students use writing to take literate action for themselves. As mentors, we meet on campus for 8 weeks with teenagers from Pittsburgh's inner city neighborhoods who are working on the challenging transition from school to work. They earn the opportunity to come to CMU as part of Start On Success (SOS), an innovative internship that helps urban teenagers with hidden learning disabilities negotiate the new demands of work or college. We mentor them through Decision Makers (a CMU computer-supported learning project that uses writing as a tool for reflective decision making.) As your SOS Scholar creates a personal Decision Maker's Journey Book and learns new strategies for writing, planning and decision making, you will support literacy in action and develop your own skills in intercultural collaboration and inquiry.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-106 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-380 Methods in Humanities Analytics
Intermittent: 9 units
The computer-aided analysis of text has become increasingly important to a variety of fields and the humanities is no exception, whether in the form of corpus linguistics, stylometrics, "distant reading," or the digital humanities. In this course, we will build a methodological toolkit for computer-aided textual analysis. That toolkit will include methods for the collection data, its processing via off-the-shelf software and some simple code, as well as its analysis using a variety of statistical techniques. In doing so, the class offers students in the humanities the opportunity to put their expertise in qualitative analysis into conversation with more quantitative approaches, and those from more technically-oriented fields the opportunity to gain experience with the possibilities and pitfalls of working with language. The first part of the term will be devoted to introducing fundamental concepts and taking a bird's eye view of their potential application in domains like academic writing, technical communication, and social media. From there, students will initiate projects of their own choosing and develop them over the course of the semester. The goal is to acquaint students with the strengths and limitations of computer-aided textual analysis and to provide them with the necessary foundational skills to design projects, to apply appropriate quantitative methods, and to report their results clearly and ethically to a variety of audiences. This class requires neither an advanced knowledge of statistics nor any previous coding experience, just a curiosity about language and the ways in which identifying patterns in language can help us solve problems and understand our world.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-381 Mad-Men, Television, and the History of Advertising
Intermittent: 9 units
Don Draper, cigarette in one hand, drink in the other, on the prowl for his next conquest - be it client or lover - may be one of the coolest characters ever created for American television. But is it just the suave style of Mad Men that has made it so popular? What is the secret to the show's success? In this class we will explore the rise and fall of the 20th century advertising model of mass culture by watching episodes from seven seasons of Mad Men, analyzing the show, and reading about the history of advertising as well as analyses of the show itself. Texts for the course will include Richard Ohmann's essay "Where did Mass Culture Come From?", Michael Schudson's Advertising: The Uneasy Persuasion, Archie Boston's Fly In The Buttermilk: Memoirs of an African American in Advertising, Design & Design Education, Susan Faludi: Backlash: The Undeclared War Against American Women, Scott F. Stoddart, editor, Analyzing Mad Men: Critical Essays on the Television Series and Lilly J. Goren and Linda Beail, editors, Mad Men and Politics: Nostalgia and the Remaking of Modern America.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-384 Race, Nation, and the Enemy
Intermittent: 9 units
Conflicts over racial and national identity continue to dominate headlines in the United States as they often have during the nation's history, from debates regarding the immigration, naturalization, and birthright citizenship of racial minorities to debates regarding racial disparities in access to civil rights. This course explores the discursive practices through which racial and national identities are formed and the frequent conflicts between them, particularly by focusing on the role of enemies, threats to the nation, and sacrifices made on behalf of the nation in American public discourse. Alongside primary sources of public discourse regarding wars, the immigration and citizenship of racial minorities, racial segregation and civil rights, and the criminal prosecutions of dissidents during periods of crisis, we will read secondary sources offering multiple theoretical and disciplinary approaches to the study of racial and national identity formation. Along with regular brief responses to readings, assignments will include a short rhetorical analysis paper and a longer research paper.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-106 and 76-108)

76-385 Introduction to Discourse Analysis
Intermittent: 9 units
"Discourse" is language: people talking or signing or writing. Discourse analysts ask and answer a variety of questions about how and why people do the things they do with language. We study the structure of written texts ¿ the semi-conscious rules people use to organize paragraphs, for example ¿ as well as the unconscious rules that organize oral discourse such as spontaneous stories and arguments. We study how people signal their intended audience-interpretations of what they say as foreground or background information, a casual remark or solemn promise, more of the same or change of topic. We look at how grammar is influenced by what people need to do with language, and how discourse affects grammar over time. We ask how children and other language learners learn how to make things happen with talk and writing. We ask how people learn what language is for, from exchanging information to writing poetry to perpetuating systems of belief. We analyze the choices speakers and writers make that show how they see themselves and how they relate to others. (Choices about how to address other people, for example, both create and reflect relationships of power and solidarity). We study how people define social processes like disease, aging, and disability as they talk about them, and how language is used to mirror and establish social relations in institutional settings like law courts and schools as well as in families and among friends. This course touches on a selection of these topics and gives students practice in analyzing the complex nuances of language. The course is meant for anyone whose future work is likely to involve critical and/or productive work with language: writers and other communication designers, critics who work with written or spoken texts, historians, actors, sociologists, and so on.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

76-386 Language & Culture
Intermittent: 9 units
This course is an introduction into the scholarship surrounding the nature of language and the question of how language shapes and is shaped by social, cultural and political contexts. We will begin by studying important literature in linguistics and language theory, both to introduce us to how scholars think about language and to give us a shared vocabulary to use for the rest of the semester. We will then move into case studies and theoretical works exploring the intersections of language use, individual and group identities, and the exercise of power, in its many forms. In particular, we will focus on the relationship between language and culture by asking, in what ways does language influence and constitute social change? How is social change reflected by changes in the way we use language? Over the course of the semester, you will work on applying the knowledge and theoretical tools you gain to your own analysis of a linguistic artifact that you choose.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-387 Writing in the Disciplines
Intermittent: 6 units
This mini will introduce you to the theory and practice of writing instruction in contexts outside of English studies. We will learn about the distinction between Writing across the Curriculum and Writing in the Disciplines and challenges to providing integrated, high quality writing instruction across the university. We will explore the implications of the wide variety of forms of academic writing for instruction in English classrooms, including high school and first-year writing classrooms. Assessments will include reading responses and a final paper reviewing research on writing in a specific writing context of your choosing. Students enrolled in the course for six units will be expected to do additional readings and give an oral presentation. Please note that in terms of time commitment, a 3-unit mini will require approximately six hours per week (three hours homework and three hours class meetings) and a 6-unit mini will require twelve hours per week.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

76-388 Coding for Humanists
Intermittent: 9 units
This introductory course provides humanities students with the foundational knowledge and skills to develop computer-aided research tools for text analysis. Through a series of hands-on coding exercises, students will explore computation as a means to engage in new questions and expand their thinking about textual artifacts. This course is designed for students with no (or very little) coding experience. During the early part of the semester, students will learn basic programming using Python through examples and problem sets that are relevant to text analysis. Then, students will be introduced to a limited set of commonly used Python packages for text analysis, such as natural language processing, statistical analysis, visualization, web scraping, and social media text mining. Students are expected to complete a small final project that examines how evidence-based data-driven insights derived from text analysis would support humanistic research in their area of interest, including (but not limited to) genre studies, rhetorical criticism, authorship attribution, discourse analysis, cultural analysis, social network analysis, spatial/temporal text analysis, and writing assessment. Doctoral students in the Department of English must register for 12 units, and are expected to write a publishable quality paper. Students who are interested in digital humanities scholarship in literary and cultural studies may also consider Professor Warren's seminar: 'Introduction to Digital Humanities.'
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-389 Rhetorical Grammar
Fall and Spring: 9 units
This course covers the anatomy of the single and multi-clause English written sentence and is useful for Master's students of professional writing (MAPWs) and English majors who wish to write with greater awareness and control of the English sentences they write and the awesome variety of sentences available to write. The course overviews the major grammatical forms and functions of the written English sentence. Students will learn to identify the major grammatical forms (Noun, Verb, Adjective), how these forms map on to grammatical functions (subject, verb, and direct object) and how forms and functions combine to create major constituents of the English sentence. Home-grown software, DiaGrammar, will allow students to diagram all the sentence varieties covered in the course. Students will leave this course with a systematic understanding of English sentence grammar as a resource for their continuing development as writers.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-390 Style
Fall and Spring: 9 units
Some people think of style as individual panache¿a graceful facility with language that is as distinctive to a given writer as his or her fingerprint. According to this theory, style is a possession¿a genetic talent that can be cultivated by one but never duplicated by another. Those who lack this innate stylistic flair often look for ways to compensate. Unable to achieve aesthetic beauty, they strive to be grammatically correct¿to follow the rules of writing. In this class, we will not treat style as an innate gift that writers possess and carry with them from situation to situation. Nor will we treat style as a set of rules that one can "live by." Instead, we will think of style as a set of strategic choices that one considers and selects from depending on the writing context. Certain stylistic choices appropriate to one context may not be appropriate to another. We cannot¿and will not¿look at all possible writing contexts in this class. Instead, we will focus our attention on professional writing contexts in which the goal (presumably) is to communicate clearly and coherently in texts composed of sentences and paragraphs.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-108 and 76-106)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-391 Document & Information Design
Fall: 12 units
This course provides students who have already learned the foundation of written communication with an opportunity to develop the ability to analyze and create visual-verbal synergy in printed documents. Students will be introduced to the basic concepts and vocabulary, as well as the practical issues of visual communication design through a series of hands-on projects in various rhetorical situations. Assigned readings will complement the projects in exploring document design from historical, theoretical, and technological perspectives. Class discussions and critiquing are an essential part of this course. Adobe InDesign, Photoshop, and Illustrator will be taught in class, and used to create the assigned projects.
Prerequisites: 76-270 or 76-271

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-393 Corpus Rhetorical Analysis
Intermittent: 9 units
As more of the world's texts become digital and systematically classified, scholars and analysts are increasingly able to analyze not only individual texts but also vast collections of texts, or textual corpora. The analysis of corpora becomes especially important when your focus of analysis is the genus rather than the individual and it has hundreds of applications. It is useful when instead of a single Aesop fable, you want to characterize Aesop's fables as a group and you want to compare them, as a group, with, say, the writings of a contemporary poet or the lyrics of contemporary musical artists. Corpus rhetorical analysis is also useful when you want to compare the styles of two columnists or critics based on a large sample of their writings. It is useful when you want to understand the ?nuts and bolts? rhetorical choices that make software documentation a different professional genre from sports journalism or science writing. This is a hands-on course where students get practice conducting corpus analyses using corpus software and statistical methods. The course is divided into three parts. In the first part, student will learn a theory of textual segmentation that is behind preparing a collection of texts for corpus study. In the second part, students will analyze corpora provided by the instructor and learn how to write a corpus report. In the third part, students will compile a corpus of their own choosing with a research question and then conduct a corpus study and submit a report that seeks to answer that question.

76-394 Research in English
Spring: 9 units
This course explores methods of researching, writing, and presenting original scholarly work in the broad interdisciplinary field of English Studies. The course allows both undergraduate and graduate students to pursue a research project on a topic of their choosing within the field of English studies to work on in the context of readings and discussions geared toward understanding the production of scholarly work in the field. We will work to understand not only traditional methods in the field such as textual analysis, but also more recent developments borrowed from other disciplines such as history and sociology, anthropology, and visual studies, among others. The course explores methods for developing topics, constructing research plans, locating, gathering, and using data and sources, along with basic principles of organizing, writing, revising, and presenting a research paper in a public presentation. Across the semester, students develop and work on an original scholarly research project culminating in a public presentation open to other students and faculty from the university.
Prerequisites: 76-275 or 76-294

76-395 Science Writing
Spring: 9 units
This course will teach students how to write clear, well-organized, compelling articles about science, technology and health topics for a general audience. Students will learn how to conduct research on scientific topics using primary and secondary sources, how to conduct interviews, and how to organize that information in a logical fashion for presentation. For writing majors, the course will increase their understanding of scientific research and how to describe it accurately and completely to a general audience. For science majors, this course will teach them how to craft fluid, powerful prose so that they can bring their disciplines to life. The course is not intended just for those who want to become science writers, but for anyone who may have the need to explain technical information to a general audience, whether it is an engineer describing a green building project at a public hearing, a doctor describing the latest research on a disease to a patient advocacy group, or a computer programmer describing new software to his firm's marketing staff. Scientists and educators today are increasingly concerned about the public's lack of understanding about scientific principles and practices, and this course is one step toward remedying that deficit.
Prerequisites: (76-108 or 76-107 or 76-106 or 76-101 or 76-102) and (76-271 or 76-270 or 76-472 or 76-375 or 76-372)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-396 Non-Profit Message Creation
Intermittent: 9 units
Non-profit organizations support a multitude of causes ranging from the arts to animals to the environment to health care to human rights to scientific research to many great causes in between. Non-profits achieve their missions by advocating on behalf of their organization's cause, raising public awareness about issues surrounding their cause, and fundraising to make their advocacy possible. In this course, students will select a local, Pittsburgh-area non-profit to examine and produce materials based on the organization's needs. Over the course of the semester students will research the organization's persona and values via interviews with chosen organization's staff and analysis of existing communication channels and different forms of content currently used by the organization. Students will use this research and analyses to inform and shape a final project that should meet the specified, needed deliverables from the selected non-profit. Previous example projects include: Revising a newsletter and specifying future best practices for an organization; developing new format and copy for an organization's website; developing a social media campaign for an upcoming event; developing a grant proposal for an organization's project; among many others. Students will have a wide selection of organizations to choose from and know projects associated with the organization at the beginning of the semester, as these will be organized by the professor. At the end of the course, students will have a portfolio ready material and an increased understanding as to how non-profit organizations advance their causes.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-397 Instructional Text Design
Intermittent: 9 units
This course focuses on the planning, writing, and evaluating of instruction of various kinds, especially instructional texts. It is particularly appropriate for professional and technical writers, but also a good option for anyone interested in fields that involve substantial instruction, such as teaching or employee training. In the first part of the course, we'll examine the recent history of instructional design and the major current theories. Then we'll take a step back and study the concepts of learning upon which these theories are based, with particular attention to their implications for how instruction is structured. You'll find that different learners (e.g., children, older adults) and goals (e.g., learning concepts and principles, learning to apply principles to solve novel problems, learning a complex skill, learning to change one's behavior, etc.) require different types of instruction. In the second part of the course, we'll look in detail at models of how people learn from texts and what features (e.g., advanced organizers, examples, metaphors, illustrations, multimedia) enhance learning under what circumstances. We will study and analyze particular types of texts. Some possible examples include an introduction to the concept of gravity; a tutorial for computer software; a self-paced unit in French; adult educational materials in health care; a workshop on sexual harassment in the workplace; or a unit to train someone how to moderate a discussion. We will also look at various methods (concept mapping, think-aloud, comprehension tests, etc.) that are used to plan and evaluate instructional text. You will do a project, either individually or in a small group (2-3), in which you design, write and evaluate instruction.
Prerequisites: 76-101 or 76-102 or 76-270 or 76-271 or 76-271 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-398 Museum of Broken Relationships
Intermittent: 9 units
The Museum of Broken Relationships in Zagreb, Croatia is a museum dedicated to "failed love relationships." Its exhibits are made up of objects and stories that have been donated after relationships have failed. In the short time since the museum was established, 37 exhibitions have been mounted in cities all over the world. In November 2016, Pittsburgh will host an exhibition. Students who enroll in this course will have the chance to see photos and read stories from other exhibits. They will learn how to conduct the collection process, and then go into the community to collect stories and objects. They will also collaborate with Masters students from Entertainment Technology's Location-Based Entertainment track, who specialize in designing and implementing exhibits. Together, these groups will then curate a show with stories and objects that reflect the culture and history of Pittsburgh. This course is designed for students who love stories and have the curiosity and motivation to travel throughout Pittsburgh to find them.
Prerequisites: 76-360 Min. grade C or 76-460 Min. grade C or 76-366 Min. grade C or 76-365 Min. grade C

76-403 The Crucible of Modernity:Vienna 1900
Intermittent: 9 units
Vienna at the turn of the century (that is, at the turn of the last century, 1900) was many things: the political center of the Habsburg dynasty of the Austro-Hungarian Empire; the meeting place of Czechs, Slovaks, Hungarians, Romanians, Slavs, Poles, Italians, Serbs, Bulgarians, and Germans; the center of German-language music and theater; the birthplace of Zionism and of psychoanalysis; the battleground for liberalism and anti-Semitism; a haven for socialism; the home of café-culture and the waltz; the garrison for an outdated army; the city of baroque urban palaces and squalid backyard tenements; the center for Enlightenment public policy and reactionary bureaucracy; and the showcase for historicism. And while the story of Viennas cultural and political turmoil is interesting, it probably would not command our attention today were it not for its role as the birthplace of Modernism. In an effort to understand todays intellectual environment, therefore, we will examine Vienna before the collapse of the Austro-Hungarian Empire in 1918. We will be looking at a huge and at times confusing canvas which by necessity includes almost every aspect of culture. We will start with politics and history and move on through art, architecture, crafts, psychoanalysis, literature, music, and philosophy. We will be looking at art nouveau buildings and furniture, reading literature, viewing films, and listening to recordings - and we will build 3D models on a digital map which will help us understand how the different arts were all connected and influenced each other. Language of instruction: English

76-404 Critical Race & Ethnicity Studies
Spring: 4.5 units
Terms commonly associated with the academic study of race and ethnicity have gained or regained prominence within our always volatile political discourse: intersectionality, identity politics, white supremacy and blackness. But what is critical race and ethnic studies? What are the "theories" about race, ethnicity, art, subjectivity, power, knowledge and the human that have driven the scholarship and intellectual work for scholars committed to an interdisciplinary exploration of race and ethnicity? This course will introduce students to some of the key figures, terms, debates that have emerged out of critical race and ethnicity studies with a particular focus on how the "structuralist controversy", which foregrounded critiques of the "subject" have changed the way scholars talk about race, ethnicity and identity since the middle of the twentieth-century. Given the wide ranging and interdisciplinary nature of critical race and ethnicity studies our readings will inherently cover disciples such as literary criticism and theory, legal studies, anthropology, linguistics, science and technology studies and film studies to name a few. Readings may include: W.E.B. Du Bois, Kimberly Crenshaw, bell hooks, Richard Dyer, Edward Said, Stuart Hall, Michel Foucault, Jacques Derrida, Henry Louis Gates Jr., Claudia Sharpe, Denise D' Silva, Gayatri Spivak, Eduardo Bonilla Silva and Achille Mbembe. There will be two short papers.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-405 Institutional Studies: English as a Discipline
All Semesters: 4.5 units
The institution on which this course will focus is the academic discipline, the specific historical form that the production of knowledge in the modern research university has assumed. This course will examine the historical development of the discourses, practices, organs, and associations that have defined English as a discipline. While we will of necessity also look at the theories and values that the discipline has proclaimed at different times, this will not mainly be a course in the history of criticism. Criticism will be considered as one practice among others including philology, literary history, literary theory, rhetoric, and composition. In order to understand the broader context, we will read work by Foucault and others on disciplinarity. We will also examine allied institutions, including the professions and the university.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-410 The Long Eighteenth Century
Fall
This course offers students a chance to understand how English literature became modern. We will explore the cultural and historical processes by which we get from Shakespeare to Austen by looking at the historical development of two media forms, the stage play and the novel. Since this archive includes an impossible amount of material to cover in a semester's work, we will focus on some points of connection and synergy between these forms. For example, we will read a novel and a play by Aphra Behn, a poet, playwright, spy and one of the inventors of the modern novel. Eliza Haywood was both an actress and a prolific and successful novelist of the early 18th century. One of the "fathers" of the modern novel, Henry Fielding, cut his literary teeth writing plays for the Haymarket Theatre, which he also managed (and Haywood acted in). Frances Burney wrote a wildly successful novel, Evelina or a Young Lady's Entrance into the World, but she also wrote plays and was part of London literary circles that included famous actors, musicians, and other performers for the stage. We will end with Austen's novel, Mansfield Park, which stages on its pages an amateur production of a play in order to reflect the pleasures and dangers of theatricality. We will look at the interplay between theater and print fiction and how they mutually inform and help to define each other. We will ask how public theatrical institutions and performances and the technology of print contributed to the modern world of proliferating media forms.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-412 Performance and 18th Century Theatrical Culture
Intermittent: 9 units
This course has the dual purpose of introducing students to performance and celebrity studies and giving them experience in using these analytic frameworks to study 18th-century literature and culture. Celebrity is a very modern phenomenon that first became a visible part of political, religious, and artistic culture over the course of the long 18th century, between 1660 and 1800. We will investigate the genealogies of modern celebrity, considering such questions as, what do the Kardashians have to do with dead English kings? What can cross-dressing actresses teach us about 21st-century drag performances? (Full disclosure: Dead English kings and cross-dressing actresses will get far more of our attention than the Kardashians or modern drag artists.) We will study some of the most powerful recent theories of performance and celebrity; we will read plays and other performance genres that took up time and space on the 18th-century stage. In addition, we will explore beyond the London theaters to consider the nature of performance in its many cultural forms: What are the connections between theater and the quieter performances of political pamphlets, newspapers, and novels as they occupy physical and mental space in coffee houses and libraries? Can a print text be performative? Finally, we will examine various relationships between performance and culture. How does performance in the early modern period shape gender and sexuality as well as class and race relations? This course will count as an upper-level course for the Gender Studies Minor, as well as a pre-1900 period course for the EBA.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-413 19th Century British Literay and Cultural Studies
Intermittent: 9 units
Topics vary by semester. Consult the course descriptions provided by the department for current offerings. Example, Fall 2010: In the early decades of the twentieth century, Irish and British writers transformed literary representation, abandoning the certainty of Realism to delve into representations of the human subconscious resulting in fractured narratives in keeping with the uncertainty of that historically pivotal time. As conceptions of national identity were called into question with traumas associated with the First World War, Modernist writers attended to the tensions between wholeness and disintegration in the individual and in collective bodies. In Irish and British Modernism we will explore the tensions between illusions of a whole associated with political movements like nationalism and fascism and the disorienting though sometimes liberating forces of disintegration that surfaced in the essays, poetry, plays, novels and short stories of four Modernist writers: James Joyce, Virginia Woolf, William Butler Yeats and T.S. Eliot. American Modernism will be offered in the spring, which will build off elements of this initial introduction to Irish and British Modernism. Requirements for this course will include active participation in class conversations, bi-weekly response papers and a fifteen to twenty page research paper.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-414 Politics, Media, and Romantic Literature 1789-1830
Intermittent: 9 units
The Romantic period in Britain was a volatile era of political and literary revolutions - but also of print-media revolutions that transformed reading, writing, and publishing. This course focuses the question of books, periodicals, and reading audiences through case studies of several Romantic writers: Mary Robinson, William Blake, Samuel Taylor Coleridge, John Keats, William Hazlitt, and William Wordsworth. Reading a selection of their poems, essays, and critical theory in the context of contemporary debates, we will aim to understand the relation between print as a set of material forms, and political as well as literary ideas and discourses that contended for attention in the period's innovative print media We will also try to grasp some wider cultural processes at work in the late eighteenth and early nineteenth century. These included disintegration of the early modern Republic of Letters and the reconfiguration of its knowledges in the nineteenth-century cultural fields; the forming and division of new reading publics and their ways of reading print; important changes in book production, typography, printing methods (hand-press to steam press), and bookselling; and the crucially important relation between the aesthetic powers of the ?text? and the material pleasures of the "book." Research papers using rare-book materials at the Hunt or Hillman library Special Collections will be especially encouraged; and the course will sometimes meet in the archive to examine "rare and curious" modes of print. One short paper and one research paper will be required.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-108 and 76-106)

76-415 Mediated Power and Propaganda
Intermittent: 9 units
For most of us, the word "propaganda" triggers a familiar script. We tend to think of totalitarian regimes where the State controls information and prohibits the expression of dissenting views. We also tend to associate propaganda with certain rhetorical techniques - highly emotional words, deceptive representations, and glittering generalities that inhibit rational thought and manipulate public opinion. According to such popular views, propaganda is linked to the dissemination of false information and is antithetical to the norms of democratic society. Our class will challenge these assumptions. First, instead of confining propaganda to authoritarian governments, we will examine how propaganda functions within democratic society. Indeed, we will focus on domestic propaganda in America, especially political propaganda but also propaganda in advertising and public relations. Next, instead of focusing exclusively on deceptive rhetorical techniques, we will ask a more elemental question: What enables propaganda to circulate? Answering this question will force us to consider the routines and values of corporate media as well as the power relations that give some people special access to channels of mass communication. Certainly, we will also examine propaganda messages themselves, attending to manipulative tactics as well as rhetorical strategies used to induce uptake in the mainstream press. We begin our seminar by studying key theories of propaganda, looking at primary texts for various definitions and criticisms of the concept. We will then examine how powerful institutions, especially media organizations, manage the dissemination of propaganda in democracies. Finally, we will consider how to analyze propaganda, generating methodological prerequisites for scholarly study. Ultimately, students will have the opportunity to conduct their own research on propaganda as it relates to their academic and professional goals.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-418 Rhetoric and the Body
Intermittent: 9 units
This course offers an introduction to rhetorical studies of the body and is centered on the following three questions: What is the role of the body in rhetorical theory? What role does rhetoric play in constructing the body as a raced, gendered, dis/abled, cultural, fleshy, and political entity? And, how might moving, feeling bodies challenge, regulate, or disrupt these rhetorical constructions and furthermore, our theories of rhetoric? Our readings will explore the role of embodiment in rhetorical theory, examining a number of contemporary and historical theories of the body. In the process, we will explore how to put rhetoric and the body into conversation with one another and what methodological implications this conversation has for rhetorical studies more broadly. The goal of this course is to provide breadth rather than depth, with the assumption that most students, even those relatively familiar with body and/or rhetorical theory, will approach rhetorical studies of the body as novices. Students will conduct their own research on a topic related to rhetorical studies of the body that also aligns with their professional and academic goals. Graduate students interested in research will benefit from this course's focus on theory and the professional genres central to rhetorical studies. Undergraduates students (both majors and non-majors) will have the opportunity to examine how the body intersects with communication and writing contexts in their everyday public and professional lives. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-419 Media in a Digital Age
Intermittent: 9 units
How are media in a digital age changing? And how are they changing us? What does it mean to be living in today's communication technology "revolution"? In a time when many forms of communication are digitally based, traveling as bits at e-speeds on global computer networks? To begin answering these questions, we will take as case studies several new discursive digital media formations, such as digital books, on-line newspapers, blogs, wikis, and so forth, along with related social formations, such as social media networksand distributed non-profit activist organizations. The readings will provide a range of lens by which to understand these developments, including cognitive, social, political, economic and technological aspects. We will briefly put the development of communication technologies in their historical context: How were new forms of communication received in the past? How were they used? How did they affect communication? How did they influence political and social institutions? We will focus, however, on using knowledge of historical developments to inform our understandings of current digital communication developments. Along the way we will ask questions, such as " What are some of the challenges that new digital formations present to traditional communication theories (e.g., How is trust established when speakers are anonymous and globally distributed? How is the "public sphere" constituted when Internet search engines dynamically construct it?). Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-420 The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process
Spring: 9 units
Understanding reading and writing as a social/cognitive process (i.e., a socially situated thinking, feeling, problem-solving process) reveals some of the conscious and unconscious work behind the ways readers comprehend and interpret texts, and the ways writers construct and communicate meanings through them. To gain insight into the why behind the surprising things readers do with a text, we will draw on the psychology of reading, where socially constructed memory networks, cognitive schemas, and meta-knowledge actively shape interpretation. User-testing to discover the representations readers are in fact creating can be critical for many kinds of writing, from informative websites, to persuasive arguments, or engaging accounts. Turning then to writers, we will examine the key processes, from interpreting the task, to planning, revision and metacognitive awareness on which expert and novice writers differ. You will also learn a set of process-tracing methods for tracking these problem-solving strategies as you do two case studies. One will uncover the (sometimes radical) differences in how a set of readers actually interpret (construct the meaning of) a text you choose. The second will be an extended case study of your own thinking process on a real task you are doing outside this class. Here you are likely to uncover old unconscious habits and problems you had to solve, as well as successful strategies, which will give you new reflective insight into your own thinking as a writer. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-421 Why Stories Matter
Intermittent: 9 units
Storytelling is a key aspect of our experience as human beings; without it we are reduced to, as one scholar put it, "the most primitive mode of existence - a life without imaginary alternatives." In this course we will study some key fictions that have provided such imaginary alternatives, alongside various theories for interpreting them. These narratives deal with some of the most important aspects of the human condition: time, justice, empathy, point of view, and reality. The authors we will cover are among the most enduring in the Western tradition, from Sophocles and Chaucer to Melville, Proust, Virginia Woolf, and Ian McEwan. Students will be required to contribute to all class meetings, write brief responses on Blackboard, and produce two substantial essays (longer for grads than undergrads).
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-422 Gender and Sexuality Studies
Intermittent: 4.5 units
We will anchor our introduction to this broad and diverse field of theory in the admittedly very limited historical period of feminist, queer, and transgender political activism, circa 1970 to the present day. Instead of attempting "coverage" (an impossible task), we will shuttle between recent work in queer, transgender, and feminist theory and a few key texts that are foundational to the development of academic theory as a reaction to and extension from the political activism of these social movements. Our goals are to strengthen our understanding of the continuities and breaks in politically informed thinking about gender and sexuality, and to deepen our knowledge of the theoretical frameworks available to us from these areas of study. Students will write short response papers to course readings that will help us focus our discussions on their particular interests in literary and cultural studies.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-425 Science in the Public Sphere
Intermittent: 9 units
Topics will vary by semester. Spring 2013: Ever since the dawn of the Industrial Revolution and the rise of the technological exhibition in the nineteenth century, there has been a growing presence for science and technology in the lives of everyday citizens. In some cases, these phenomena have sparked the public's imagination and their promise has stirred their confidence in a better future. In other cases, they have kindled fears and generated protests over the risks of new technologies and the threats of novel scientific ideas to prevailing social, cultural, economic, and political orders. This course examines the complex dynamics in the relationships between science, technology, and society. Towards this end it engages with questions such as: How do we decide who an expert is? To what extent do scientists have an obligation to consider the social and ethical consequences of their work? Is public education about science and technology sufficient for addressing social concerns about risk and controversial scientific ideas? We will grapple with these and other questions by exploring modern public debates in which science, technology, and society play a primary role such as the AIDS crisis, global warming, and the autism vaccine debate. With the help of analytical theories from sociology, rhetoric, and public policy, we will develop a general framework for thinking about argument and the dynamics of the relationship between science, technology and the public. In addition, we will look to these fields for tools to assess specific instances of public debate and to complicate and/or affirm the prevailing theories about their relationship. (See Department for full description.)
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-428 Visual Verbal Communication
Fall: 9 units
People create a wide range of communicative artifacts that integrates visual and verbal elements-newsletters, product brochures, web pages, graphical novels, journal articles, resumes, software references, yellow stickies, etc. Yet, such visual-verbal discourse has only recently attracted the serious attention of research communities. Some of the relevant research questions include: Why do visual variations exist across different contexts? (e.g., Popular science looks different from Discover.) Why and how do visual styles change over time? (e.g., Magazines from the 1950s don't look like present day magazines.) Do visual elements have persuasive power? If so, what roles do they play in shaping an argument? How do people learn to communicate using visual-verbal artifacts? In this seminar, we will address these and other questions through readings and discussions on various threads of studies around the analysis of communicative artifacts that integrate visual and verbal expressions. We will review key research publications concerning visual-verbal communication from relevant disciplines, including professional & technical communication, rhetoric, argumentation, and literacy. Particular attention will be paid to descriptive methods (e.g., social-semiotic analysis, visual argument, and rhetorical structure theory) and the types of questions these methods can help us answer. Throughout the semester, students will be encouraged to explore the visual-verbal communication artifacts found around them and use those to connect class discussions to the practice of design. Required assignments include a brief bi-weekly response to the readings, several short analysis papers, and a longer term paper with a topic chosen by students based on their professional or research interests. Please see English Dept. for full course description.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-429 Digital Humanities: Politics and Early Modern Drama
Intermittent: 9 units
This course will explore a range of questions related to the manifestation of political thinking on the early modern English stage, a key medium for the dissemination and cultivation of information and ideas. Our central curriculum will include plays by William Shakespeare, Thomas Middleton, Christopher Marlowe, and others alongside a selection of critical essays and related literature from the period. To complement this collective investigation, students will also complete a hands-on, entry-level assignment that introduces digital methodologies for visualizing and analyzing early modern texts. No previous experience with the digital humanities is necessary to participate. Technological neophytes, seasoned programmers, and persons at all skill levels in-between are all very welcome to participate.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-430 Greatest Hits from the Medieval World
Fall: 9 units
Some stories never go out of style. Much of what we will read in this course was popular throughout Europe, and all of it is still widely retold and enjoyed in various media: for example, Beowulf, Decameron, and Dante's Inferno in film, Tristan in opera, Malory's Morte D'Arthur in lots of formats. We will consider the medieval telling of these tales and others from the eighth to the fifteenth centuries. Anglo-Saxon, French, German, Italian, and some Middle English texts will be read in translation, but Chaucer and Malory in edited versions of their writer's idioms. A particular emphasis will be placed on personal subjectivities to counter the rumor that individual selfhood began with Shakespeare (the inventor of the human, according to Harold Bloom). Some of our texts are reflective, some are outrageous, some are charming, some are funny; all are populated by human beings we can recognize in spite of the unfamiliar styles in which they are presented. Learning outcomes include a sense of both the historical conditions for storytelling and the ways tales can take on new meanings over time. Graduate students will be responsible for reading additional historical and critical materials and writing longer papers than undergrads.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-431 Chaucer
Intermittent: 9 units
We will read most of Chaucer's Canterbury Tales and his narrative poem Troilus and Criseyde (considered by some the first English novel). Our texts are in Middle English-Chaucer's language is odd-looking, but easily mastered. We will also read some brief accounts of 14th-century institutions and traditions (chivalry, religious life, marriage, etc.). Most class meetings will consist of discussions that examine these fictions in relation to the social conditions they imply and the tellers' stakes in the telling. While we are discussing the General Prologue, I will ask each of you to identify the pilgrim through whose eyes you will try to read each of the tales (in addition, of course, to seeing from your own vantage point). As the course goes on, you will become an expert on one of the social roles portrayed in Chaucer's fictional universe. Required are near-perfect attendance, steady participation, and three papers. Graduate students will meet for an extra hour a week, read additional materials, and write longer papers.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-432 Advanced Seminar in African American Studies
Intermittent: 9 units
Topics will vary by semester. Consult the course descriptions provided by the department for current offerings. Example, Fall 2011: This course will be an in-depth study of James Baldwin's works as well as the writers and thinkers that influenced him. Baldwin's rumination on American life during and after the epoch defining events of Civil Rights Era reflects the great political and cultural transformations the country struggled through. In this course students will read canonical works such as Notes of A Native Son and Giovanni's Room as well as lesser know works like One Day When I Was Lost, Baldwin's screenplay for a never-to-be-produced film project on Malcolm X and Little Man, Little Man: A Story of Childhood, a children's novel he published in 1976. Besides Baldwin's works we will read and connect Baldwin's thoughts on literature, race, sexuality and politics to some of his immediate contemporaries like Richard Wright, William Faulkner, Flannery O'Connor and others who had an influence on Baldwin's imagination and craft.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-106 and 76-108)

76-435 Politics and Popular Culture
Intermittent: 9 units
Over the course of the last one hundred years what has been the influence of left-wing social movements on popular culture? Michael Kazin, in his recent best seller American Dreamers argues that the left has had a more powerful effect on culture than on politics. But what about the idea that cultural influence is inherently political? In this class we will read a mix of cultural history, film studies, music studies, literary studies, art history, television studies, and cultural theory. We will look at the intersection of radical movement politics and high modernism in the 1930s and 1940s. We will look at how left culture survived under the cloud of the blacklist. We will look at the Civil Rights culture and Feminist culture that emerged out of the 1950s and 1960s. Finally, we will look at how the left/right debates and struggles over the thirties, fifties and sixties have persisted into our current political/cultural narrative forms. Key texts for the course include Michael Kazin, American Dreamers: How the Left Changed the Nation, Paul Buhle, Hide in Plain Sight, the Hollywood Blacklistees in Film and Television, T.V. Reed, The Art of Protest, Susan Douglas, Where the Girls Are: Growing Up Female with Mass Media, Sasha Torres, Black, White and In Color: Television and Black Civil Rights, and Judith Halberstam, The Queer Art of Failure.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-106 and 76-108)

76-438 The Wire: Crime, Realism, and Long-Form TV
Intermittent: 9 units
The HBO series The Wire (2002-2008) has been called the greatest TV show ever. Part of the first wave of "quality television" series by which HBO changed the way people conceived of the artistic possibilities of the medium, the Wire differed from its contemporaries like The Sopranos and Six Feet Under in its realism and its smaller audience. Unlike most other shows on television, The Wire addressed the racism, poverty, the failures of the criminal justice system, and other social problems head on. It was able to do this in part because it had enough time to develop complex story threads. This moment of TV history produced what I am calling "long-form" TV, in which narrative continuity was stretched over multiple seasons. TV in this form resembles 19th century novels that were first released serially in magazines and newspapers. In both cases, audiences waited expectantly for new episodes, since they could not be "binge-watched." The Wire was rooted in producer/writers David Simon and Ed Burns' experiences in Baltimore, where the former had been a crime reporter and the latter a police detective. Simon has said that he made the series in order to tell truths about the city he could not tell in the newspapers. This course will consider the wire in the context of realist fiction of the 19th century, twentieth-century crime fiction, earlier TV crime series, and other long-form TV, including Mad Men. We will try to explore The Wire's realism, its continuing appeal, and its impact. We will probably watch 3 seasons of The Wire.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-439 Seminar in Film and Media Studies: Class, Race, & Gender in Film
Fall: 9 units
We usually think of movies as misrepresenting the realities of class, race, and gender. Certainly Hollywood, known as the "dream factory," usually ignored these realities or systematically distorted them. In this class, we will focus on fiction films which were intended to represent the truth about these social hierarchies. While we will watch a few examples of standard Hollywood product, most of course will concern the realist tradition in cinema. Beginning with Italian neorealism of the 1940s and early 1950s and continuing to the present day, films in this tradition have rejected glamour and glitz, and replaced them with actuality and grit. While these films have been especially interested in exploring class relations and the lives the working class, some of them also have also have focused on issues of race and gender. Among the directors whose films we will watch are Roberto Rossellini, Vittorio De Sica, Frederico Fellini, Agnes Varda, Ken Loach, Jean-Pierre Dardenne, Laurent Cantet, John Sayles, and Denzel Washington.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-440 Postcolonial Theory: Diaspora and Transnationalism
Intermittent: 9 units
Arjun Appadurai argues that one of the primary transformations in this period of globalization has been in the capacity for people to imagine themselves or their children will live and work in places other than where they were born. Although the novel has long been considered a national form, contemporary novels frequently represent transnational mobility, both in their plots and as global commodities. A significant body of contemporary fiction focuses on imaginative and physical movement across national borders. This global literature course combines literary and theoretical readings to examine the experiences of transnationalism and diaspora. Theories of transnationalism look at the interconnections that cut across nations. The concept of diaspora, a term first used to reference the movement of a people out of a homeland, has become a way to think about the identities of immigrants, migrant workers, and refugees. Readings for the course will be drawn from a diverse group of writers from around the globe. Literary readings might include works by Caryl Phillips, Jamaica Kincaid, Christina Garcia, Nadeem Aslam and Jhumpa Lahiri; theoretical readings might include works by Salman Rushdie, Paul Gilroy, Gloria Anzaldúa, Arjun Appadurai, Inderpal Grewal and Avtar Brah.

76-441 Theorizing Sexuality
Intermittent: 9 units
This course offers a foundation in the history of theorizing sexuality that brings us from the Greek classical concept of man/boy love, through medieval concepts of the "one-sex body," and up to contemporary transgender theory. We will read canonical theories of sexuality in the modern period, such as Freud's psychoanalytic Three Essays on Sexuality and Michel Foucault's revisionist History of Sexuality. To ground our theoretical investigations in social and historical context, we will focus on three discursive sites: the feminist "sex wars" of the 1980s, the theory and practice of "trans" both gender and sexuality from modern and contemporary periods, and late 20th and 21st century queer concepts of sexuality.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-443 Shakespeare and Theory
Intermittent: 9 units
Shakespeare's plays have been produced and read under all sorts of conditions for more than 400 years. It seems that each generation has a different take on their meanings and implications. Early criticism weighed their "beauties" and "flaws," and more recently their place in intellectual and social life has been analyzed by deconstructive, historical, psychoanalytic, marxist, and feminist commentary. In the seminar, we will read six plays (one comedy, one history, one "problem play," one romance, and two tragedies) each accompanied by an essay proposing a particular theoretical position and some related criticism. Students will be honing their skills as readers of some of the most complex and challenging texts in the English language and simultaneously learning to write criticism of their own. This seminar is not an introduction to Shakespeare; it is designed for students who have thought seriously about some of the plays (studied at the college level, acted in or directed productions, or the like) and wish to broaden and deepen their understanding. It is not limited to English and Drama majors. Regular attendance and participation (including occasional in-class writing) are required. Everyone will present a "position statement" to the seminar and submit two prepared papers. Grads and undergrads will work together every week for three hours; grad students will meet for an extra hour each week to discuss additional readings and prepare conference-ready seminar papers.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-444 History of Books and Reading
Intermittent: 9 units
Rather than putting an end to the book, digital media have had the oddly exhilarating effect of making us look at all kinds of print, past and present, through newly focused lenses. This course will introduce you to the history of books and reading, a cross-fertilizing field of study that is having an impact on many disciplines, from the history of science to literary history, cultural studies, and the arts. Scholarship in this still-emerging field will include work by Roger Chartier, Michel Foucault, Elizabeth Eisenstein, Pierre Bourdieu, Michel de Certeau, , and the current scholars who appear in one of our key books, "Interacting with Print: A Multigraph." We'll also read primary texts by Joseph Addison, Jane Austen, Samuel Coleridge, and Wilkie Collins to see how differing modes of print and reading became highly contested cultural and political matters in the eighteenth and nineteenth centuries. Other topics include the division between new reading publics and their ways of reading books; important changes in book production, typography, printing methods (hand-press to steam press). Such knowledge of the history of print has become especially crucial in an era of emerging "new media" and the field of digital humanities in the university. Two papers will be requiredone shorter paper (5-7 pp.) and a longer research paper on the uses of books and print by producers and readers. Though the course meets in Baker Hall, you will have hands-on experience with early books and other forms of print as we also meet periodically in the Rare Book Room at Hunt Library.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-445 Race in Early Modern Drama
Intermittent: 9 units
This seminar explores the representation and fashioning of race in sixteenth and seventeenth century drama from England, Spain, and France. In early sixteenth century Europe, race was a complex system of power distribution that relied primarily on religious or rank-based difference. With the development of colonization and color-based slavery in the Atlantic world, the early modern racial matrix produced a new paradigm: Europeans started thinking about physiological difference - for which skin color was a shorthand - in racial terms too. How were those various racial paradigms (religion, rank, skin color) represented in one of the most important mass media of the time - theatre? How did those paradigms interact in one given play or one given national culture? Did they reinforce or work against one another? Which features were specific to nationally defined racial epistemes? Which features circulated across national borders? How did the translation and mistranslation of racial notions from one culture into another shape a sense of shared whiteness in early modern Europe? Which performance techniques did actors use to impersonate racial others, and what effect did those techniques have on spectators? In short, how did early modern theatre participate in the making of race? To answer those questions, we will focus on a rich corpus of plays staging Jews, Moors and Blackamoors, New World Indians, Gypsies, and Turks. We will read plays by Shakespeare, Ben Jonson, Cervantes, Lope de Vega, and Molière (among others) in conversation with secondary readings drawn from the field of Critical Race Studies. French and Spanish plays will be available in translation.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-446 Revenge Tragedy
Intermittent: 9 units
Attendants to the early modern English theater seem to have had an almost insatiable appetite for revenge tragedy: a lurid, blood-soaked genre distinguished by plots involving insanity, skulls, ghosts, poisonings, stabbings, suicide, and other forms of unnatural death. This course will cover key examples of the genre, putting particular emphasis on the depiction and interrogation of justice, analyses of death, and playful engagement with theatricality. Our central curriculum will include plays by Seneca, William Shakespeare, Thomas Middleton, Christopher Marlowe, and Thomas Kyd, alongside a selection of critical essays and related literature from the period. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

76-448 Shakespeare on Film
Intermittent: 9 units
The dramatic works of William Shakespeare have inspired an extraordinarily rich and varied cinematic legacy that began in the era of silent films and now boasts masterpieces by directors such as Akira Kurosawa, Roman Polanski, Peter Greenaway, and Orson Welles, not to mention history-making performances by icons including Marlon Brando, Elizabeth Taylor, Laurence Olivier, Al Pacino, Leonardo DiCaprio, and Ian McKellen (among many others). This course will consider a selection of key Shakespeare films alongside critical readings centered on questions of adaptation and performance. As we watch and read together, we will work toward a broader understanding of what Shakespearean drama means in a 21st century context, and how film has helped to shape the author's massive cultural impact.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-449 Race and Media
Intermittent: 9 units
This course will introduce students to useful methodological approaches, ranging from film studies, media archeology and book history to Black studies, Transnationalism and Post-Marxism, to analyze race and representation within a variety of media formats. Media in this course is understood broadly: technologies used to store and deliver information. With this rather broad understanding in mind our course will look at how artists and intellectuals use discrete formats (print, film/video, electronic, and other recording mediums) to imagine, remediate and study the circulation of racialized bodies and identities within global capitalism.
We will also think about the concept of race itself as another, particularly problematic "media" format used to store and deliver information about the human for political, economic, ideological and juridical purposes. The class will be organized around specific material and "immaterial" media objects that will allow us to explore the processes of (re)mediation that characterize racialized bodies and formats. We will look at a range of works that might include D.W. Griffith, Nella Larson, Iceberg Slim, Raul Peck, Christina Choy, Renee Tajima, Janelle Monae, Ramiro Gomez, Dana Shultz, and 50-Cent. We will also read the theoretical works of Stuart Hall, Christina Sharpe, Carol Vernallis, Lisa Lowe, Teju Cole, Lisa Gitelman and Michael Gillespie, Simone Browne, Martin Heidegger, Theodore Adorno and others. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-450 Law, Culture, and the Humanities
Intermittent: 9 units
"I'm not a lawyer, but..." How many times have you heard this disclaimer, closely followed by a lay analysis of law? This course, an introduction to the cultural study of law for graduate students and advanced undergraduate students, can be seen as an introduction to what goes into the making of such a statement. Where do we get our ideas about law? What do we mean when we say "law"? What counts as law? How does culture influence law, and law, culture? And to what degree should historical context condition any answers we might be tempted to give? Students in the course will study works in a range of genres (novels, plays, poems, judicial opinions, pamphlets) and develop methods for investigating ways that law and culture have been made by one another from the 16th-century to the present. Readings will include influential theoretical accounts of law (Aristotle, Hobbes, Cover, Habermas, Bordieu, MacKinnon), canonical texts in Law and Literature (Shakespeare's Measure for Measure, Melville's Billy Budd, Kafka's The Trial) and some "weird fiction" by the novelist/legal theorist China Miéville. As a counterpoint to the fiercely anti-historical "law and economics" movement, however, the course will put special emphasis on rooting intersections of law and culture in rich historical context, considering both local and international legal contexts (sometimes in fairly technical detail) alongside so-called "ephemera" of culture. Students will tackle the especially fruitful "case" of Renaissance Britain before developing final research projects, whether on the Renaissance or another period of their choosing.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-451 Language and Globalization
Intermittent: 9 units
It is a paradox of globalization that the same factors that cause people to become more alike also make people become aware of difference. In this course we explore this process with respect to language. We look at the history of language standardization and its relationship with political and economic history, exploring when and why different ways of speaking and writing become more alike, both as an automatic result of social interaction and as a planned result of policy. We look at the language ideology that gives rise to and undergirds standardization and the rhetoric that gets used to forward it. Then we explore reasons for and mechanisms of localization in language. What ideas about language, communication, and identity underlie attempts to push back against standardization, and what rhetorical strategies forward these ideas? We then turn to three case studies: arguments about Global English versus local Englishes and ways of using English, ongoing struggles over the standardization of the Putonghua variety of Chinese in China and the development of regional and national standards in Taiwan and elsewhere, and the history of Catalan, a regional dialect that has become a quasi-national standard in the Catalunia region of Spain. In addition to presenting and leading discussion on two of the readings, students will be expected to complete two 500-word writing assignments and undertake a substantial original research project that expands on one or more of the themes of the course. This project will be presented orally and in a 20-25 page paper.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-452 Generations and Culture
Intermittent: 9 units
We hear about generations all the time—the Millennials rising, Gen X and their minivans, and the Baby Boomers retiring. Yet, generations have usually been ignored in cultural studies as an amorphous, popular concept. While we discuss factors that shape identity such as race, class, gender, sexuality, there is little work on generations. In addition to those factors, contemporary researchers have determined that generations in fact often have significant impact on opinions, consumer choices, and political views. This course will study the theory of generations, from sociology, history, marketing, and other fields. It will also look at how the concept might apply to cultural products, such as literature or theory itself. In addition, in the course you will develop a project to study one generation and its culture.

76-453 Literature of Empire
Fall: 9 units
Nineteenth and early twentieth-century British literature was shaped by events taking place outside as well as inside of national borders. Even in the eighteenth and nineteenth centuries, with international trade and slavery supporting the manor house and plantations abroad providing the cotton for British looms, the "England" of English literature spanned the globe. By the first half of the twentieth century, this empire had begun to collapse in upon itself, a process witnessed by writers inside Britain and its colonies. This course will investigate British literature within the international context of global imperialism. A section on gothic stories takes us into the realm of popular culture with Mary Shelley's Frankenstein and Arthur Conan Doyle's short stories. We take to the seas with Joseph Conrad's Lord Jim, before we consider W. Somerset Maugham's exploration of sexuality in the tropics in The Painted Veil. Finally, we return to England to outline the links between colonial empire and international war rendered in Virginia Woolf's Mrs. Dalloway. These literary works will be read alongside some of the most important works of postcolonial theory. While course readings focus on 19th and early 20th century, student's will undertake a research project over the semester in their own period of interest in British literature in connection with empire studies.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-106 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-456 Independent Study in Film & Media Studies
All Semesters
TBA
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-457 Rhetorical Invention
Fall: 9 units
Rhetorical invention refers to the discursive process of inquiry, discovery, and problem solving, or how we decide what to say, what arguments to advance, and what means of persuasion to use in any situation. Although invention is centrally important to rhetoricwithout which it becomes a superficial and marginalized study of clarity, style, and arrangementfrom the Scientific Revolution and Enlightenment through the mid-twentieth century invention all but disappeared as a topic of rhetorical study under the pressure of the view that invention should be exclusively governed by deductive logic and the scientific method rather than rhetorical considerations such as audience or the figurality of language. This repudiation of rhetorical invention fundamentally shaped modern thought and continues to influence the ways we think and communicate today. In this course, we begin by examining the status of rhetorical invention in the development of modern thought before focusing on various scholarly efforts to revive a rhetorical understanding of invention from the mid-twentieth century forward, surveying a variety of contemporary theories of rhetorical invention including those promoted by postmodern, posthuman, and digital rhetorics. The course is designed to explore the central importance of invention to contemporary rhetorical theory through a pairing of historical and contemporary readings.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-460 Beginning Fiction Workshop
Fall and Spring: 9 units
In this course you'll continue to learn the craft of fiction writing through conducted discussions about various elements of craft: point of view, structure, use of imagery, scene, dialogue, and most importantly, characterization. We'll also be talking about the thematic concerns these writers raise, and how these stories fit into a conversation about the wider culture.
Prerequisite: 76-260 Min. grade B

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-462 Advanced Fiction Workshop
Fall and Spring: 9 units
In this writing-intensive workshop students will be laser-focused on producing and polishing their own fiction. We'll complement our workshops with readings from masters of short fiction and novels, with an eye on sharpening our own facility with dialogue, structure, and voice. Each student must be prepared to constructively critique and deconstruct her/his peers' work, as well as actively contribute to class discussions about the elements of craft that undergird successful works of fiction. Each student will be expected to produce a significant portfolio of original writing by the end of the semester as well as shorter exercises originating from thematic prompts.
Prerequisite: 76-460 Min. grade B

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-464 Creative Nonfiction Workshop: Magazines and Journals
Intermittent: 9 units
Creative Non-fiction Workshop is a good class to take if you like to tell (write) stories about your own life and the lives of other people, all situated in the world we inhabit, the world that is ours to investigate and celebrate and question. The class will teach you how to write a good story, by focusing on aspects of craft. Class is almost always run as a discussion. We'll read books by authors of creative non-fiction, and learn from them how to work with a variety of forms. Every student will create a portfolio of roughly 25 pages of non-fiction by term's end.
Prerequisites: 76-365 Min. grade B or 76-460 Min. grade B or 76-265 Min. grade B or 76-262 Min. grade B or 76-260 Min. grade B

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-465 Advanced Poetry Workshop
Fall and Spring: 9 units
In this course, you will be expected to take your knowledge of the principles and techniques of poetry and utilize them in workshop discussions, written analysis, and the composition of your own poems. In addition, readings of books by visiting poets will be required, Participation in a book-making project, cross-genre writing, and/or a mentoring project with high school students will also be included.
Prerequisite: 76-365

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-468 Space and Mobilities
Intermittent: 9 units
This course will investigate space and movement as social constructions. Space appears as something that exists around us: our houses, our neighborhoods, our cities might seem like they are simply there to be moved through. In the same way mobility, from our means of transport to an evening walk, can appear as just movement from A to B. In the late 20th century, an interdisciplinary group that included geographers, urban studies scholars, architects, sociologists, anthropologists, and literary theorists began to theorize the social construction of space. They argued that space is something dynamically created that may be interpreted for the ways it creates meaning. Following this spatial turn, mobilities studies scholars looked to understand movement as something that reproduces and constitutes power and institutions. This interdisciplinary course considers theories of space and movement as a field of study and in reference to literary and film texts. The course will be organized topically, and include such units as the regulation of freedom of movement over borders through the construction of boundaries; the heterotopia of the boat or train carriage; the poetics of space; the dynamic mapping of the city by a wanderer; neoliberal recalibrations of global space, and the spatialization of performance. Readings might include Henri Lefebvre, Doreen Massey, Edward Soja, Gaston Bachelard, Wendy Brown, John Urry, Tim Cresswell, Marian Aguiar; literary texts might include Brian Friels Translations, Christina Garcia's Dreaming in Cuban, W.G. Seabald's Austerlitz and Teju Cole's Open City. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-469 Screenwriting Workshop: Screenwriting/Television Writing
Spring: 9 units
This is an advanced screenwriting workshop that builds on the fundamentals covered in the Survey of Forms: Screenwriting course. The objective of the course is to help students gain a greater critical and artistic sensibility as screen and television writers. We will spend the first part of the semester working on 3 different screenwriting projects; the second part of the semester will be devoted to television writing. An visiting professor who works in television will teach several classes and help the students translate one of their screenplays into television pilots. Class sessions will be rigorous and challenging consisting primarily of group readings and open critiques. Students should arrive to the first class prepared to discuss the idea and status of the screenwriting project they plan to pursue first.
Prerequisite: 76-269 Min. grade B

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-472 Topics in Journalism: Storytelling in a Digital Age
Spring: 9 units
Advanced Journalism students will learn how to plan and execute long-form news feature stories from the ground up, starting with recognizing a promising idea, organizing a solid proposal then ultimately producing a publication-ready report that is both accurate and compelling. We will focus on four types of feature stories over the course of the semester: a trend story, a profile, an explanatory report and a data-driven investigative story. Each will require strong news judgment and solid writing skills, plus the ability to adapt as some story leads unexpectedly come to a dead end while promising other angles rise to the surface. Don't be surprised if the final product is notably different than the original idea; that's often the path of the most successful reports. While each student is responsible for his or her work, class sessions will be highly collaborative as ideas and strategies are critiqued with an eye toward helping all students achieve their best work.
Prerequisite: 76-372

76-474 Software Documentation
Spring: 9 units
This course teaches theory, techniques, and best practices for creating software documentation. We will learn to plan, architect, write, and publish audience-appropriate user assistance, while applying concepts and approaches like minimalism, topic-oriented authoring, single-source publishing, content reuse, and metadata. Students will complete homework assignments and larger projects to reinforce principles and provide experience in all phases of the software documentation lifecycle. Readings and class discussion will bridge theory and practice.
Prerequisites: 76-271 or 76-270

76-475 Law, Performance, and Identity
Intermittent: 9 units
Although rhetoric and law have long been closely associated, the modern professionalization of law has often promoted the idea that legal discourse is not rhetorical but a rigorously defined technical discourse that can be applied free of social, cultural, or political considerations. This view of legal discourse is disputed by critics who point out the figurative aspects of legal language, the relevance of character, emotion, and narrative in legal communication, and the ways in which law protects social structures of power such as race, class, and gender privilege. The course broadly examines the fraught relationship between rhetoric and law by considering the ways in which a variety of legal discourses serve to construct and reinforce identities, with a particular focus on the ways in which legal systems are portrayed to reflect the ideals of democracy to suit particular foreign relations goals. We begin by studying the ways in which Cold War foreign policy goals influenced desegregation and civil rights discourse in the United States, then we turn to the ways in which the prosecutions of deposed authoritarian rulers in various regions of the globe have been orchestrated to persuade global audiences that emerging democracies observe the "rule of law" for purposes of garnering international support. Alongside primary sources of legal discourse, we will study a selection of interdisciplinary scholarship about the relationship between rhetoric and law. Students write a two-stage research paper on a topic of their choosing regarding the relationship between legal discourse and the construction of identity. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-476 Rhetoric of Science
Fall: 9 units
This course explores questions about scientific argument and communication that are of interest to scientists, rhetoric of science scholars, and professional/technical writing practitioners. These include questions like: How are scientific arguments structured? How is scientific information and argument transformed when it moves from research papers to publications for non-specialist audiences? How does the social, historical, and cultural context of science shape the way it is communicated and/or argued? What contributions do visuals make to scientific argument and communication? To investigate these questions, we will be examining a wide variety of real-world communications in and about science as well as texts in rhetoric, history, and philosophy of science.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-479 Public Relations & Marketing for Writers
Spring: 9 units
Effective marketing and communications are essential to the success of businesses, non-profit agencies, academic institutions, public interest groups, and other entities that have a shared purpose and identity to promote. This course explores marketing and communications in organizational settings, where professional communicators manage relationships with a wide variety of constituencies: customers, investors, news agencies, employees, members, volunteers, local communities or government agencies. To succeed, communicators must be able to identify and articulate the communication needs of the organizations they represent, develop well-informed strategies for advancing organizational objectives, think and act quickly in high-pressure situations, and write clear and persuasive prose. In this course, you will develop the written and oral communication skills needed by a professional communicator in an organization. You will learn to identify and define a coherent, integrated strategy for all of an organization's communications and to devise and apply effective marketing and public relations tactics in traditional and social media for achieving business objectives. You will gain practice in writing op-ed essays, press releases, critiques of organizational communications, and marketing and communication plans.
Prerequisites: 76-270 or 76-271

76-481 Introduction to Multimedia Design
Fall: 12 units
There is increasing demand for professional/technical writers who understand multimedia and its communicative possibilities. This class will provide students with the opportunity to develop the ability to create and analyze multimedia experiences that merge text, spoken voice, music, animation and video. Students will be introduced to the basic concepts and vocabulary of motion graphics, as well as the practical issues surrounding multimedia design and digital storytelling through a series of hands-on projects involving various contexts. Students will explore what it means to write for a dynamic medium and how to take advantage of elements of time, motion and sound to help expand their visual communicative skills. The essentials of Adobe After Effects will be taught in order to build the skills necessary to complete assignments, explore multimedia possibilities and foster each student's unique creative voice. Adobe Premiere and Audition will be employed to support specific tasks. Students will also be taught to capture their own original images, video and narration audio to craft the elements of their projects. It is helpful to have some prior basic experience with Photoshop or Illustrator. In-class discussion and critiques are an essential part of this course.
Prerequisites: (76-270 or 76-271) and (51-261 or 51-262 or 76-391)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-483 Corpus Analysis in Rhetoric
9 units
This course investigates methods for analyzing rhetoric as it mainly exists in digital environments (e.g. blogs, newsgroups, homepages, political sites, facebooks and so on). The focus will be on verbal rhetoric, but students who wish to analyze visual rhetoric interactively with verbal rhetoric will be welcome to do so. In the first part of the course, we will review various methods for analyzing digital texts descriptively (viz., concordance, collocate and keyword analysis) and inferentially, through multivariate analysis (e.g., manova, factor analysis, discriminant analysis, cluster analysis). To learn these methods, in the first half of the course, we will use simple textual data sets supplied by the instructor. In the second half of the class, students will choose their own digital environments to analyze and they will be expected to write publishable-quality rhetorical analyses of these environments. To meet this expectation, students will need to do considerable background research in the digital environments they are studying.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-484 Discourse Analysis
Fall: 9 units
Discourse is a focus of study in most of the humanities and social sciences, and discourse analysis is practiced in one way or another by anthropologists, communications scholars, linguists, literary critics, and sociologists, as well as rhetoricians. Discourse analysts set out to answer a variety of questions about language, about writers and speakers, and about sociocultural processes that surround and give rise to discourse, but all approach their tasks by paying close and systematic attention to particular texts and their contexts. We are all familiar with the informal discourse analysis involved in paraphrasing the meanings of written texts and conversations, a skill we learn in writing and literature classes and in daily life. Here we ask and answer other questions about why people use language as they do, learning to move from a stretch of speech or writing or signing outward to the linguistic, cognitive, historical, social, psychological, and rhetorical reasons for its form and its function. As we look at resources for text-building we read analyses by others and practice analyses of our own, using as data texts suggested by the class as well the instructor. In the process, we discuss methodological issues involved in collecting texts and systematically describing their contexts (ethnographic participant-observation and other forms of naturalistic inquiry; transcription and "entextualization;" legal and ethical issues connected with collecting and using other people's voices) as well as methodological issues that arise in the process of interpreting texts (analytical heuristics; reflexivity; standards of evidence). The major text will be Johnstone, Barbara. 2008. An Introduction to Discourse Analysis. 2nd ed. (Malden, MA: Blackwell Publishers). Other reading will be made available as .pdf files.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-485 The New Public Sphere
Intermittent: 9 units
Public deliberation is at the heart of the rhetorical tradition. But is public dialogue really a live option in a media-saturated world of sound bites addressed to plural publics? Is the process of debate, deliberation, and decision (in which the best argument wins) really the ideal model? Or can people use public spaces to develop new, more inclusive positions? Could such a process occur in a boundary-crossing public when diverse groups enter intercultural deliberation around racial, social, or economic issues? This course looks at diverse ways people use rhetoric to take literate social action within local publics. From the canonical debate around Habermas and the public sphere, we move to a feminist "rereading" of the Sophists, to contemporary studies of deliberation in workplaces, web forums, grassroots groups, new media, and community think tanks. To support your own inquiry into the meaning making process of a local public, you will learn methods for activity analysis and for tracing social/cognitive negotiation within a public of your choice. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission
Prerequisite: 76-373

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-486 Argument Theory
Intermittent: 9 units
Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: (76-101 and 76-373) or (76-102 and 76-373) or (76-106 and 76-107 and 76-373) or (76-108 and 76-373 and 76-107) or (76-106 and 76-108 and 76-373)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-487 Web Design
Fall: 12 units
The World Wide Web is a vast collection of information, far more than we can comfortably handle; even individual websites can pose so much information that they become overwhelming. In this client-facing, project-oriented class, we aim to look at ways to tackle this problem, and design content for the web that is easy to access and digest. We will look at how websites manage and present organized information, with an eye to understanding what works well. We will use methods to learn who is using a website and why, and develop our toolset to test our decisions when implementing a new design. Along the way, we will develop a familiarity with the core web technologies of HTML5 and CSS3, with discussion of graphics, sound, social media, and other tools to enrich our presence on the World Wide Web. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: (76-270 or 76-271 or 76-102 or 76-101 or 76-272) and (76-382 or 76-391 or 51-261 or 51-262)

76-488 Web Design Lab
Fall: 3 units
Lab exercises for Web Design include the following: basic HTML, images, tables, animation, image maps, interactive forms, Web interfaces to databases, and basic Javascripting. All students must do the lab exercises. The exercises are designed so that those students who already know particular topics (e.g., basic HTML) do not need to attend the lab session. Students who would like guided practice in doing the lab exercises must attend the lab session. Lab sessions take place in a computer cluster.
Prerequisites: (76-379 or 76-271 or 76-270) and (76-382 or 76-391 or 76-383)

76-491 Rhetorical Analysis
Intermittent: 9 units
Students in this course will learn various approaches to analyzing discourse artifacts from a rhetorical point of view. Early in the course, students will identify an artifact or artifacts they wish to analyze. From there, students will be encouraged to explore their own methods of analysis based on two required books for the course and reviews of literature. For the midterm, students will create an annotated bibliography of five specimens of criticism taken from a single journal. For the final project student will first present and then hand in a polished 15 page piece of criticism based on one or some combination of methods. The presentation and final paper count 50% of the grade, with the mid-term, class attendance, participation, and homework making up the final 25%.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-492 Rhetoric of Public Policy
Intermittent: 9 units
This course explores a rhetorical approach to public policy which focuses on the interconnected role that data, values, beliefs, and argument play in the policy process. From this perspective we will examine the important public debate over the pros and cons of various forms of energy production including nuclear, natural gas, and solar. In these investigations, we will explore questions like "How do policy makers use rhetoric to shape public perspectives on energy production?" "How can rhetorical approaches to argument function as tools for policy analysis and development?" And "What role does technological expertise play in public debate?" To pursue these questions, we will be reading works in rhetorical theory and public policy and applying the concepts and methods in those works to exploring primary artifacts of public argument like records of public hearings, social media memes, handbooks designed by activists, and stories about energy production in the popular media.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-494 Healthcare Communications
Fall: 9 units
Healthcare communications is designed for students with an interest in how medical and health care information is constructed and transferred between medical experts, health care providers, educators, researchers, patients and family members who are often not experts but need a thorough understanding of the information to make important health decisions. Throughout the course, we will explore the interactions of current theory and practice in medical communication and the role of writing in the transfer and adoption of new therapies and promising medical research. We will also study how the web and social media alter the way information is constructed, distributed, and consumed. We will examine the ways medical issues can be presented in communication genres (including entertainment genres) and discuss how communication skills and perceptions about audience can influence clinical research and patient care. Additionally, we will explore clinical trials, grant writing, and press releases, and will feature guest speakers from these fields will discuss their experiences.
Prerequisites: 76-395 or 76-271 or 76-270

76-497 Culture: Interdisciplinary Approaches
Fall: 9 units
to be determined

76-511 Senior Project
Intermittent: 9 units
Seniors in all four majors within the English Department may, with faculty permission and sponsorship, design and complete an original, student-planned Senior Project. Creative Writing majors may work on a book-length manuscript in fiction or poetry. Students in all majors within the Department may also, with the permission of a faculty advisor who will supervise and sponsor the project, develop and complete senior projects that involve either traditional academic research or investigations of problems in professional or technical communication.

76-700 Professional Seminar
Fall: 3 units
This weekly, 3-unit seminar is designed to give professional writing majors an overview of possible career and internship options and ways to pursue their professional interests. Each session will feature guest presenters who are professionals working in diverse communications-related fields such as web design, journalism, public relations, corporate and media relations, technical writing, medical communications, and working for non-profits. The visiting professionals talk about their own and related careers, show samples of their work, and answer student questions. The course is required for first-year MAPW students and open to all English undergraduates, who are urged to participate in their sophomore or junior years to explore options for internships and careers.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-702 Global Communication Center Practicum
Fall: 6 units
This practicum is restricted to students who have applied and accepted a position as a Global Communication Center tutor. For more information on applying, contact the course instructor. Students in this six-unit mini will learn about best practices in tutoring, gain experience analyzing and responding to a wide range of academic and professional genres, and learn to adapt their tutoring style for different kinds of students. In addition, we will learn to support oral, visual, and collaborative modes of communication alongside more traditional written genres. Assessments include regular hands-on activities, reading responses, and participation in class discussions. Please note that in terms of time commitment, a 6 unit mini is equivalent in weekly workload to a 12 unit full semester course. The mini is half the credits because it requires the same workload but only for half the semester.

Course Website: https://www.cmu.edu/gcc/faqs/index.html

76-719 Environmental Rhetoric
Fall
Environmental rhetoric is a place of commitment and contention in which competing discourses celebrate our relationship with the natural world, frame environmental problems, and argue for public action. As we compare the environmental rhetoric of naturalists, scientists, policy makers, and activists, we will trace an American history that has managed to combine mystical celebration with militant critique, and scientific research with public debate. Equally important, this course will prepare you to act as a rhetorical consultant and writer, learning how writers communicate the three "Rs" of environmental rhetoric: relationship with nature, the presence of risk, and the need for response.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-720 Leadership & Organizational Communication
Intermittent
Please note: In order to register for this course, students must have had an internship with an organization prior to registration. Even as most organizations continue to change, one constant is the importance of effective communication. Upward, downward, and lateral communications are the lifeblood of organizations. If you are in a leadership position, communication become your key tool for managing teams, improving performance, and creating change. In any position, you can spearhead progress by designing effective documents and improving existing communication practices. Proficiency in written and oral communications tends to be recognized and rewarded in organizations. Combined with the ability to leverage formal organizational structures and social networks, it helps one excel, and thrive, in organizations. This course is designed as an overview to the field of organizational communication with an emphasis on leadership roles and behaviors. The content will blend the conceptual with the practical. It will focus on problems that are likely to arise in the workplace and ways to solve them through communication. The students will build a portfolio of "solutions" that will demonstrate their evolving skills of applying rhetoric in organizational contexts. Specific topics will include the attributes of great communicators (including leaders and managers as communicators), the challenges of communicating in organizations as we play particular roles (e.g., individual contributor, manager or team member), ways to build credibility and enhance internal resumes, and techniques to master communication requirements related to performance management processes, conflict situations, and changing organizational culture and design. We will also explore a myriad of organizational issues such as communicating across generations and cultures, communicating externally, and communicating through technology.

76-729 Unruly Women in Early Modern Drama
Intermittent
"Unsex me here" Lady MacBeth famously exclaims on her path to murder, power, and psychological collapse. The connections between sex, gender, and agency that she articulates are connections that early modern theater-makers, from Shakespeare to Aphra Behn, obsessively revisited as they created some of the most haunting characters of the canon, both tragic and comic. In this course, we will look at shrews, witches, she-devils, ranting widows, aspiring divorcees, sex workers, roaring girls, evil queens, and all sorts of nasty women that would tread the boards in early modern London. At the heart of those theatrical depictions lie strong cultural anxieties surrounding the desire and possibility to fashion, control, and discipline¿in other words, to regulate and rule over¿femininity in a time period that witnessed the invention of the "two-sex model" (Thomas Laqueur) and "the cultural production of domestic heterosexuality" (Valerie Traub). How did theatre participate in the invention of early modern femininity? How did performance relate and/or resist the discourses about women deployed in the domains of law, religion, medicine, economy, and politics? How did women of color specifically fare in early modern dramaturgy? And what changed when women were allowed to act and actresses replaced boy actors under the Restoration? To study unruly women in early modern drama, we will read plays by Shakespeare, Elizabeth Cary, Ben Jonson, John Webster, Thomas Middleton, Thomas Heywood, Thomas Dekker, John Fletcher, Aphra Behn, and others in conversation with contextual materials and theoretical texts from the field of Women's, Gender, and Sexuality studies.

76-731 Dissenters and Believers: Romanticism, Revolution, and Religions
Intermittent
We usually think of the American and French revolutions as primarily political, but they also confronted dominant religious beliefs and generated alternatives ranging from enthusiasm and pantheism to atheism. We will explore the literary and political meanings of religious belief and dissent in major writers like Samuel Coleridge, Thomas Paine, Edmund Burke, William Wordsworth, Matthew Lewis and others who grappled with Protestantism, Catholicism, Dissent, and such interesting extreme alternatives as evangelicalism, enthusiasm, pantheism, and atheism. Two interpretive papers and in-class presentations will be required.

76-758 Rhetoric & Storytelling
Spring
What are stories and why do we tell them? What purpose do they serve? What makes a story true? What effect do stories have on those who hear them? In this course, we will ask how narratives work rhetorically to shape how we perceive and encounter events, movements, places, and experiences. Students can expect to read and discuss narrative theories and practice employing these theories to analyze story artifacts, such as written collections, political speeches, newspaper articles, curated experiences, and oral histories. We will begin the semester by exploring and analyzing the many stories surrounding September 11 but will also consider the stories that infuse recent or local subjects of interest. Students will investigate the effect these and other narratives have on contemporary contexts. Any student who is interested in developing a critical awareness of the rhetorical power of storytelling and enhancing their analytical toolkit will benefit from this course. Most class sessions will involve guided student discussions of theoretical texts as well as collaborative opportunities to analyze story artifacts. Weekly assignments will include short analyses and reflection activities. The course will culminate in a final project where students will select and analyze a collection of stories within a cultural, social, and/or historical context.

76-762 Introduction to Translation
Fall: 9 units
In "Introduction to Translation," we will survey a number of different translation theories in order to understand the various approaches that are at our disposal when translating a text. In addition, we will briefly explore several fields of translation studies, such as health care, business or literature, that require specialized terminology and expertise in the subject. All theory taught in class will be accompanied by hands-on translation projects that will give students the opportunity to try out their knowledge first-hand and evaluate the usefulness of different approaches on a personal basis.

76-763 Translation as Profession I
All Semesters: 3 units
In "Translation as a Profession," we will learn from professionals in the field of translation. Every class will feature a guest speaker from the Pittsburgh area and beyond who will present his or her own educational background, experience in the field and current relation to the translation industry. Students will meet a variety of professionals, learn about the field, and establish valuable connections for the future.

76-766 Essay Writing Workshop
Fall
In this course we will analyze the different types of narrative structure, narrative suspense, voice, metaphor, and point of view that make for effective non-fiction writing. We will also examine the difference between good writers and good work, the functions of objective distance from and intimate investment in a subject, as well as the philosophical questions spurred by non-fiction writing. What is the non-fiction writer's role, and how does it differ from that of the fiction writer? Where do the two genres overlap? What gives non-fiction writing integrity? What does the term "creative non-fiction" mean? How have the form and aims of non-fiction writing - from memoir to essays to long-form journalism - evolved for better and for worse? We will scrutinize the writing of Eula Bliss, Kate Fagan, Joan Didion, James Baldwin, Jo An Bear, Gary Younge, David Foster Wallace, Umberto Eco, and many others. In addition to critical writing assignments, students will have several opportunities to write their own non-fiction pieces.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-771 Innovation in Teamwork
Fall
Academic teams, campus organizations, workplaces are all dynamic activity systems, organized and driven by institutional habits and rules, by roles, status and power, and by the material and conceptual tools we draw on. Yet as we have all observed, these Rules, Roles and Tools often operate in contradictory ways, even in conflict with one another. Effective team leaders are able to recognize these contradictions and draw a writing group, a project team, a social organization or a workplace into what is called an "expansive transformation." That is, to innovate new ways of working together. In this course, you will learn how to become more effective not only as a team member, but also a project leader, and even group consultant in your college work and workplace. Looking at films, case studies, research, and your own experience, we will learn how to analyze how teams of all sorts are working, to communicate more effectively across different expectations and values, and to collaboratively innovate new ways of working together. Your final project will let you document your ability to be a knowledgeable team leader and effective collaborator.

76-784 Race, Nation, and the Enemy
Intermittent
Conflicts over racial and national identity continue to dominate headlines in the United States as they often have during the nation's history, from debates regarding the immigration, naturalization, and birthright citizenship of racial minorities to debates regarding racial disparities in access to civil rights. This course explores the discursive practices through which racial and national identities are formed and the frequent conflicts between them, particularly by focusing on the role of enemies, threats to the nation, and sacrifices made on behalf of the nation in American public discourse. Alongside primary sources of public discourse regarding wars, the immigration and citizenship of racial minorities, racial segregation and civil rights, and the criminal prosecutions of dissidents during periods of crisis, we will read secondary sources offering multiple theoretical and disciplinary approaches to the study of racial and national identity formation. Along with regular brief responses to readings, assignments will include a short rhetorical analysis paper and a longer research paper.

76-786 Language and Culture
Fall
This course is an introduction into the scholarship surrounding the nature of language and the question of how language shapes and is shaped by social, cultural and political contexts. We will begin by studying important literature in linguistics and language theory, both to introduce us to how scholars think about language and to give us a shared vocabulary to use for the rest of the semester. We will then move into case studies and theoretical works exploring the intersections of language use, individual and group identities, and the exercise of power, in its many forms. In particular, we will focus on the relationship between language and culture by asking, in what ways does language influence and constitute social change? How is social change reflected by changes in the way we use language? Over the course of the semester, you will work on applying the knowledge and theoretical tools you gain to your own analysis of a linguistic artifact that you choose.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-787 Writing in the Disciplines
All Semesters
This mini will introduce you to the theory and practice of writing instruction in contexts outside of English studies. We will learn about the distinction between Writing across the Curriculum and Writing in the Disciplines and challenges to providing integrated, high quality writing instruction across the university. We will explore the implications of the wide variety of forms of academic writing for instruction in English classrooms, including high school and first-year writing classrooms. Assessments will include reading responses and a final paper reviewing research on writing in a specific writing context of your choosing. Students enrolled in the course for six units will be expected to do additional readings and give an oral presentation. Please note that in terms of time commitment, a 3-unit mini will require approximately six hours per week (three hours homework and three hours class meetings) and a 6-unit mini will require twelve hours per week.

76-789 Rhetorical Grammar
Fall and Spring
This is a course in fundamental grammatical structures of English and how these structures fit into the writer's toolkit. This means you will learn a lot about English-language grammar in this course en route to understanding a lot about English language writing. This course is designed for MA students in professional writing and undergraduates who want to improve their grammar, their writing, and their depth of understanding of how improvement in grammar impacts improvement in writing.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-791 Document & Information Design
Spring: 12 units
This course provides students who have already learned the foundation of written communication with an opportunity to develop the ability to analyze and create visual-verbal synergy in printed documents. Students will be introduced to the basic concepts and vocabulary, as well as the practical issues of visual communication design through a series of hands-on projects in various rhetorical situations. Assigned readings will complement the projects in exploring document design from historical, theoretical, and technological perspectives. Class discussions and critiquing are an essential part of this course. Adobe InDesign, Photoshop, and Illustrator will be taught in class, and used to create the assigned projects
Prerequisite: 76-870

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-805 Institutional Studies: English as a Discipline
All Semesters: 6 units
The institution on which this course will focus is the academic discipline, the specific historical form that the production of knowledge in the modern research university has assumed. This course will examine the historical development of the discourses, practices, organs, and associations that have defined English as a discipline. While we will of necessity also look at the theories and values that the discipline has proclaimed at different times, this will not mainly be a course in the history of criticism. Criticism will be considered as one practice among others including philology, literary history, literary theory, rhetoric, and composition. In order to understand the broader context, we will read work by Foucault and others on disciplinarity. We will also examine allied institutions, including the professions and the university.

76-818 Rhetoric and the Body
Intermittent
This course offers an introduction to rhetorical studies of the body and is centered on the following three questions: What is the role of the body in rhetorical theory? What role does rhetoric play in constructing the body as a raced, gendered, dis/abled, cultural, fleshy, and political entity? And, how might moving, feeling bodies challenge, regulate, or disrupt these rhetorical constructions and furthermore, our theories of rhetoric? Our readings will explore the role of embodiment in rhetorical theory, examining a number of contemporary and historical theories of the body. In the process, we will explore how to put rhetoric and the body into conversation with one another and what methodological implications this conversation has for rhetorical studies more broadly. The goal of this course is to provide breadth rather than depth, with the assumption that most students, even those relatively familiar with body and/or rhetorical theory, will approach rhetorical studies of the body as novices. Students will conduct their own research on a topic related to rhetorical studies of the body that also aligns with their professional and academic goals. Graduate students interested in research will benefit from this course's focus on theory and the professional genres central to rhetorical studies. Undergraduates students (both majors and non-majors) will have the opportunity to examine how the body intersects with communication and writing contexts in their everyday public and professional lives.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-822 Gender and Sexuality Studies
Intermittent: 6 units
We will anchor our introduction to this broad and diverse field of theory in the admittedly very limited historical period of feminist, queer, and transgender political activism, circa 1970 to the present day. Instead of attempting "coverage" (an impossible task), we will shuttle between recent work in queer, transgender, and feminist theory and a few key texts that are foundational to the development of academic theory as a reaction to and extension from the political activism of these social movements. Our goals are to strengthen our understanding of the continuities and breaks in politically informed thinking about gender and sexuality, and to deepen our knowledge of the theoretical frameworks available to us from these areas of study. Students will write short response papers to course readings that will help us focus our discussions on their particular interests in literary and cultural studies.

76-829 Digital Humanities: Politics and Early Modern Drama
Intermittent
This course will explore a range of questions related to the manifestation of political thinking on the early modern English stage, a key medium for the dissemination and cultivation of information and ideas. Our central curriculum will include plays by William Shakespeare, Thomas Middleton, Christopher Marlowe, and others alongside a selection of critical essays and related literature from the period. To complement this collective investigation, students will also complete a hands-on, entry-level assignment that introduces digital methodologies for visualizing and analyzing early modern texts. No previous experience with the digital humanities is necessary to participate. Technological neophytes, seasoned programmers, and persons at all skill levels in-between are all very welcome to participate.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-844 History of Books and Reading
Fall
Rather than putting an end to the book, digital media have had the oddly exhilarating effect of making us look at all kinds of print, past and present, through newly focused lenses. This course will introduce you to the history of books and reading, a cross-fertilizing field of study that is having an impact on many disciplines, from the history of science to literary history, cultural studies, and the arts. Scholarship in this still-emerging field will include work by Roger Chartier, Michel Foucault, Elizabeth Eisenstein, Pierre Bourdieu, Michel de Certeau, , and the current scholars who appear in one of our key books, "Interacting with Print: A Multigraph." We'll also read primary texts by Joseph Addison, Jane Austen, Samuel Coleridge, and Wilkie Collins to see how differing modes of print and reading became highly contested cultural and political matters in the eighteenth and nineteenth centuries. Other topics include the division between new reading publics and their ways of reading books; important changes in book production, typography, printing methods (hand-press to steam press). Such knowledge of the history of print has become especially crucial in an era of emerging "new media" and the field of digital humanities in the university. Two papers will be requiredone shorter paper (5-7 pp.) and a longer research paper on the uses of books and print by producers and readers. Though the course meets in Baker Hall, you will have hands-on experience with early books and other forms of print as we also meet periodically in the Rare Book Room at Hunt Library.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-846 Revenge Tragedy
All Semesters
Attendants to the early modern English theater seem to have had an almost insatiable appetite for revenge tragedy: a lurid, blood-soaked genre distinguished by plots involving insanity, skulls, ghosts, poisonings, stabbings, suicide, and other forms of unnatural death. This course will cover key examples of the genre, putting particular emphasis on the depiction and interrogation of justice, analyses of death, and playful engagement with theatricality. Our central curriculum will include plays by Seneca, William Shakespeare, Thomas Middleton, Christopher Marlowe, and Thomas Kyd, alongside a selection of critical essays and related literature from the period.

76-849 Race and Media
Intermittent
This course will introduce students to useful methodological approaches, ranging from film studies, media archeology and book history to Black studies, Transnationalism and Post-Marxism, to analyze race and representation within a variety of media formats. Media in this course is understood broadly: technologies used to store and deliver information. With this rather broad understanding in mind our course will look at how artists and intellectuals use discrete formats (print, film/video, electronic, and other recording mediums) to imagine, remediate and study the circulation of racialized bodies and identities within global capitalism. We will also think about the concept of race itself as another, particularly problematic "media" format used to store and deliver information about the human for political, economic, ideological and juridical purposes. The class will be organized around specific material and "immaterial" media objects that will allow us to explore the processes of (re)mediation that characterize racialized bodies and formats. We will look at a range of works that might include D.W. Griffith, Nella Larson, Iceberg Slim, Raul Peck, Christina Choy, Renee Tajima, Janelle Monae, Ramiro Gomez, Dana Shultz, and 50-Cent. We will also read the theoretical works of Stuart Hall, Christina Sharpe, Carol Vernallis, Lisa Lowe, Teju Cole, Lisa Gitelman and Michael Gillespie, Simone Browne, Martin Heidegger, Theodore Adorno and others.

76-852 Generations and Culture
Intermittent
We hear about generations all the time—the Millennials rising, Gen X and their minivans, and the Baby Boomers retiring. Yet, generations have usually been ignored in cultural studies as an amorphous, popular concept. While we discuss factors that shape identity such as race, class, gender, sexuality, there is little work on generations. In addition to those factors, contemporary researchers have determined that generations in fact often have significant impact on opinions, consumer choices, and political views. This course will study the theory of generations, from sociology, history, marketing, and other fields. It will also look at how the concept might apply to cultural products, such as literature or theory itself. In addition, in the course you will develop a project to study one generation and its culture.

76-853 Literature of Empire
Fall
Nineteenth and early twentieth-century British literature was shaped by events taking place outside as well as inside of national borders. Even in the eighteenth and nineteenth centuries, with international trade and slavery supporting the manor house and plantations abroad providing the cotton for British looms, the "England" of English literature spanned the globe. By the first half of the twentieth century, this empire had begun to collapse in upon itself, a process witnessed by writers inside Britain and its colonies. This course will investigate British literature within the international context of global imperialism. A section on gothic stories takes us into the realm of popular culture with Mary Shelley's Frankenstein and Arthur Conan Doyle's short stories. We take to the seas with Joseph Conrad's Lord Jim, before we consider W. Somerset Maugham's exploration of sexuality in the tropics in The Painted Veil. Finally, we return to England to outline the links between colonial empire and international war rendered in Virginia Woolf's Mrs. Dalloway. These literary works will be read alongside some of the most important works of postcolonial theory. While course readings focus on 19th and early 20th century, student's will undertake a research project over the semester in their own period of interest in British literature in connection with empire studies.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-854 Introduction to Literary and Cultural Studies
Fall
Cultural Studies is an intellectual and professional movement identified with the Center for Contemporary Cultural Studies in Birmingham. This movement grew out of literary studies. It is neither identitcal with literary studies, nor opposed to literary studies. It is today one form that the study of literature or other cultural works may take. This course offers a theoretical genealogy of cultural studies, showing how and why its theories and practices emerged and developed. As a genealogy, the course does not assume that cultural studies has an essence or an origin. The texts and topics will reflect the heterogeneity of its emergence and development. The course does, however, embody what we see as several historical changes in cultural studies, from idealism to materialism, from mono to multiculturalism, and from high culture exclusiveness to democratic inclusivity. The course is not designed to teach "approaches," but to explore and interrogate the founding assumptions of the academic project that you are being trained to join. Students should, by the end of the class, have a sense of where cultural studies came from and of the problems and possibilities raised by the theories it continues to invoke.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-864 Creative Non-Fiction Workshop: Magazines and Journals
Fall
Creative Non-fiction Workshop is a good class to take if you like to tell (write) stories about your own life and the lives of other people, all situated in the world we inhabit, the world that is ours to investigate and celebrate and question. The class will teach you how to write a good story, by focusing on aspects of craft. Class is almost always run as a discussion. We'll read books by authors of creative non-fiction, and learn from them how to work with a variety of forms. Every student will create a portfolio of roughly 25 pages of non-fiction by term's end.

76-868 Space and Mobilities
Intermittent
This course will investigate space and movement as social constructions. Space appears as something that exists around us: our houses, our neighborhoods, our cities might seem like they are simply there to be moved through. In the same way mobility, from our means of transport to an evening walk, can appear as just movement from A to B. In the late 20th century, an interdisciplinary group that included geographers, urban studies scholars, architects, sociologists, anthropologists, and literary theorists began to theorize the social construction of space. They argued that space is something dynamically created that may be interpreted for the ways it creates meaning. Following this spatial turn, mobilities studies scholars looked to understand movement as something that reproduces and constitutes power and institutions. This interdisciplinary course considers theories of space and movement as a field of study and in reference to literary and film texts. The course will be organized topically, and include such units as the regulation of freedom of movement over borders through the construction of boundaries; the heterotopia of the boat or train carriage; the poetics of space; the dynamic mapping of the city by a wanderer; neoliberal recalibrations of global space, and the spatialization of performance. Readings might include Henri Lefebvre, Doreen Massey, Edward Soja, Gaston Bachelard, Wendy Brown, John Urry, Tim Cresswell, Marian Aguiar; literary texts might include Brian Friels Translations, Christina Garcia's Dreaming in Cuban, W.G. Seabald's Austerlitz and Teju Cole's Open City.

76-881 Introduction to Multimedia Design
Fall
There is increasing demand for professional/technical writers who understand multimedia and its communicative possibilities. This class will provide students with the opportunity to develop the ability to create and analyze multimedia experiences that merge text, spoken voice, music, animation and video. Students will be introduced to the basic concepts and vocabulary of motion graphics, as well as the practical issues surrounding multimedia design and digital storytelling through a series of hands-on projects involving various contexts. Students will explore what it means to write for a dynamic medium and how to take advantage of elements of time, motion and sound to help expand their visual communicative skills. The essentials of Adobe After Effects will be taught in order to build the skills necessary to complete assignments, explore multimedia possibilities and foster each student's unique creative voice. Adobe Premiere and Audition will be employed to support specific tasks. Students will also be taught to capture their own original images, video and narration audio to craft the elements of their projects. It is helpful to have some prior basic experience with Photoshop or Illustrator. In-class discussion and critiques are an essential part of this course.
Prerequisites: 76-391 or 51-262 or 76-791

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-884 Discourse Analysis
Fall
Discourse is a focus of study in most of the humanities and social sciences, and discourse analysis is practiced in one way or another by anthropologists, communications scholars, linguists, literary critics, and sociologists, as well as rhetoricians. Discourse analysts set out to answer a variety of questions about language, about writers and speakers, and about sociocultural processes that give rise to discourse and are constituted in discourse. But all approach their tasks by paying close and systematic attention to particular constellations of texts and contexts. We are all familiar with the informal discourse analysis involved in paraphrasing the meanings of written texts and conversations, a skill we learn in writing and literature classes and in daily life. Here we ask and answer other questions about why people use language as they do, learning to move from a stretch of speech or writing or signing outward to the linguistic, cognitive, historical, social, psychological, and rhetorical reasons for its form and its function. As we look at resources for text-building we read analyses by others and practice analyses of our own, using as data texts suggested by the class as well as the instructor. In the process, we discuss methodological issues involved in collecting texts and systematically describing their contexts (ethnographic participant-observation and other forms of naturalistic inquiry; transcription and "entextualization"; legal and ethical issues connected with collecting and using other people's voices) as well as methodological issues that arise in the process of interpreting texts (analytical heuristics; reflexivity; standards of evidence). We will also spend a few minutes each week reviewing key concepts in English grammar.

Course Website: http://www.cmu.edu/dietrich/english/index.html

76-885 The New Public Sphere
Fall
Public deliberation is at the heart of the rhetorical tradition. But is public dialogue really a live option in a media-saturated world of sound bites addressed to plural publics? Is the process of debate, deliberation, and decision (in which the best argument wins) really the ideal model? Or can people use public spaces to develop new, more inclusive positions? Could such a process occur in a boundary-crossing public when diverse groups enter intercultural deliberation around racial, social, or economic issues? This course looks at diverse ways people use rhetoric to take literate social action within local publics. From the canonical debate around Habermas and the public sphere, we move to a feminist "rereading" of the Sophists, to contemporary studies of deliberation in workplaces, web forums, grassroots groups, new media, and community think tanks. To support your own inquiry into the meaning making process of a local public, you will learn methods for activity analysis and for tracing social/cognitive negotiation within a public of your choice.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-891 Rhetorical Analysis
Fall and Spring
Students in this course will learn various approaches to analyzing discourse artifacts from a rhetorical point of view. Early in the course, students will identify an artifact or artifacts they wish to analyze. From there, students will be encouraged to explore their own methods of analysis based on two required books for the course and reviews of literature. For the midterm, students will create an annotated bibliography of five specimens of criticism taken from a single journal. For the final project student will first present and then hand in a polished 15 page piece of criticism based on one or some combination of methods. The presentation and final paper count 50% of the grade, with the mid-term, class attendance, participation, and homework making up the final 25%.

76-894 Digital Humanities
Intermittent: 6 units
Digital Humanities is an emerging discipline as well as a broad collection of scholarly activities that apply new technologies to humanities research while expanding traditional forms of scholarly communication. Some of its many facets include: book history, cartography (using maps to better understand the cultural production of texts), the preservation and sharing of collections that are otherwise difficult to access. DH can also include the fostering of new creative expression by using digital media. In this mini we'll be reading a variety of leaders in the field including Robert Binkley, Franco Moretti, Matthew Jockers, Peter deBolla, Johanna Drucker, Alan Liu, Jerome McGann, Christopher Warren, and Bethany Nowviskie, attending the CMU DH lunch workshops, and taking some field trips around the city to see some DH projects in action.

76-898 Marxisms
Intermittent: 6 units
Karl Marx just turned 200 and in many ways his ideas is more popular than ever. But what is Marxism, and how can we best use Marxism to think about culture? This mini will be a crash course in what we call Marxisms, a cluster of theories tracing their roots to the materialism of Karl Marx. On our list will be writings from: Antonio Gramsci, Rosa Luxemburg, Raymond Williams, Stuart Hall, CLR James, and Silvia Federici.

Course Website: http://www.cmu.edu/dietrich/english/index.html

Department of History

Donna Harsch, Department Head
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www.cmu.edu/dietrich/history

Undergraduate Degree Options in the Department of History

The B.A./B.S. in Social & Political History

The B.A. in Global Studies

The B.A./B.S. in Ethics, History, and Public Policy

The Department of History offers undergraduates a choice of three majors: Social & Political History, Global Studies, and Ethics, History, and Public Policy (administered by the Philosophy Department). Specific requirements and courses for each major are detailed below.

All three History majors are grounded firmly in the liberal arts. Each has a strong interdisciplinary bent and an equally strong commitment to using knowledge of the past to illuminate present-day social, cultural, and political affairs.

In different ways, all three majors emphasize empirical research methods and conceptual analysis, and cultivate reading, research, and writing abilities central to a variety of professions. Our students develop strong analytic and writing skills; choose among diverse U.S., global, and thematic courses; learn experientially through internships and/or study abroad; and benefit from small class sizes and easy access to faculty who are internationally known for innovative historical, anthropological, and other social science approaches to investigating the past. The study of history necessarily includes diverse societies and controversial public policy issues, usefully blending liberal education with professional development.

History is also excellent preparation for leadership positions in law, business, journalism, politics, education, and government service (e.g., U.S. Foreign Service, Health & Human Services, Federal Trade Commission). The resumes of innumerable CEOS and government statesmen show how effectively the study of history serves as a foundation for preparing leaders both at home and abroad.

Having been trained to analyze subtle and complex issues, to develop breadth of understanding, to dig out information and make sense of it, and to present their findings effectively, graduates of the History Department do extremely well in many types of for-profit, non-profit, governmental, and non-governmental organizations. Because history training combines research and writing skills with analysis of social and policy trends, it also prepares graduates for journalism and other writing careers in the modern media age.

All three History degree programs combine easily with majors in Business, Economics, English, Information Systems, Modern Languages, Philosophy, Professional Writing, Social and Decision Sciences, and Statistics.

Additional Majors

The majors in Social & Political History, Global Studies, and Ethics, History, and Public Policy may be declared as additional majors in consultation with the Academic Advisor of each program: Dr. Andrew Ramey for Social & Political History and Global Studies (aramey@andrew.cmu.edu), and Correy Dandoy for Ethics, History, and Public Policy (Philosophy Department, correy@cmu.edu).

Interdepartmental Majors

In addition to the Ethics, History, and Public Policy major, History faculty are also integral participants in three interdepartmental majors described elsewhere in this catalog: International Relations and Politics in the Institute for Politics and Strategy, Arabic Studies, and Russian Studies in the Modern Languages Department. History courses are also central to the Environmental Policy major (additional major only).

Minors

Options for pursuing a minor in Social & Political History or Anthropology are discussed below, following the sub-section on Ethics, History, and Public Policy.

Several other minors with strong History content, detailed elsewhere in the Undergraduate Catalog, can be linked with any degree. Students should contact the relevant History faculty members listed below:

- African and African American Studies: Professor Edda Fields-Black (fieldsblack@cmu.edu)
- Environmental and Sustainability Studies: Professor Abigail E. Owen (aeown@cmu.edu)
- Gender Studies: Professor Lisa M. Tetrault (tetrault@andrew.cmu.edu)
- Religious Studies: Professor Allyson F. Creasman (allysonc@andrew.cmu.edu)
- Russian Studies: Professor Wendy Goldman (goldman@andrew.cmu.edu), Professor Tatyana Gershkovich (tgershko@andrew.cmu.edu)
- Science, Technology, and Society: Professor Christopher J. Phillips (cjp1@cmu.edu)

Research and Outreach Centers

History Department faculty members lead three research and outreach centers that advance new interdisciplinary knowledge and help translate knowledge into public policies that further the pursuit of social, economic, and political justice.

1. CAUSE (Center for African American Urban Studies and the Economy), Joe W. Trotter, Director
2. The Bajaj [India] Rural Development Lab, Nico Slate, Director
3. The Center for Human Rights Science, Jay D. Aronson, Director

The Major in Social & Political History (SPH)

Professor Steven Schlossman, Director of Undergraduate Studies
sls@cmu.edu, Baker Hall 236A, 412-268-2885

Dr. Andrew Ramey, Academic Advisor
aramey@andrew.cmu.edu, Baker Hall 240, 412-268-7906

www.cmu.edu/dietrich/history/undergraduate/sph

Social & Political History (*SPH*) is a research- and writing-intensive major that emphasizes analysis of change over time and in-depth understanding of the societies, cultures, economies, political systems and conflicts that have shaped our world. History electives focus on areas of faculty expertise such as science, technology, race, culture, public health, environment, gender, labor, war, politics, sports, education, and criminal justice.

All majors take Introduction to Historical Research & Writing (79-200, 9 units) and the capstone Historical Research Seminar (79-420, 12 units), where they conduct individualized projects using archival and other primary sources. Several students have published the results of their research, and we are exploring new ways to facilitate future publication of students' research in both undergraduate and professional history journals.

The broad analytic, research, and writing skills cultivated by the SPH major prepare students for success in a wide variety of graduate and professional schools, and for exercising leadership in careers in business, law, government, education, journalism, public policy, social work, the armed services, Foreign Service, media, museums and libraries. Often, history graduates pursue post-undergraduate professional school, such as law, business administration, education, public policy, urban planning, librarianship, journalism, the ministry, and social work.

For students interested in pursuing a professional career in History, options today include not only research and teaching -- our graduates have earned Ph.D. degrees at Harvard, Northwestern, and other major universities -- but also expert positions as historians in museums, archives, historic sites, the armed services, media outlets, and other public history venues.

Students graduating with a primary major in Social & Political History may pursue a B.A. or B.S. degree. *SPH* may also be taken as an additional (i.e., second) major.

Curriculum (93 units)

Requirements for both primary and additional *SPH* majors are Global Histories (79-104), which all Dietrich College and Tepper College students must take, plus an additional 84 units, for a total of 93 units.

All students in the Social & Political History major are required to complete two research-training courses: Introduction to Historical Research & Writing (79-200, 9 units), and Historical Research Seminar (79-420, 12 units), which is regularly offered in the Fall semester of the senior year. Students must earn a final grade of “C” or better in these two courses in order to fulfill the requirements for the *SPH* major.

In addition, students must take two historical *survey courses* from a wide range of attractive options that include most major regions of the world.

Otherwise, students enjoy great flexibility: they are free to take additional survey courses or to specialize in thematic topics or regions of the world that are of special interest to them.

If you are interested in pursuing a minor in SPH, please view the section (see below) for the Minor in Social and Political History.

Social & Political History Major (*SPH*)

I. Required General Education Course (9 units)

79-104	Global Histories	9

II. Required History Department Courses (21 units)

79-200	Introduction to Historical Research & Writing	9
79-420	Historical Research Seminar	12

III. Required Survey Courses (*choose two* -- 18 units)

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-206	Crime and Punishment in Early Modern Europe	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-233	The United States and the Middle East since 1945	9
79-235	Caribbean Cultures	9
79-240	Development of American Culture	9
79-241	African American History: Africa to the Civil War	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-249	20th & 21st Century U.S. History	9
79-258	French History: From the Revolution to De Gaulle	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-269	Russian History: From Socialism to Capitalism	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-307	Religion and Politics in the Middle East	9
79-320	Women, Politics, and Protest	9

IV. Social & Political History Elective Courses (45 units)

Students must complete 45 elective History units (*typically 5 courses*) for the Social & Political History major. Any History Department courses not fulfilling another major requirement may be chosen as an elective.

Social & Political History majors have considerable flexibility in choosing their elective courses, but should consult with the Academic Advisor, Dr. Andrew Ramey, (Baker Hall 240), in making their selections.

For a complete list of elective course options in History, please consult the History course descriptions elsewhere in this catalog. The selections below are designed to give you a sense of the great variety of thematically centered courses (in addition to the survey courses listed earlier) that History Faculty members regularly teach:

79-257	Germany and the Second World War	9
79-268	World War I: The Twentieth Century's First Catastrophe	9
79-276	Beyond the Border	6
79-278	How (NOT) to Change the World	9
79-280	Coffee and Capitalism	9
79-299	From Newton to the Nuclear Bomb: History of Science, 1750-1950	9
79-300	Guns in American History: Culture, Violence, and Politics	9
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-305	Moneyball Nation: Data in American Life	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-314	The Politics and Culture of Memory	9
79-316	Photography, the First 100 Years, 1839-1939	9
79-317	Art, Anthropology, and Empire	9
79-318	Sustainable Social Change: History and Practice	9
79-322	Stalin and the Great Terror	9
79-323	Family, Gender, and Sexuality in European History, 500-1800	9
79-331	Body Politics: Women and Health in America	9
79-338	History of Education in America	9
79-339	Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)	6
79-345	Roots of Rock & Roll	9
79-346	American Political Humor	9
79-350	Early Christianity	9
79-352	Christianity Divided: The Protestant and Catholic Reformations, 1450-1650	9
79-359	Truth, Lies, and Propaganda: A Historical Inquiry	9
79-363	The Rise of Modern Golf, 1860 to the Present	6
79-371	African American Urban History	9
79-372	Cities, Technology, and the Environment	6
79-377	Food, Culture, and Power: A History of Eating	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-385	Out of Africa: The Making of the African Diaspora	9
79-395	The Arts in Pittsburgh	9
79-396	Music and Society in 19th and 20th Century Europe and the U.S.	9

Social & Political History Major — Sample Curriculum

Required Dietrich College General Education Course: 79-104 Global Histories (need not be completed before beginning the major).

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
79-104 Global Histories	SPH Survey or Elective Course	SPH Survey or Elective Course	SPH Survey or Elective Course
76-101 Interpretation and Argument	36-200 Reasoning with Data	Second Course (open)	Second Course (open)
Freshman Seminar	General Education Course	Third Course (open)	Third Course (open)
General Education Course	Fourth Course (open)	Fourth Course (open)	Fourth Course (open)
General Education Course	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)
99-101 Computing @ Carnegie Mellon			

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
79-200 Introduction to Historical Research & Writing	SPH Elective Course	79-420 Historical Research Seminar	SPH Elective Course
SPH Elective Course	SPH Elective Course	Second Course (open)	Second Course (open)
Third Course (open)	Third Course (open)	Third Course (open)	Third Course (open)
Fourth Course (open)	Fourth Course (open)	Fourth Course (open)	Fourth Course (open)
Fifth Course (open)	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)

The table above represents a four-year plan for completing all requirements for the Social & Political History Major. Students may declare the major and begin course requirements as early as the start of the sophomore year and in some instances in the freshman year. Students should meet with the department's Academic Advisor,Dr. Andrew Ramey, (aramey@andrew.cmu.edu), for both short- and long-term course planning.

*Some Social & Political History majors choose to apply for the senior honors thesis program. The department strongly encourages students to take advantage of this option.

V. Courses in Other Departments that Satisfy SPH Elective Requirements (*up to 27 units*)

Students may satisfy the elective requirements in SPH with *up to 27 units* of the following courses offered by other departments in Dietrich College:

73-476	American Economic History	9
76-230	Literature & Culture in the 19th Century: Environmentalisms	9
76-239	Introduction to Film Studies	9
76-295	Topics in Russian Language & Culture: 20th Century Russian Masterpieces	9
76-449	Race and Media	9
80-135	Introduction to Political Philosophy	9
80-226	Revolutions in Science	9
80-335	Social and Political Philosophy	9
82-208	Topics in European Studies	9
82-245	New Directions in Hispanic Studies	9
82-247	The Hispanic World: History, Culture and Globalization	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-327	The Emergence of the German Speaking World	9
82-420	The Crucible of Modernity:Vienna 1900	9
82-427	Nazi and Resistance Culture	9
84-275	Comparative Politics	9
84-308	Political Economy of Latin America	9
84-322	Nonviolent Conflict and Revolution	9
84-324	The Future of Democracy	6
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-366	The American Presidency	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-389	Terrorism and Insurgency	9
85-380	In Search of Mind: The History of Psychology	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

VI. 79-505: SPH Internship (6-9 units)

The Social & Political History program strongly encourages students to locate internship opportunities in Pittsburgh or elsewhere that complement their historical interests (as, for example, in a museum or historical society) or in areas of policy research that complement their historical interests (as, for example, in a government agency or non-profit organization).The Academic Advisor will assist students with matching their interests to local organizations. SPH students can earn up to 9 units in each internship. Please note, however, that internship credits do not count toward fulfillment of course requirements for the SPH major (though the units do count toward graduation).

VII. Additional Major in Social & Political History (*SPH*)

The Social & Political History Major may be scheduled as an additional major in consultation with the Academic Advisor, Dr. Andrew Ramey, (aramey@andrew.cmu.edu).

VIII. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Academic Advisor, Dr. Andrew Ramey, (aramey@andrew.cmu.edu), to accept equivalent courses as substitutions.

21-257	Models and Methods for Optimization	9
36-202	Statistics & Data Science Methods	9
or 36-208	Regression Analysis	
or 70-208	Regression Analysis	
36-207	Probability and Statistics for Business Applications	9
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
70-257	Optimization for Business	9
80-222	Measurement and Methodology	9
80-305	Choices, Decisions, and Games	9
84-265	Political Science Research Methods	9
88-221	Analytical Foundations of Public Policy	9
88-223	Decision Analysis	12
88-251	Empirical Research Methods	9
88-300	Programming and Data Analysis for Social Scientists	9

The Major in Global Studies

Professor John Soluri, Director
jsoluri@andrew.cmu.edu, Baker Hall 363, 412-268-7122

Dr. Andrew Ramey, Academic Advisor
aramey@andrew.cmu.edu, Baker Hall 240, 412-268-7906

www.cmu.edu/hss/globalstudies

The major in Global Studies offers an interdisciplinary course of study designed for students interested in humanistic approaches to understanding past and present processes of globalization. Participating faculty in the departments of History, Modern Languages, and English conduct research in Africa, Asia, Europe, Latin America, the Middle East, and the Pacific. The rigorous yet flexible Global Studies curriculum combines anthropology, history, literary and cultural studies, and foreign language training in order to help students make sense of complex interactions among global processes, regional and local cultures, and societal structures. Global Studies majors develop a broad understanding of their prospects and responsibilities as citizens of the world confronting challenging contemporary problems.

Global Studies majors are encouraged to incorporate a study abroad experience into their course of study in order to immerse themselves in a society different from their own with unfamiliar cultural practices, language, and history. Global Studies majors may also enroll in 79-506 Global Studies Internship, a course that enables them to earn credit while gaining first-hand experience working with Pittsburgh-based organizations that work across borders.

Majors should consult regularly with the program's Academic Advisor, the Faculty Director, and participating faculty who will help students to craft a coherent course of study on specific topics and/or regions that may lead to their capstone research project (79-400 Global Studies Research Seminar) or a Dietrich College senior honors thesis.

Students graduating with a primary major in Global Studies receive a Bachelor of Arts degree. Global Studies may also be taken as an additional (e.g., second) major.

Curriculum

(102 units plus demonstration of language proficiency)

There are three required courses for the major: Global Histories (79-104), Introduction to Global Studies (79-275), and Global Studies Research Seminar (79-400). In addition to these three courses, majors must also complete 72 units of electives and demonstrate proficiency in a modern language other than English. Students may double count a maximum of two courses taken for the Global Studies major that are also being used to fulfill the requirements of other majors and programs. Students should consult with the Global Studies Academic Advisor about new courses and study abroad courses that may be approved for students pursuing the major in Global Studies.

I. Required General Education Course (9 units)

79-104	Global Histories	9

II. Global Studies Introductory Course (9 units)

Students must earn a final grade of "C" or better for the course to count toward the major.

79-275	Introduction to Global Studies	9

III. Language Requirement

Demonstrating intermediate to advanced level proficiency in a language other than English is a crucial component of the major in Global Studies. Normally this requirement can be satisfied by successfully completing a course conducted in the second language at the 300 level or above for French, German, Italian, or Spanish, or the fourth semester (Intermediate II) level or above for Arabic, Chinese, Japanese, or Russian. Comparable proficiency for other languages can be considered. Additional advanced cultural, historical, and literary study in the second language is strongly recommended. Courses in a language other than English may also be counted as Global Studies transnational, global, or regional courses or Global Studies electives as appropriate.

IV. Theoretical and Topical Core Courses (18 units)

Students must earn a final grade of "C" or better in these courses to fulfill the theoretical and topical core course requirement.

79-201	Introduction to Anthropology	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-278	How (NOT) to Change the World	9
79-280	Coffee and Capitalism	9
79-289	Animal Planet: An Environmental History of People and Animals	9
79-314	The Politics and Culture of Memory	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-317	Art, Anthropology, and Empire	9
79-318	Sustainable Social Change: History and Practice	9
79-377	Food, Culture, and Power: A History of Eating	9
79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-383	The History of Capitalism	9

V. Transnational, Global, and Regional Courses (27 units)

<u>Transnational and Global Courses</u>

76-353	Transnational Feminisms: Fiction and Film	9
76-384	Race, Nation, and the Enemy	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
79-224	Mayan America	9
79-233	The United States and the Middle East since 1945	9
79-237	Comparative Slavery	9
79-276	Beyond the Border	6
79-280	Coffee and Capitalism	9
79-282	Europe and the World Since 1800	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-333	Sex, Gender & Anthropology	9
79-350	Early Christianity	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-385	Out of Africa: The Making of the African Diaspora	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
82-283	Language Diversity & Cultural Identity	9
82-304	The Francophone World	9
82-345	Introduction to Hispanic Literary & Cultural Studies	9
84-322	Nonviolent Conflict and Revolution	9
84-326	Theories of International Relations	9
84-370	Global Nuclear Politics	9
84-389	Terrorism and Insurgency	9

<u>Regional Courses</u>

Africa:		
79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-291	Globalization in East African History	6
79-386	Entrepreneurs in Africa, Past, Present and Future	9

Eastern and Southern Asia and the Pacific:		
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-264	Tibet and China: History and Propaganda	6
88-411	Rise of the Asian Economies	9

Europe:		
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-208	Witchcraft and Witch-Hunting	9
79-268	World War I: The Twentieth Century's First Catastrophe	9
79-270	Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present	6
79-323	Family, Gender, and Sexuality in European History, 500-1800	9
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-415	Topics in French and Francophone Studies	9
82-441	Studies in Peninsular Literature and Culture	9

The Middle East:		
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-307	Religion and Politics in the Middle East	9
79-336	Oil & Water: Middle East Perspectives	6
79-398	Documenting the 1967 Arab-Israeli War	9
84-323	War and Peace in the Contemporary Middle East	9

The Americas:		
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-235	Caribbean Cultures	9
82-245	New Directions in Hispanic Studies	9
82-343	Latin America Language and Culture	9
82-451	Studies in Latin American Literature and Culture	9
82-455	Topics in Hispanic Studies	9

82-456	Topics in Hispanic Studies	9
84-308	Political Economy of Latin America	9

(27 units)

VI. Elective Courses

Students are required to take an additional 27 units (typically 3 courses) of electives, selected from one or both of the subcategories below. Category IV and V courses listed above that are not used to fulfill those requirements may also be counted as electives. Students may also substitute courses not found on these lists with prior approval from the Academic Advisor.

79-506 Global Studies Internship (6-9 units)

This course offers students the opportunity to gain academic credit while gaining first-hand experience interning with Pittsburgh-based organizations that work across borders. Students must consult with the Academic Advisor and Faculty Director before enrolling. The Faculty Director will assist students with matching their interests to local organizations and identifying an on-site supervisor available to collaborate in the ongoing and final evaluation of the student's work.

Thematic Elective Courses

57-306	World Music	9
70-365	International Trade and International Law	9
76-241	Introduction to Gender Studies	9
76-386	Language & Culture	9
76-449	Race and Media	9
76-450	Law, Culture, and the Humanities	9
76-468	Space and Mobilities	9
79-228	The Civil Rights Movement and the World	9
79-281	Introduction to Religion	9
79-286	Archaeology: Understanding the Ancient World	6
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-316	Photography, the First 100 Years, 1839-1939	9
79-324	#MeToo: Naming and Resisting Gender Violence	6
79-330	Medicine and Society	9
79-343	Education, Democracy, and Civil Rights	9
79-349	United States and the Holocaust	6
79-397	Environmental Crises and the City	6
80-244	Environmental Ethics	9
80-335	Social and Political Philosophy	9
82-215	Arab Culture Through Film & Literature	9
82-541	Special Topics: Hispanic Studies	Var.
84-275	Comparative Politics	9
84-310	International Political Economy	9
84-318	Politics of Developing Nations	9
84-362	Diplomacy and Statecraft	9

Nation–based Elective Courses

79-214	Paris in Revolt: History, Literature, Film	6
79-216	Genghis Khan and the Mongol Empire	3
79-256	Sex, Guns, and Rock 'n Roll: Youth Rebellion in 1960s & 1970s Europe	6
79-257	Germany and the Second World War	9
79-258	French History: From the Revolution to De Gaulle	9
79-259	France During World War II	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-269	Russian History: From Socialism to Capitalism	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-320	Women, Politics, and Protest	9
79-322	Stalin and the Great Terror	9
79-326	German History through Film	9
79-331	Body Politics: Women and Health in America	9
79-392	America at War: From Vietnam to Afghanistan	9
82-253	Korean Culture Through Film	9
82-254	World of Korea, Then and Now	9
82-273	Introduction to Japanese Language and Culture	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-294	Topics in Russian Language and Culture	9
82-303	Introduction to French Culture	9
82-305	French in its Social Contexts	9
82-333	Introduction to Chinese Language and Culture	Var.
82-342	Spain: Language and Culture	9
82-344	U.S. Latinos: Language and Culture	9
82-361	Italian Language and Culture I	9
82-420	The Crucible of Modernity:Vienna 1900	9
82-425	Topics in German Literature and Culture	9
82-427	Nazi and Resistance Culture	9
82-428	History of German Film	9
82-433	Topics in Contemporary Culture of China	9
82-434	Studies in Chinese Traditions	9
82-440	Studies in Chinese Literature & Culture	9
82-473	Topics in Japanese Studies	9

VII. Senior Capstone Course (12 units)

The research seminar is the capstone course for Global Studies majors and is designed to give students the chance to define and carry out a research project of personal interest. Students are strongly encouraged to incorporate their prior coursework (including foreign language training), study abroad, or internships into their research. Students must earn a final grade of "C" or better for the course to count toward the major.

79-400	Global Studies Research Seminar	12

Global Studies Major — Sample Curriculum

This sample curriculum presents a course of study for completing the requirements for the Global Studies major that includes an optional study abroad semester. Students may declare the Global Studies major and take required courses as early as the second semester of the freshman year and as late as the junior year.

Freshman		**Sophomore**	
Fall	**Spring**	**Fall**	**Spring**
79-104 Global Histories	79-275 Introduction to Global Studies	GS Theoretical & Topical Core Course	GS Theoretical & Topical Core Course
76-101 Interpretation and Argument	Language Course or Gen Ed	GS Transnational, Global, Regional Course	GS Transnational, Global, Regional Course
Freshman Seminar	36-200 Reasoning with Data	Language Course or Elective	Language Course or Elective
Language Course or Gen Ed	Fourth Course (open)	Fourth Course (open)	Fourth Course (open)
Fifth Course (open)	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)
99-101 Computing @ Carnegie Mellon			

Junior		**Senior**	
Fall	**Spring**	**Fall**	**Spring**
GS Transnational, Global, Regional Course	STUDY ABROAD*	79-400 Global Studies Research Seminar	Language Course or Elective
GS Elective	GS Elective	Language Course or Elective	Elective**
Language Course or Elective	GS Elective	Elective**	Third Course (open)
Fourth Course (open)	Language Course or Elective	Fourth Course (open)	Fourth Course (open)
Fifth Course (open)	Fourth Course (open)	Fifth Course (open)	Fifth Course (open)
	Fifth Course (open)		

*Spring semester of the junior year is a popular semester for study abroad. However, Global Studies majors may instead choose to study abroad in spring of sophomore year, or fall of junior year. Students should discuss study abroad and curricular planning with the Academic Advisor, Dr. Andrew Ramey, (aramey@andrew.cmu.edu). Study Abroad in a summer program is also an option.

**Many Global Studies majors choose to apply for the senior honors thesis program. The department strongly encourages students to take advantage of this option.

VIII. Additional Major

Global Studies may be elected as a primary or an additional major; the requirements for each are the same. Contact the Academic Advisor, Dr. Andrew Ramey,(aramey@andrew.cmu.edu), to elect the additional major.

The Major in Ethics, History, and Public Policy

Alex John London, *Director*
Location: Baker Hall 150A
ajlondon@andrew.cmu.edu
www.cmu.edu/dietrich/ehpp

The B.A./B.S. in Ethics, History, and Public Policy is an interdepartmental major offered jointly by the Departments of History and Philosophy. It prepares students for leadership positions by providing them with a rigorous, interdisciplinary humanistic and social-scientific education. It also serves as an excellent springboard for graduate study in a wide variety of disciplines such as law, public policy, ethics, and advocacy. The program focuses equally on the historical understanding of how modern-day problems have evolved, and the importance of developing clear criteria for ethical decision-making. The capstone project course provides students with the opportunity to engage with real-world public policy challenges using the methods, theories, and knowledge that they have gained through the major. Offered jointly by the departments of History and Philosophy, the B.A./B.S. in EHPP encourages specialization, internship experiences, and research in a wide range of policy areas.

Curriculum

Students graduating with a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science Degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 9 units in Economics, 36 units in History, 36 units in Philosophy, 27 units of elective courses, and a 12-unit senior capstone course. This program may also be taken as an additional (e.g., second) major. All courses toward the major must be taken for a letter grade, and 79-300 must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundations of Public Policy 9 units

Choose one 9-unit course from the list below.

73-102	Principles of Microeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-110	Foundations of Political Economy	9

II. History Core 36 units

Choose one 9-unit course from each category below:

Policy History (9 units)

79-300	Guns in American History: Culture, Violence, and Politics	9

U.S. History (9 units)

79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-249	20th & 21st Century U.S. History	9
79-320	Women, Politics, and Protest	9

Non-U.S. History (9 units)

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-237	Comparative Slavery	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-307	Religion and Politics in the Middle East	9

History Elective (9 units)

Take at least 9 additional units in the History Department with course number 79-200 or above. The following courses may not count: 79-400, 79-420, 79-449, 79-491, 79-505, 79-506.

III. Philosophy Core 36 units

Choose one 9-unit course from each category below. No more than 9 units at the 100 level may be counted toward the Philosophy Core.

Ethics (9 units)

80-130	Introduction to Ethics	9
80-330	Ethical Theory	9

Political Philosophy (9 units)

80-135	Introduction to Political Philosophy	9
80-335	Social and Political Philosophy	9

Foundations of Social Science (9 units)

80-221	Philosophy of Social Science	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9

Applied Philosophy (9 units)

80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

IV. Senior Capstone Project Course 12 units

79-449	EHPP Project Course [cross-listed]	12
80-449	EHPP Project Course	12

The Ethics, History and Public Policy Project Course is required for the Ethics, History and Public Policy major and is taken in the fall semester of the senior year. In this capstone course, Ethics, History and Public Policy majors carry out a collaborative research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis. The students develop an original research report based on both archival and contemporary policy analysis and they present their results to a client organization in the community.

V. Elective Courses 27 units

Choose any three courses (at least 27 units) from any category or categories shown below. Substitution of elective courses that cohere with a student's interest or concentration may be allowed after consultation with and approval from the Director.

Engineering and Public Policy (some courses have prerequisites; see EPP catalog listing)		
19-424	Energy and the Environment	9
Business		
70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-332	Business, Society and Ethics	9
70-364	Business Law	9

70-365	International Trade and International Law	9
70-430	International Management	9

Economics (some courses have prerequisities; see Economics catalog listing)

73-352	Public Economics	9
73-359	Benefit-Cost Analysis	9
73-365	Firms, Market Structures, and Strategy	9
73-372	International Money and Finance	9
73-408	Law and Economics	9
73-476	American Economic History	9

English

76-492	Rhetoric of Public Policy	9

History

Courses from the EHPP History Core (above) may be taken as electives only if they are not being used to fulfill the core requirement. Double counting is not permitted.

79-206	Crime and Punishment in Early Modern Europe	9
79-228	The Civil Rights Movement and the World	9
79-233	The United States and the Middle East since 1945	9
79-234	Technology and Society	9
79-242	African American History: Reconstruction to the Present	9
79-247	African Americans, Imprisonment, and the Carceral State	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-298	Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal	6
79-299	From Newton to the Nuclear Bomb: History of Science, 1750-1950	9
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-305	Moneyball Nation: Data in American Life	9
79-310	Modern U. S. Business History: 1870 to the Present	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-320	Women, Politics, and Protest	9
79-322	Stalin and the Great Terror	9
79-325	U.S. Gay and Lesbian History	6
79-330	Medicine and Society	9
79-331	Body Politics: Women and Health in America	9
79-336	Oil & Water: Middle East Perspectives	6
79-338	History of Education in America	9
79-339	Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)	6
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6
79-342	Introduction to Science and Technology Studies	9
79-343	Education, Democracy, and Civil Rights	9
79-349	United States and the Holocaust	6
79-370	Disasters in American History (2):Epidemics & Fires	6
79-371	African American Urban History	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-397	Environmental Crises and the City	6

Philosophy

Courses from the EHPP Philosophy Core (above) may be taken as electives only if they are not being used to fulfill the core requirement. Double counting is not permitted.

80-256	Modern Moral Philosophy	9
80-305	Choices, Decisions, and Games	9
80-405	Game Theory	9

Institute for Politics and Strategy

84-310	International Political Economy	9
84-380	Grand Strategy in the United States	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6

Social and Decision Sciences

88-223	Decision Analysis	12
88-281	Topics in Law: 1st Amendment	9
88-444	Public Policy and Regulation	9

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

21-257	Models and Methods for Optimization	9
36-202	Statistics & Data Science Methods	9
or 36-208	Regression Analysis	
or 70-208	Regression Analysis	
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
70-257	Optimization for Business	9
80-305	Choices, Decisions, and Games	9
80-405	Game Theory	9
84-265	Political Science Research Methods	9
88-251	Empirical Research Methods	9
88-221	Analytical Foundations of Public Policy	9
88-223	Decision Analysis	12
88-300	Programming and Data Analysis for Social Scientists	9

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy, Professor Alex John London, ajlondon@andrew.cmu.edu.

Ethics, History, and Public Policy Sample Curriculum

Junior Year		Senior Year	
Fall	**Spring**	**Fall**	**Spring**
Core requirement in Economics	Core requirement in History or Philosophy	Capstone Course	EHPP Elective Course
Core requirement in History or Philosophy	Core requirement in History or Philosophy	EHPP Elective Course	Second Course (open)
Core requirement in History or Philosophy	Core requirement in History or Philosophy	EHPP Elective Course	Third Course (open)
Core requirement in History or Philosophy	Core requirement in History or Philosophy	Fourth Course (open)	Fourth Course (open)
Core requirement in History or Philosophy	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be. Students may enter the EHPP major, and begin major course requirements, as early as the start of the sophomore year, or even in the first year. Students should consult their advisor when planning their program.

The Minor in Social & Political History (*SPH*)

Professor Steven Schlossman, Director of Undergraduate Studies
sls@cmu.edu, Baker Hall 236A, 412-268-2885

Dr. Andrew Ramey, Academic Advisor
aramey@andrew.cmu.edu, Baker Hall 240, 412-268-7906

www.cmu.edu/dietrich/history/undergraduate/minors/sph.html

The minor in Social & Political History involves a minimum of 54 units of History course work.

Curriculum (54 units)

I. Required History Survey Courses (choose two -- 18 units)

Students must complete 18 units (typically 2 courses) from the following list of survey courses:

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-206	Crime and Punishment in Early Modern Europe	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-233	The United States and the Middle East since 1945	9
79-235	Caribbean Cultures	9
79-240	Development of American Culture	9
79-241	African American History: Africa to the Civil War	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-249	20th & 21st Century U.S. History	9
79-258	French History: From the Revolution to De Gaulle	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-269	Russian History: From Socialism to Capitalism	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-307	Religion and Politics in the Middle East	9
79-320	Women, Politics, and Protest	9

II. Elective courses for the Minor in Social & Political History (36 units)

Students must complete 36 elective History units (typically 4 courses). Social & Political History minors have considerable flexibility in choosing their elective courses, but should feel free to consult with the Director of Undergraduate Studies in making their selections.

The Minor in Anthropology

Professor Paul Eiss, Faculty Advisor
pke@andrew.cmu.edu, Baker Hall 366, 412-268-6580

Dr. Andrew Ramey, Academic Advisor
aramey@andrew.cmu.edu, Baker Hall 240, 412-268-7906

www.cmu.edu/dietrich/history/undergraduate/minors/anthropology.html

The Minor in Anthropology is offered by the Department of History to train students in ethnographic methods and in theoretical understandings of culture. Students examine the evolution, depth, and complexities of ethnography, and explore notions of "culture" in diverse settings, over time and across space. In today's world, students are increasingly aware of the importance of developing a sophisticated approach to culture and its articulation with changes in the domains of the arts, technology, economics, and politics. The Minor in Anthropology, which may be taken alone but especially complements the majors in Global Studies and in Social & Political History, provides students with the tools to link diverse kinds of cultural practices to various aspects of globalization.

The Minor in Anthropology requires that students complete two "Introductory and Methods" courses (18 units) and four "Anthropological Perspectives" courses (36 units). In addition, 79-104 Global Histories is required (9 units), but it may be taken at any time during the student's coursework. Including this course, the Minor in Anthropology totals 63 units.

The minor in Anthropology involves a minimum of 54 units of History Department course work (not including 79-104 Global Histories), as described below.

Curriculum (63 units)

I. Required General Education Course (9 units)

This requirement need not be satisfied before beginning any minor in the History Department.

79-104	Global Histories	9

II. Introductory and Methods Courses (18 units)

Students must complete 18 units (typically 2 courses) for the Introductory and Methods Courses, selecting from the list below. (Other courses may fulfill these requirements, with permission of the Faculty Advisor.)

79-201	Introduction to Anthropology	9
79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

III. Anthropological Perspectives (36 units)

Students must complete 36 units (typically 4 courses) for Anthropological Perspectives Courses, selecting from the list below.

57-306	World Music	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-224	Mayan America	9
79-235	Caribbean Cultures	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-275	Introduction to Global Studies	9
79-276	Beyond the Border	6
79-278	How (NOT) to Change the World	9
79-286	Archaeology: Understanding the Ancient World	6
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-314	The Politics and Culture of Memory	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-317	Art, Anthropology, and Empire	9
79-333	Sex, Gender & Anthropology	9
79-334	Climate Change and Climate Justice: Global Perspectives	6
79-342	Introduction to Science and Technology Studies	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-377	Food, Culture, and Power: A History of Eating	9

Relevant Anthropology courses may be taken at another university (for instance study abroad, or the University of Pittsburgh or other Pittsburgh institutions) with permission of the Anthropology Minor's Faculty Advisor.

Senior Honors

Senior Honors Thesis: Dietrich College

The Dietrich College Honors Program may be undertaken by students completing the major in Social & Political History, the major in Global Studies, or the interdepartmental major in Ethics, History, and Public Policy. An Honors Thesis requires two semesters of work. Eligibility requirements are set by the College; contact the Associate Dean of Dietrich College for details.

Study Abroad

Study abroad is especially encouraged for all students in the History Department; this experience can help students better understand the relationship between cultural heritage and modern political processes in a host country. To make study abroad successful and determine how specific study abroad programs fit into History Department graduation requirements, History majors should consult with a relevant faculty member and/or with the Academic Advisor.

Faculty

JAY D. ARONSON, Professor of History – Ph.D., University of Minnesota; Carnegie Mellon, 2004–

ALLYSON F. CREASMAN, Associate Professor of History – Ph.D., University of Virginia; Carnegie Mellon, 2005–

LAURIE Z. EISENBERG, Teaching Professor of History – Ph.D., University of Michigan; Carnegie Mellon, 1992–

PAUL EISS, Associate Professor of Anthropology and History – Ph.D., University of Michigan; Carnegie Mellon, 2000–

EDDA FIELDS-BLACK, Associate Professor of History – Ph.D., University of Pennsylvania; Carnegie Mellon, 2001–

WENDY Z. GOLDMAN, Paul Mellon Distinguished Professor of History – Ph.D., University of Pennsylvania; Carnegie Mellon, 1988–

EMANUELA GRAMA, Associate Professor of Anthropology and History – Ph.D, University of Michigan; Carnegie Mellon, 2013–

DONNA HARSCH, Professor of History; Department Head – Ph.D., Yale University; Carnegie Mellon, 1990–

WHITNEY E. LAEMMLI, Assistant Professor of History – Ph.D., University of Pennsylvania; Carnegie Mellon, 2019–

RICKY W. LAW, Associate Professor of History – Ph.D., University of North Carolina; Carnegie Mellon, 2013–

KATHERINE A. LYNCH, Professor of History – Ph.D., Harvard University; Carnegie Mellon, 1980–

DEEPA NAIR, Assistant Teaching Professor of History, Carnegie Mellon-Qatar – Ph.D., National University of Singapore; Carnegie Mellon, 2019–

ABIGAIL E. OWEN, Assistant Teaching Professor of History; Director of Education, Steinbrenner Institute for Environmental Education & Research – Ph.D., Columbia University; Carnegie Mellon, 2016–

CHRISTOPHER J. PHILLIPS, Associate Professor of History – Ph.D., Harvard University; Carnegie Mellon, 2014–

BENJAMIN REILLY, Teaching Professor of History, Carnegie Mellon-Qatar – Ph.D., University of Pittsburgh; Carnegie Mellon, 2004–

EDMUND RUSSELL, Professor of History – Ph.D., University of Michigan; Carnegie Mellon, 2019–

SCOTT A. SANDAGE, Associate Professor of History – Ph.D., Rutgers University; Carnegie Mellon, 1995–

STEVEN SCHLOSSMAN, Professor of History; Director of Undergraduate Studies – Ph.D., Columbia University; Carnegie Mellon, 1988–

NICO SLATE, Professor of History; Director of Graduate Studies – Ph.D., Harvard University; Carnegie Mellon, 2009–

JOHN SOLURI, Associate Professor of History; Director of Global Studies – Ph.D., University of Michigan; Carnegie Mellon, 1999–

JOEL A. TARR, Richard S. Caliguiri University Professor of History and Policy – Ph.D., Northwestern University; Carnegie Mellon, 1967–

LISA M. TETRAULT, Associate Professor of History – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2005–

NOAH THERIAULT, Assistant Professor of Anthropology and History – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2017–

JOE WILLIAM TROTTER, Giant Eagle Professor of History and Social Justice – Ph.D., University of Minnesota; Carnegie Mellon, 1985–

BENNO R. WEINER, Assistant Professor of History – Ph.D., Columbia University; Carnegie Mellon, 2015–

Affiliated Faculty

JOSEPH E. DEVINE, Associate Dean for Undergraduate Studies, Dietrich College of Humanities and Social Sciences – D.A., Carnegie Mellon University; Carnegie Mellon, 1979–

CARRIE SETTLE HAGAN, Associate Director and Academic Advisor, Special Faculty, BXA Intercollege Degree Programs – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2013–

TIMOTHY HAGGERTY, Director of the Humanities Scholars Program – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2000–

LAUREN HERCKIS, Simon Initiative Research Faculty – Ph.D., University of Pittsburgh; Carnegie Mellon, 2016–

JEFFREY HINKELMAN, Special Faculty, English Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016–

Visiting Faculty

MICHAL R. FRIEDMAN, Visiting Assistant Professor of History – Ph.D., Columbia University; Carnegie Mellon, 2010–

LANSINE KABA, Distinguished Visiting Professor of History, Carnegie Mellon-Qatar – Ph.D., Northwestern University; Carnegie Mellon, 2009–

Emeriti

CAROLINE JEAN ACKER, Associate Professor Emeritus of History – Ph.D., University of California, San Francisco; Carnegie Mellon, 1993–

EDWIN FENTON, Professor Emeritus of History – Ph.D., Harvard University; Carnegie Mellon, 1954–

RICHARD MADDOX, Professor Emeritus of Anthropology and History – Ph.D., Stanford University; Carnegie Mellon, 1993–

DAVID W. MILLER, Professor Emeritus of History – Ph.D., University of Chicago; Carnegie Mellon, 1967–

JOHN MODELL, Professor Emeritus of History – Ph.D., Columbia University; Carnegie Mellon, 1982–

DANIEL P. RESNICK, Professor Emeritus of History – Ph.D., Harvard University; Carnegie Mellon, 1966–

JUDITH SCHACHTER, Professor Emeritus of Anthropology and History – Ph.D., University of Minnesota; Carnegie Mellon, 1984–

DONALD S. SUTTON, Professor Emeritus of History and Anthropology – Ph.D., Cambridge University, England; Carnegie Mellon, 1969–

Department of History Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

79-104 Global Histories
Fall and Spring: 9 units
Human activity transcends political, geographical, and cultural boundaries. From wars to social movements, technological innovations to environmental changes, our world has long been an interconnected one. Acquiring the ability to understand such transnational and even worldwide processes is an indispensable part of any college education. This course provides students with an opportunity to develop the skills and perspectives needed to understand the contemporary world through investigating its global history. All sections are comparable in their composition of lectures and recitations, required amounts of reading, and emphasis on written assignments as the central medium of assessment. The sections all aim to help students: (1) master knowledge through interaction with the instructors, reading material, and other students, (2) think critically about the context and purpose of any given information, (3) craft effective verbal and written arguments by combining evidence, logic, and creativity, and (4) appreciate the relevance of the past in the present and future. For descriptions of specific sections, see "First Year Experience" at the Dietrich College General Education Website: http://www.hss.cmu.edu/gened/topics-79104.html
Course Website: http://www.hss.cmu.edu/gened/topics-79104.html

79-198 Research Training: History
Fall and Spring: 9 units
This course is part of a set of 100-level courses offered by Dietrich College departments as independent studies for second-semester freshmen and first- or second-semester sophomores in the College. In general, these courses are designed to give students some real research experience through work on a faculty project in ways that might stimulate and nurture subsequent interest in research participation. Faculty and students devise a personal and regularized meeting and task schedule. Each Research Training course is worth 9 units, which generally means a minimum for students of about 9 work-hours per week. Prerequisites/restrictions: For Dietrich College students only; minimum cumulative QPA of 3.0 (at the time of registration) required for approved entry; additional prerequisites (e.g., language proficiency) may arise out of the particular demands of the research project in question. By permission of the relevant professor and the Director of Undergraduate Studies. Students sign up for these courses through both the History Department and the Dean's Office.

79-200 Introduction to Historical Research & Writing
Fall and Spring: 9 units
This course introduces students to methods and materials that historians use to study the past. Its goals are: first, to familiarize students with ways that historians think about their research, how they carry it out, and how they debate findings with other historians; second, to train students in "best practices" for doing historical research in primary and secondary sources. We discuss how to ask questions about the past and develop a one-semester research topic, find appropriate primary and secondary sources, take notes from those sources, and write a paper that answers an original question using skills we have studied. In the Spring 2019 semester, we will use the topic of the history of witchcraft and witch-hunting to focus the class. Although Western beliefs in witchcraft and "devil worship" dated back to antiquity, the 16th and 17th centuries witnessed the "Great European Witch-Hunt," which cost the lives of thousands across Europe and in its American colonies. Ever since, historians have struggled to explain why fears of witchcraft suddenly became so acute in this period. And although the witch-hunts in early modern Europe and its colonies gradually came to an end, beliefs in witchcraft persist into the modern era and, in many parts of the world today, continue to generate campaigns of popular violence against alleged perpetrators. In this course, we'll examine both primary historical sources and secondary scholarship to explore competing interpretations of this complex historical puzzle. At the end of the term, students will submit a final 10-15 page research paper on a topic of their choice related to the themes of the course.

79-201 Introduction to Anthropology
Intermittent: 9 units
Cultural anthropologists "make the strange familiar and the familiar strange," attempting to understand the internal logic of cultures which might, at first glance, seem bizarre to us, while at the same time probing those aspects of our own society which might appear equally bizarre to outsiders. The goal of this course is to raise questions basic to the study of culture and social relationships in a multitude of contexts. We will also discuss the anthropologist's relationship to the people s/he studies, and the responsibilities inherent in that relationship. The readings have been chosen to focus on topics that have long captured anthropologists' attention and that continue to be intensely debated: social inequality, race, colonialism, body, kinship, gender, history and memory, social lives of things, affect, globalization, and migration and humanitarianism. They reveal the diversity of human practices and experiences across time and space, as well as the wide range of approaches to these practices within the field of anthropology. This class will follow the format of a seminar. I will introduce the readings by placing them within larger debates, but the course will mainly be discussion-oriented. Through written work, readings, films, and in-class discussion, we will examine how anthropology makes us more aware of our own culturally-ingrained assumptions, while broadening our understanding of human experiences.

79-202 Flesh and Spirit: Early Modern Europe, 1400-1750
Intermittent: 9 units
This course examines European history from the Black Death to the French Revolution, a period known to history as the "early modern" period. That is, it marks a period in European history that was not quite medieval, and yet not quite modern. Many features of modern society, such as the nation-state, free-trade economies, religious pluralism, scientific rationalism, and secular culture trace their origins to the early modern era, yet the period was also marked by important continuities with the Middle Ages. During this course, we will explore how Europeans re-imagined their world in its transition from the medieval to the modern. Topics to be considered will include the "renaissance" of the arts, the problems of religious reform, exploration and colonialism, the rise of science, and the expansion of the state. Through these developments, we will focus on Europeans' changing notions of the human body, the body politic, and the natural world, as well as their re-interpretations of the proper relation between the human and the divine, the individual and the community, and the present and the past.

79-203 Social and Political Change in 20th Century Central and Eastern Europe
Intermittent: 9 units
Organized as a combination of lectures and seminar discussions, this course explores the political, intellectual, social, and cultural changes occurring in 19th century and 20th century Central and Eastern Europe. It begins with an examination of the emergence of nationalist movements during the 19th century, to then explore the darker side of romantic nationalisms as they unfolded into the radical political ideologies such as socialism and fascism of the interwar period. We will ask to what extent these earlier histories continued to subtly influence post-1945 Central and Eastern Europe under socialism. The second part of the course will focus on the social and political transformations occurring at distinct moments in the history of the Soviet bloc: the 1950s Stalinization, the 1960s De-Stalinization, the emergence of the more subtle forms of dissent in the late 1970s and the early 1980s, and the revolutions of 1989. Course materials include not only historical and anthropological readings, but also historical documents, memoirs, and documentaries. The assignments include: mandatory attendance of lectures, regular participation in the class discussions, weekly diary entries and two take-home exams (midterm and final). The diary entries aim to make you better understand the mentalities and social and political changes at an individual level, by vicariously experience the events through "your" historical character. At the beginning of the semester, you will be assigned two specific characters that you will "impersonate" throughout the semester (one at the time), bringing in material from lectures and readings to bear on "your" character's own experiences.

79-205 20th Century Europe
Intermittent: 9 units
This course surveys the history of Europe from 1900 to 2000 and beyond. While it covers major political trends and social changes in 20th century Europe, it concentrates on the following themes: The end of empire and the rise of the nation-state and ethno-nationalism in Europe; the extraordinary violence of two World Wars and the Spanish Civil War — and their continuing impact on politics, society, and culture; social and political movements/regimes of the far right and of the socialist/communist left; the rise and crisis of the European welfare state and of the European Union; the wars of the 1990s in the former Yugoslavia; conflicts within the European Union such as Brexit and the crisis between Spain & Catalonia; contemporary debates over historical memory of the Spanish Civil War, World WWII and the Balkan wars; cultural and political controversies surrounding Islam and Muslims and re-emergent antisemitism in Europe.

79-206 Crime and Punishment in Early Modern Europe
Intermittent: 9 units
This course will examine European legal institutions and their role in defining and enforcing societal norms of conduct and belief in the early modern era (c. 1400-1800). European society was fundamentally transformed in this period of transition between the medieval and the modern eras, and the laws and legal systems that exist in the Western world today reflect those influences at the deepest levels. This course will focus on how shifting definitions of "crime" and "punishment" reflected prevailing societal attitudes and anxieties toward perceived acts of deviance and persons on the margins of society. Assigned readings will examine the evolution of early modern European criminal court systems, the investigation and punishment of crime, the criminalization of social deviance (witches, vagrants, religious minorities and other outcasts), and the legal enforcement of sexual morality and gender roles. We will address not only the historical significance of these developments, but their influence upon current debates concerning social deviancy, policing, torture, and criminal punishment.

79-208 Witchcraft and Witch-Hunting
Intermittent: 9 units
Between the late 15th and the early 18th centuries, many Europeans became convinced that their society was threatened by a conspiracy of diabolic witches. Although Western beliefs in witchcraft and "devil worship" dated back to antiquity, the 16th and 17th centuries witnessed the most intense campaign of witch-hunting in all of Europe's history. Before it was over, the "Great European Witch-Hunt" of the early modern era cost the lives of thousands across Europe and in its colonies. And although the witch-hunts in early modern Europe and its colonies gradually came to an end, beliefs in witchcraft persist into the modern era and, in many parts of the world today, continue to generate campaigns of popular violence against alleged perpetrators. This course examines witchcraft beliefs and witch-hunting in historical perspective in both their European and colonial contexts. In addition to the early modern witch-hunts, it will address modern witchcraft beliefs and consider witch-hunting as a global problem today. It will focus on the origin and rationale of witch beliefs, the factors driving the timing and intensity of witch-hunts, and the patterns of accusations. Throughout, we will examine the many historical and regional variations in witch beliefs and prosecutions and explore how they reflect major social and cultural issues such as the relationship between "popular" and "elite" culture; religious change; state formation; gender and patriarchy; and the rationalization of law, medicine, and science. This course satisfies one of the elective requirements for the Religious Studies minor.

79-209 The Art of Historical Detection
Intermittent: 6 units
How do historians determine how and why episodes in the past transpired? This course takes students behind the scenes and acquaints them with the techniques by which historians practice their craft in interpreting historical events. Using dramatic case studies in American history, we will examine a wide array of tools and sources at the historian's disposal, among them oral evidence, photographs and images, maps, official documents, memoirs, psycho-history, media and popular culture. Through in-class workshops and solo and group assignments, students will experiment with different methods of historical analysis using a variety of source material. Students will develop a familiarity with the historian's toolbox and a new-found appreciation for the painstaking efforts that go into producing the history books they may otherwise take for granted.

79-210 Identity, Nationhood, and State
Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. This broad introductory course to general history through the prism of literature and politics aims at appreciating humanism and identity from the distant past on. 1. It discusses the significance of language and speech aptitude as a primordial and universal trait upon which rests the possibility of association and organization. This aptitude has made humans history conscious. 2. It explores some basic facts about the pre-19th century Western tradition of governance and the place of the individual within it, along with the expansion of these European states into the world in the aftermath of the maritime navigation and colonial conquest. An emphasis is placed on the pivotal European movements of the Renaissance and Enlightenment. The first, with its humanism in the 16th century, promoted a sense of identity associated with the language spoken in ones area and the rise from the old medieval notion of suzerainty of the local gentry over local communities to the sovereignty of the monarchy of the area, thereby the nation state. The second, the 18th century Enlightenment, led to reforms and revolutions. These transformations, including the growth of literacy, have significantly marked Europe and subsequently the rest of the world that experienced European domination or influence. All this has resulted in the making of broad communities of European language speakers who are not of European descent.

79-211 Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange
Intermittent: 9 units
When you hear the term "Southeast Asia," what comes to mind? The Vietnam War? The ruins of the Angkor civilization? Rich culinary traditions? Or perhaps your own ethnic heritage? However you imagine it, Southeast Asia is an incredibly diverse and dynamic region that has long been integral to world affairs and whose importance continues to grow. This course offers a wide-ranging survey of Southeast Asia's peoples, their histories, and some of the issues they face today. Together we will explore the region as a "global crossroads," where the world's religions, economies, cultures, and politics come together in generative, sometimes traumatic, and often surprising ways.

79-213 The American Railroad: Decline and Renaissance in the Age of Deregulation
Intermittent: 6 units
Railroads in the USA are often considered as a subject for nostalgia or public sector failure, an image largely based on passenger service. However, the USA's private sector freight rail industry is considered a model for the world as the result of its renaissance following deregulation in 1980. This is a "stealth" industry whose history and economics are both intertwined and complex. Starting with the development of the first U. S. railroads, students will gain a basic understanding of the industry's history and economics, with special attention to the past half-century. In addition, students will participate in small group research projects in particular areas of special interest — for example, economic history, industry culture, network economics, utility regulation or transportation policy.

79-214 Paris in Revolt: History, Literature, Film
Intermittent: 6 units
This course asks a simple question with a complex answer: Why is it that the modern history of the French capital has been so marked by uprisings that challenged and sometimes overthrew the existing political regime? What accounts for this political instability? We answer these questions by studying a selection of well-known examples of Paris uprisings from the period of great the French Revolution (began 1789) through May, 1968. We examine major causes of the revolt, the kinds of people who led and followed it, and its consequences in the short- and longer-term. We also learn about the "culture" that surrounded political and social movements through eyewitness accounts, speeches, literature and the arts. While we are doing this, we'll try to learn as much as we can about continuities and changes in the city itself — its population and built environment. Coursework will consist of attending lectures, responding orally and in writing to assigned readings and several films, and a comparative final essay.

79-216 Genghis Khan and the Mongol Empire
Intermittent: 3 units
This course examines the rise, rule, and impact of the Mongol Empire on global history. In the 13th century, Eurasia was shaken by a force contemporary chroniclers likened to an apocalypse. Within a few decades, horsemen under the command of Chinggis (Genghis) Khan swept out of the northeastern steppe to establish the largest land empire the world would ever know. Few events in world history have inspired such fear and awe. However, the Mongol period also ushered in the so-called pax Mongolica, the first period of sustained contact and exchange across Eurasia as people, technologies, arts, biodiversity, and ideas spread throughout the Mongol domains and beyond. Questions to be examined include: Who was Genghis Khan and how did he lead a little known nomadic people to conquer much of the known world? What cultural and technological innovations aided the Mongols rise and conquest? How did Genghis's successors rule their vast, diverse domains? What role did religion play in Mongol Eurasia? Why did a unified Mongol empire fall apart in such a relatively short period of time? And how did the Mongols and their empire help shape the world we live in today?

79-217 The War in Vietnam
Intermittent: 6 units
The Vietnam War, the first war to be televised, is one of the most controversial and influential events in the post-World War II history of the United States. A limited advisory role for U. S. troops to help the pro-Western government of South Vietnam fight off a Communist insurgency soon escalated to a full-scale American-led war against North Vietnam. This provoked widespread domestic protest and resistance to compulsory military service - "the Draft." Eventually, the strategic basis for U. S. foreign policy in general came into question. The U. S. withdrew combat troops and much financial support in 1973; Saigon (now Ho Chi Minh City) fell to the North in 1975 as Americans watched from their living rooms. This course covers war in Vietnam from the intervention of the U. S. in the mid-1950s through the fall of Saigon in 1975, with particular emphasis on the last decade, which saw the "Americanization" and subsequent "Vietnamization" of the war under the administrations of presidents Johnson and Nixon. It examines the military and political aspects of the war, as well as some of the social and cultural consequences in the U. S. as a result.

79-218 Tiananmen Square and Popular Protest in Modern China
Intermittent: 6 units
Thirty years ago, on June 4, 1989, the world watched as tanks rolled into Beijing's Tiananmen Square ending what had been six weeks of student-led protest calling for reform of the Chinese Communist Party and its policies. This was not the first time students had gathered at Tiananmen to demand political change. This year also marks the centennial anniversary of the student-led protests that launched the May 4th Movement, a social and intellectual revolution that fundamentally changed China and helped birth both the Nationalist Party of Chiang Kaishek and Communist Party of Mao Zedong. This class examines the causes and consequences of popular protest in twentieth-century China. While the focus is on the protests of 1919 and 1989, we will also look at other popular protests, including the Cultural Revolution (1966-1969), Democracy Wall Movement (1979), and post-Tiananmen protests among workers, farmers, ethnic minorities (especially Tibetans and Uyghurs), and others.

79-220 Screening Mexico: Mexican Cinema, 1898 to Present
Intermittent: 6 units
This mini-course is a survey of Mexican cinema from its origins in silent film to the present. Some areas of focus will include documentary footage and films of the Mexican Revolution (1910-1920), films of the Mexican "Golden Age" (1930-1960), and "New Mexican Cinema" from the 1990s forward. We will explore cinema as a window on Mexico's changing social, cultural and political dynamics, and as a way to probe such topics as: changing conceptions of Mexican identity; political critique and revolutionary movements; and urbanization, migration and the "drug war" in contemporary Mexico. **Please Note**: in addition to two weekly class meetings, this course also includes a required weekly film screening at 6:30 on Tuesday evenings.

79-223 Mexico: From the Aztec Empire to the Drug War
Intermittent: 9 units
This course provides a survey of Mexican history and culture over a variety of periods, from the rise of the Aztec empire, to Spanish conquest and colonization, to national independence, to the Mexican Revolution and contemporary Mexico. A wide range of topics will be addressed, such as: race, ethnicity, and indigeneity; state formation and politics; national identity and the politics of memory; migration and the border; and the drug war. Students will discuss historical and anthropological scholarship on Mexico, but will also consider cultural documents of various kinds, like Mexican music, art, and food.

79-224 Mayan America
Intermittent: 9 units
This course will explore the history and culture of the Maya from before the European conquest of the Americas to the present. After a survey of ancient Mayan society and of the European conquest of Mexico and Central America, we will consider the experience of the indigenous Maya under Spanish colonial rule and under the rule of Latin American nation-states in the nineteenth and twentieth centuries. Finally, we will cover the recent history of political conflict and military repression in Guatemala, the Zapatista uprising in southern Mexico, and increasing Mayan migration to the United States. Drawing upon the varied perspectives of archaeology, cultural anthropology, and social history, this course will explore several recurrent themes in Mayan America, such as: conquest, adaptation and resistance; indigenous political and communal organization; popular religion, prophecy and apocalypse; Mayan cultural and ethnic identity; "tradition" and "modernity"; state violence and human rights; and indigenous political and cultural mobilization at the local, national, and transnational levels.

79-225 West African History in Film
Intermittent: 9 units
West Africa is a vibrant, diverse, and rich region, which has had the largest influence demographically, culturally, socially, and linguistically on the Americas. This course will examine West Africa's history from the pre-colonial to the independence period. It will cover such topics as states vs. stateless societies, urbanization, trans-Saharan trade, Islamization, European interaction, the trans-Atlantic slave trade, colonialism, cash crops, missionaries, nationalism, and independence. Students will understand how this dynamic region changed over time as a result of internal factors, such as state formation, as well as external factors, interaction with Muslim and European traders. Students will also be exposed to the variety of sources used by historians to reconstruct West Africa's rich history. The course will use historical films by some of West Africa's most famous filmmakers, such as Ousman Sembene, to illustrate the diversity of the region and its historical change over time. Course includes two class meetings and mandatory film screenings on Tuesdays from 6:30-9:20pm.

79-226 African History: Earliest Times to 1780
Intermittent: 9 units
A beginning point for this course will be the question: how do historians reconstruct history when few written sources are available? Breaking disciplinary boundaries, the course will draw on linguistics, "climateology," archaeology, and anthropology to reconstruct dynamic social, cultural, political, and economic processes in Africa before the arrival of Europeans and before the availability of written source materials. When written sources are available, the course will interrogate them to illuminate the changes that occurred in African societies during the early period of contact with Europeans. Lastly, by focusing on long-term processes, such as economic specialization, urbanization, and Islamization, the course will begin to put the slave trade in an African-centered perspective.

79-227 Modern Africa: The Slave Trade to the End of Apartheid
Intermittent: 9 units
The course is designed to give students an understanding and appreciation of African history and culture from the "inside out." Though it deals with the period of European expansion in Africa, it is centered on African language/ethnic groups, villages, and individuals as historical actors who daily make collective and personal decisions to pass down, innovate, and borrow practices, technology, spiritual systems, etc. in the face of social, political, and economic realities. The course is also designed to get students thinking critically about how historians select and interpret sources to construct and reconstruct history at these different levels.

79-228 The Civil Rights Movement and the World
Intermittent: 9 units
The American civil rights movement was a global phenomenon. Throughout the twentieth century, the fight for racial justice involved multiple areas of conflict that transcended national boundaries. The purpose of this course is to understand how global events and crises influenced the ways in which activists understood political power. How did civil rights activists pioneer a global identity for American blacks and create solidarities with oppressed people worldwide, and how did these solidarities in turn influence activism at home? Answering these questions will require us to analyze various ideologies and political movements and their impact on anti-racist activism within the United States. World historical events, and their impact on the civil rights movement, will cover the 1917 Russian Revolution, the rise of Fascist Europe, the Second World War, the United Nations, the Cold War, and today's struggle for racial justice. By examining these issues, this class will shed light on the dynamic geo-political and socio-economic conditions that shaped the civil rights movement as well as today's activism.

79-229 Origins of the Arab-Israeli Conflict, 1880-1948
Intermittent: 9 units
This course considers the historical origins of the contemporary Arab-Israeli conflict, beginning with the decline of the Ottoman Empire and the rise of Arab nationalism and Zionism in the late 19th century and emphasizing the period of the British Mandate over Palestine (1920-1948). Students will move beyond textbooks to explore primary source documents, maps, photographs, biographies and historical testimony. For five weeks in the middle of the semester, students will immerse themselves in an extended role-playing exercise, "The Struggle for Palestine, 1936," an elaborate simulation game linked to Barnard College's "Reacting to the Past" program. Students portraying British examiners, specific Arab and Zionist characters and journalists will recreate the activities of the 1936 Royal Commission which came to Palestine to investigate the causes of an Arab rebellion and Arab-Jewish strife. This historical reenactment experience constitutes an exciting pedagogical opportunity for delving deeper into the topic material than regular coursework allows. All the role-playing will take place during regular class time, but students should be aware that they will need to devote outside time for preparation and research. Outstanding attendance is also a requirement. Regular classroom activity resumes at the end of the five weeks. The goal of the course is for students to develop a nuanced understanding of the varying goals and priorities of all the actors in Mandate Palestine. Running throughout the course is the question, was peace ever possible?

79-230 Arab-Israeli Conflict Since 1948
Intermittent: 9 units
This course begins in 1948 with the establishment of the State of Israel, the Palestinian dispersal and the first of many Arab-Israeli wars, and continues up to the present time. The examination of the many facets of the Arab-Israeli and Palestinian-Israel conflicts is accompanied by attention to the search for peace and its frustration. We will also situate this conflict within the framework of the war, chaos and religious extremism currently consuming the Middle East. The course culminates in an intensive role-playing game in which students conduct simulated Arab-Israeli negotiations. For the role-playing we will be partnering with Arab and Israeli students from universities in the Middle East: real-time negotiations will take place via Facebook and continue via various social media. The simulation game experience constitutes an exciting pedagogical experiment and an opportunity for delving deeper into the topic material than regular coursework allows.

79-232 Arabian Peninsula Environmental History
Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course will look at the history of the Arabian Peninsula from a fresh perspective, examining human/environmental interactions over a long stretch of time. In contrast to the way that Arabian history is typically taught in academia, this course will take the pre-Islamic period of Arabian history (al-jahiliyya) as seriously as the post-Islamic period, and will focus on continuities between the two periods as much as discontinuities. What is more, while conventional histories of the Arabian Peninsula focus on political and religious affairs, this course will try to understand Arabian history on a deeper level by focusing on the lifeways of the Arabian people, including pastoralism, oasis "bustan garden" agriculture, fishing and pearling, and shifting patterns of long-distance trade. What is more this course will draw heavily from material from other disciplines, especially medical sciences, to better understand patterns of change over time. Finally, this course will examine to what degree these older patterns of human/landscape interactions are still valid for the Arabian Peninsula today, which has undergone a transformation almost unparalleled in world history due to the discovery natural gas and oil.

79-233 The United States and the Middle East since 1945
Intermittent: 9 units
This course begins by introducing students to the Middle Eastern priorities and policies which the US inherited from the British in the aftermath of the Second World War. The focus then moves to American interests and involvement in the region from the Cold War through today, with special attention to recurrent historical themes. Topics include the US role in the Arab-Israeli conflict and peace process, the role of oil, politics and conflicts in the Persian Gulf, the impact of 9/11 on American foreign policy in the Middle East, and selected case studies of US political and military intervention there. Readings and discussion progress with a dual goal in mind: to understand American foreign policy interests in the Middle East, and to understand the forces and nuances endemic to the region itself. Students will learn how to analyze primary source documents, such as presidential speeches and UN resolutions. The course culminates in a week-long role-playing exercise in which students portraying NSA members must advise the US President on a policy response to a Middle East crisis.

79-234 Technology and Society
Intermittent: 9 units
How has technology shaped human society? And how have human beings shaped technology in return? This course investigates these questions across history-from stone tools, agriculture, and ancient cities to windmills, cathedrals, and the printing press; from railroads, electricity, and airplanes to atom bombs, the internet, and the dishwasher. In analyzing these tools, we will explore the dynamic relationships between technological systems and the social, political, religious, artistic, and economic worlds in which they emerged. We will also pay particular attention to technology's effects, asking both who benefited from and who was harmed by technological change. By the end of the course, students will be able to reflect critically on how humanity chooses which technologies to exploit and how human societies have been transformed by these choices.

79-235 Caribbean Cultures
Intermittent: 9 units
This course will examine the cultures and societies of the Caribbean focusing on their colonial past, their current positioning in the world, their social structure, cultural patterns and current transnationalism. Using social history, film and music we will explore the topics of race, class, family, gender, religion, national identity and underdevelopment. Comparative research projects will provide concrete instances of the differences and similarities between the Anglo-Caribbean, Franco-Caribbean, and Hispanic Caribbean. This course is open to all students.

79-236 Coming to America: The View from New York City, Past and Present
Intermittent: 6 units
Immigration became a prominent issue in national politics during the 2016 presidential campaign, and a contentious debate around immigration policy has carried forward into the Trump administration. American immigration history is long and complicated, but by pairing it with the history of a particular place (New York City) we can better understand the social, political, and cultural trends that have affected the policies of the United States government, the perceptions of Americans towards newcomers, and the lived experience of immigrants since as early as the 1600s. This course will explore such issues as whether New York, the nation's quintessential city of immigrants, has been a "melting pot" and entry point to the Land of Liberty. Has the city been a place where diverse groups of people from around the world have acculturated and Americanized? Or have immigrants to New York City mainly struggled to find acceptance, maintain their culture and traditions, and gain an economic foothold?

79-237 Comparative Slavery
Intermittent: 9 units
This course will examines the pervasive, world-spanning institution of human slavery. Although the time frame this course deals with is broad - from the rise of complex societies in the ancient world to slavery-like labor systems in the modern era - this class will focus more thoroughly on a few case studies, especially slavery in the Middle East and sub-Saharan Africa, the US, and the Caribbean. These disparate examples will be related to a number of core themes, including race, class, family, gender, religion, national identity and underdevelopment. This course will be co-taught on CMU's Pittsburgh and Qatar campuses.

79-239 The Great Depression in America, 1929-1941
Intermittent: 6 units
Until the "Great Recession" of 2008, it had become virtually unthinkable that the United States would ever again experience a financial downturn coming close to that which followed the stock market crash of 1929. Lasting for more than a decade, the Great Depression affected American life and culture in ways that were both pronounced and profound. This course looks at the multiple ways that American life changed in the decades between the two world wars. It assesses social, cultural, political, economic, and technological changes that, in the midst of deprivation and economic uncertainty, ultimately brought "modernity" to everyday American life. Relating to the Great Depression itself, students will evaluate varying political approaches to the complex financial and social issues wrought by economic downturn, comparing and contrasting Herbert Hoover's local and regional relief focus with Franklin Roosevelt's massive, federally funded New Deal initiatives. In addition, students will analyze first-person narratives from everyday Americans describing their day-to-day experiences. Finally, the course will explore how the Depression became a near-constant cultural focus in this era, reflected in popular movies, music, and works of fiction.

79-240 Development of American Culture
Intermittent: 9 units
This is an introductory survey of American history from colonial times to the present. The course focuses on cultural history instead of the more traditional emphasis on presidents, wars, and memorizing facts or timelines. The major theme of the course is the changing meaning of freedom over three centuries. Required readings include several short books, historical documents, and a study of the concept of freedom. There is no textbook; background facts and events are covered in lectures to provide students with context needed to think about and understand America's cultural history. Assignments include exams and essays.

79-241 African American History: Africa to the Civil War
Intermittent: 9 units
The African American experience had deep roots in the rapid globalization of the world's people during the transatlantic slave trade. Like people of European, Asian, and Latino/Latina descent, Africans were part of the early Great Migrations of people from the Old World to the New. Unlike other ethnic and nationality groups, however, African people arrived in chains and swiftly acquired the legal status of "slaves for life." Was their enslavement inevitable? Was their transformation into commodities complete? Were they able to form viable families, communities, and movements to topple the institution of human bondage? Did they find dependable white allies? Did they Africanize American culture, politics, and economics? How did some 500,000 of these African people become free (some significant property holders) before the Civil War? Focusing on the development of African and African American life from the beginning of the colonial era through the late antebellum years, this course will explore these and many other questions in the lives of the earliest generations of African people on American soil. Based upon a variety of assigned texts, primary and secondary sources, and lectures, students will become familiar with a wide range of intellectual debates in African American history; write a series of short analytical essays; and advance their own well-argued and well-documented analyses of major controversies in both popular and scholarly interpretations of early African and African American life in the United States.

79-242 African American History: Reconstruction to the Present
Intermittent: 9 units
This course explores changes in the African American experience from the end of the Civil War to the emerging era of Donald Trump. The course emphasizes transformations in both inter- and intra-race relations; economic mobility as well as economic inequality; and forms of political engagement and grassroots movements for social change. In Part I, the course opens with an examination of the notion of a "Post-Racial Society" in the United States. This idea emerged in the wake of the Modern Black Freedom Movement and persists to this day as the 21st century unfolds. Part II locates the roots of 20th century black life and history in the emancipation of enslaved people in the years after the Civil War. This segment of the course will not only give close attention to the meaning of emancipation and freedom for black people, but also charts the rise of a new Jim Crow social order by World War I. Third and most important, this course will illuminate the transformation of African American culture, politics, and community under the impact of the 20th century Great Migration; the rise of the urban-industrial working class; increasing residential segregation; growth and expansion of the middle class; and the fluorescence of the Modern Black Liberation Movement. Students will compare the dynamics of the contemporary Black Lives Matter Movement with earlier 20th century grassroots social and political movements in African American and U.S. history. Finally, based upon a mix of primary and secondary sources and lectures, students will examine a wide range of intellectual debates in African American history; write a series of short analytical essays; and establish their own unique interpretation of key issues in Black History.

79-243 The Civil War in American Memory
Intermittent: 6 units
The American Civil War remains among the most cherished and fought over stories in American history. This class explores those debates. Was the war fought over slavery? Was the Confederate cause noble? Did the North oppose slavery? Why do Americans flock to reenact the Civil War? What does it mean to fly the Confederate flag? Tackling ongoing debates in the news today, including recent events in Charleston, we'll trace the roots of those events back to the American Civil War. And we'll strive to understand why the war continues to be one of the most defining moments in U.S. history - 150 years later.

79-244 Women in American History
Intermittent: 9 units
This course is a survey. It examines U.S. history through the eyes of women and gender. It begins in the colonial era (1600s) and runs chronologically to the present. It covers topics such as witchcraft, the story of Pocahontas, women's work, motherhood, slavery, and much more. We will look at the lives of individual women, as well as trends among women, paying attention to questions of race and class. At the same time, we will explore changing concepts of gender, meaning ideas about what women are or should be. Finally, the course asks: how different does American history look when we factor in women and gender?

79-245 Capitalism and Individualism in American Culture
Intermittent: 9 units
This small discussion course traces ideas about individualism and capitalism in the U.S., from colonial times to the present. We will focus on three main themes: 1) the relationship between capitalism, work, and identity; 2) changing definitions of success and failure; and 3) the historical origins of students' attitudes toward 1 & 2. In short, we will study the economics and emotions of the American dream: how class, race, gender, occupation, and ambition shape our identities. Readings include "The Autobiography of Benjamin Franklin," studies by Alexis de Tocqueville and Max Weber, writings of Frederick Douglass, Ralph Waldo Emerson, Herman Melville, Henry Thoreau, Charlotte Perkins Gilman, Andrew Carnegie's classic essay "Gospel of Wealth," Arthur Miller's "Death of a Salesman," and Malcolm Gladwell's "Outliers." Grading is based upon a readings journal, participation in discussion, three short essays and a longer final paper.

79-246 Industrial America
Intermittent: 9 units
This course examines the transformation of America into an urban industrial society during the 19th and 20th centuries. The transformation of work, culture, and politics will receive close attention, but the course will primarily focus around how workers defined their own labor and changes in the culture of work over time. This course will investigate how race, class, and gender informed workplace relations as well as how immigration and migration changed the nature of American work. Through lecture, discussion, and three short writing assignments we will uncover how workers defined America.

79-247 African Americans, Imprisonment, and the Carceral State
Intermittent: 9 units
The mass incarceration of people of African descent has emerged as one of the most daunting issues in contemporary U.S. society and politics. But too often discussions of this important phenomenon proceeds without sufficient historical perspective. Thus, this course explores the history of African Americans in the nation's prison system from the emancipation of some four million enslaved people following the Civil War through recent times. Specifically, we examine the process by which the nation's prison population shifted from predominantly white inmates during the mid-19th century through the inter-World War years to majority African Americans and other people of color by the closing years of the 20th century. In addition to examining the role of law, policing, and racist social policies and practices, students explore the lived experiences of imprisoned people, with an emphasis on the impact of class and gender as well as racial considerations. Along with selected primary documents, assigned readings include a series of scholarly case studies on the carceral experiences of black men and women in the North and South during the industrial and emerging postindustrial eras in African American and U.S. history. Finally, students will write a series of short essays on particular facets of African American life in the American prison system.

79-249 20th & 21st Century U.S. History
Intermittent: 9 units
[Note: students who have already taken this course under its former title, 79-249, 20th Century U.S. History may not enroll.] The twentieth century marked the rise of the United States as a global power. By the end of the century, the United States had achieved economic, military, and political dominance. The United States also made great strides in expanding political and civil rights for workers, women, African Americans, and gays and lesbians. This course explores the social and cultural implications of these developments on the generations of American people who came of age in the twentieth century. It assesses both the triumphs and tribulations of twentieth-century life. We will analyze continuities, contradictions, and conflicts in American history, especially in regard to the nation's dueling political ideologies: conservatism and liberalism. Special attention will be paid to the relationship between movements for social change and the maintenance of law and order. Topics include: the Progressive Era, World War I, the Great Depression, World War II, the Cold War, Civil Rights, Vietnam, and the New Conservatism.

79-256 Sex, Guns, and Rock 'n Roll: Youth Rebellion in 1960s & 1970s Europe
Intermittent: 6 units
Between 1960 and 1980, young Europeans rebelled against the conservatism of their parents and politicians. Heterosexual mores became strikingly looser. Women demanded sexual freedom and abortion rights. In capitalist Paris and in socialist Prague, masses of students challenged their government in the streets. In West Germany and Italy, a minority of radicals took up the gun to bring former Nazis and Fascists to "justice." From The Beatles to The Clash, British bands created variations on rock and roll that were spectacularly popular from London to Moscow. Rebellion took different forms in every country but also became European as activists, musicians, and fans carried ideas about politics and sex, fashions, and music across national boundaries and the "Iron Curtain." The course will mix lectures with discussion of scholarly articles/chapters, a novel, and films. Students will write one 4/5 and one 6/7-page essay based on class readings/films.

79-257 Germany and the Second World War
Intermittent: 9 units
This course examines the Second World War from the perspective of the country that was central to it in every way. The course will cover: Hitler's ideology, war plans, and military strategy; the military/technological history of the War in Europe and North Africa; the role of the SS; the Holocaust; the occupation of Europe and Resistance movements; the political, social, and economic history of the Third Reich, including popular opinion, the German Resistance, and the use of slave labor in factories and on farms. Readings will include historical studies, a novel, and a memoir/diary.

79-258 French History: From the Revolution to De Gaulle
Intermittent: 9 units
This survey course looks at French society and culture from the period after the French Revolution (roughly 1815) to the Nazi invasion of 1940. We first look at the multiple impacts of the Revolution on French society. We try to understand some of the lasting features of nineteenth and early-twentieth century France by studying the lives of different social groups including workers, peasants, and members of the elites. We follow the continuing problem of French political instability in the nineteenth century, trying to understand the deep rifts that divided different groups of French people from one another. We look at the devastating impacts of World War One and the Great Depression, and end with the collapse of France in 1940. Coursework is based on the use of works of fiction, film, personal memoirs, and art as well as historians' writings. Written work includes papers and in class tests.

79-259 France During World War II
Intermittent: 9 units
This course surveys French society, economy, and culture in the years 1939 to 1945 focusing on problems that the war and German Occupation presented. Understanding life under the Occupation and the collaborationist government in Vichy requires us to look back at major political, social and economic conditions of the 1930s that divided the French people. We use film and personal memoirs as well as recent historical studies to recreate and understand life during the war, and try to answer such questions as: What accounts for the French military collapse of 1940? Which groups of French men and women benefitted from collaboration with Germany? How did France's collaboration in the Holocaust come about? We also consider how the French people have tried to come to terms with their wartime experience since the 1940s. Classes include lecture and discussion as well as several in-class writing responses to the reading and lectures.

79-260 Adolf Hitler
Intermittent: 9 units
Who was Adolf Hitler? What motivated him? What did he believe? Why did Germans support him? How did he rise to power? How did he use his power? This course covers the biography of Hitler, placing his life in the political and economic context of his era. Through a combination of lectures and discussion, the class will consider: Hitler and his political movement, Hitler and his people, Hitler and his enemies, Hitler and his war, Hitler and his crimes, Hitler and his place in history. We will discuss his upbringing, personality, and strengths and weaknesses as a political leader and military strategist. We will study his worldview, including his ethno-nationalism, antisemitism, and anti-Communism. We will examine his role in the origins and implementation of the Holocaust. Readings will include works by historians, excerpts from Mein Kampf, and the writings of his fellow Nazis and other contemporaries. The class will also analyze the portrayal of Hitler in documentary and feature films. Students will write three papers: two papers of 5-6 pages each, based on in-class readings/films, and a final research paper of 12 pages, based on six outside readings.

79-261 The Last Emperors: Chinese History and Society, 1600-1900
Intermittent: 9 units
This course is an introduction to late-imperial "Chinese" history and society with a focus on the Qing dynasty (1644-1912). We begin by examining the Qing not just as the last of China's imperial dynasties but also as an early-modern, multi-ethnic empire that included Mongolia, Tibet, and Xinjiang. In fact, China's "last emperors" were actually Manchus from northeast Asia. Secondly we investigate the social, economic, intellectual and demographic developments that transformed late-imperial China prior to the coming of the West. Thirdly, we examine Qing responses to a string of nineteenth-century disruptions, including but not limited to western imperialism, that threatened to not only end the dynasty but also challenged the very tenants of Chinese civilization. Lastly, we will look at the fall of China's imperial system, the end of empire, and the post-imperial struggle to reformulate the state and re-imagine society for the twentieth century.

79-262 Modern China: From the Birth of Mao ... to Now
Intermittent: 9 units
This course is an introduction to major themes in twentieth-century Chinese history, including the transition from empire to nation, revolution, social change and modernization, western and Japanese imperialism, the rise of the party-state, Chinese socialism, economic liberalization and the so-called "Chinese Dream." The first half of the class is devoted to the period between the fall of the imperial system and the founding of the People's Republic of China (1911-1949). If the victory of the Chinese Communist Party and development of the socialist state are to be considered in historical context, it is necessary to first understand the political, cultural, economic and intellectual currents that immediately preceded them. During the second half of the course, we will examine the Maoist period (1949-1976). We will investigate the Chinese Communist Party as both a state-building institution and an engine of social transformation, and consider the tensions these dual roles produced. Finally, we will look at the Reform Period (1978-present), and reflect on a newly robust China's attempts to come to terms with its own recent past and what the consequences might be for both China and the world.

79-263 Mao and the Chinese Cultural Revolution
Intermittent: 9 units
This course is an in-depth examination of China's "Great Proletarian Cultural Revolution" (1966-1976), one of the most impactful and bewildering events of the twentieth century. It started when Mao Zedong announced that enemies had infiltrated the Communist Party that he led. Soon students were attacking their teachers, teenagers in army uniforms were raiding homes and destroying remnants of "feudal" and "bourgeois" culture, and armed fighting had erupted among factions of ordinary Chinese people. Why? What were the political and social dynamics of Maoist China that propelled it along this violent trajectory? What was everyday life like during the Cultural Revolution, an event that could be both terrifying and empowering for those that lived through it? What were the social, political and cultural consequences? How has the Cultural Revolution been judged in China and the west, and are their other possible interpretations? This class will explore these questions from a variety of perspectives and sources, including documents, literature, memoir, film, academic writings, visual arts and performing arts.

79-264 Tibet and China: History and Propaganda
Intermittent: 6 units
This course is an introduction to the "Tibet Question," the dispute over whether Tibet should be part of China, an independent nation-state, or, as the current Dalai Lama now advocates, something in between. "History" often serves as the battleground on which competing visions of the nation are fought - who should be included and excluded, where "natural" boundaries begin and end. This almost always requires a process of simplification in which inconvenient details are forgotten or repurposed in the service of national agendas. The "Tibet Question" is a telling example. In this class, we investigate the historical relationship between "China" and "Tibet" from the 13th century through the present, and note the ways advocates on both sides of the "Tibet Question" have constructed historical narratives (propaganda) in support of their political positions. We will also discuss the prospects for a political solution and consider the lessons the "Tibet Question" may hold for understanding other outstanding "historical" disputes.

79-265 Russian History: From the First to the Last Tsar
Intermittent: 9 units
This course covers a broad sweep of Russian history beginning with the first settlements of tribal nomads in the ninth century and ending with the fall of the 300-year-old Romanov dynasty in 1917. Our course profiles how the Russian state was formed and how its territory expanded to become a mighty empire. Over the centuries, we make the acquaintance of Mongol marauders, greedy princes, and peasant rebels, as well as Ivan the Terrible, Peter the Great, and the long succession of reformers and reactionaries who occupied the Russian throne. We explore terrorism, general strikes, and development of the revolutionary movement that ultimately brought down the Tsar in 1917.

79-266 Russian History and Revolutionary Socialism
Intermittent: 9 units
This course covers an epic set of events in Russian history from the emancipation of the serfs in 1861 to the death of Stalin in 1953. Spanning almost a century of upheaval and transformation, it examines what happened when workers and peasants tried to build a new society built on social justice and economic equality. Learn about Lenin, Trotsky, Stalin, and other revolutionary thinkers and dreamers. The course surveys the revolutions in 1917, the Civil War and the Red victory, the ruthless power struggles of the 1920s, the triumph of Stalin, the costly industrialization and collectivization drives, the "Great Terror," and the battle against fascism in World War II. It ends with the death of Stalin, and the beginning of a new era of reform.

79-267 The Soviet Union in World War II: Military, Political, and Social History
Intermittent: 9 units
On June 22, 1941, Hitler invaded the Soviet Union. German troops quickly reached the hills above Moscow, surrounded Leningrad in the longest running siege in modern history, devastated the country's economy, and slaughtered millions of Soviet civilians. Over 26 million Soviet citizens died in the war. Eventually, the Red Army came back from defeat to free the occupied territories and drive Hitler's army back to Berlin. Using history, films, poetry, veterans' accounts, documentaries, and journalism, this course surveys the great military battles as well as life on the home front. It highlights the rise of fascism, the Stalinist purges of the Red Army, and the Nazi massacres of Soviet Jews, peasants, and partisans. Occasional evening film screenings required.

79-268 World War I: The Twentieth Century's First Catastrophe
Intermittent: 9 units
This course offers a comprehensive retrospective of the First World War (1914-1918), focusing primarily on the American experience. The course will cover the military, political, social, and business history of the war. Guiding questions will be: Why did the US enter the war? How did the country adjust its economic output to rapidly field an Army of nearly five million? How did the war impact the country's immigrant and African-American communities? What role did women play in the war effort? What was the war's legacy on American culture and politics? Students will read approximately five secondary sources over the course of the semester, and engage with primary sources including songs and records, soldiers' and welfare workers' letters and diaries, and government and welfare organizations' documents. Students will complete three 7-8 page essays and a longer 10 page final essay.

79-269 Russian History: From Socialism to Capitalism
Intermittent: 9 units
Beginning with Stalin's death in 1953, this course will focus the efforts of a new group of Soviet leaders to eliminate the repression of the Stalinist period and to create a more democratic socialism. It will examine the reforms of Khrushchev and the reaction against them, the long period of Brezhnev's rule, and the hopeful plans of Gorbachev. Finally, it will survey Gorbachev's loss of control, the collapse of socialism and the Soviet Union, and the growth of "wild west" or "gangster" capitalism. We will look at the rise of the oligarchs and the impact of the capitalist transition on ordinary people. The course provides essential background for anyone interested in understanding Russia's place in the world today and its relationship with the West.

79-270 Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present
Intermittent: 6 units
This course will examine the history of anti-Jewish hatred and violence from the Middle Ages through the Holocaust. The course will focus on representative case studies, texts, and films. These will include pre-modern incidents of "fake news" such as the medieval rumor of "blood libel" that unleashed massacres and mass expulsions of Jews from countless communities. In examining the rise of modern anti-Semitism we shall focus on debates over Jewish assimilation and citizenship and consider the popular impact of the print media's dissemination of conspiracy theories of Jewish world domination, including the infamous forgery "The Protocols of the Elders of Zion." We will also examine cases of mass anti-Jewish violence, known as pogroms, in Eastern Europe and Russia, and the genocidal onslaught against European Jewry by the National Socialist regime. Finally, we will discuss the resurgence of anti-Semitism in contemporary Europe.

79-275 Introduction to Global Studies
Spring: 9 units
We live in an increasingly interconnected world, one in which our everyday actions have repercussions across vast distances. To understand this ever-denser web of connections, we must think beyond simplistic accounts of globalization as a uniformly positive, negative, or homogenizing process. Economic crisis, impoverishment, rising inequality, environmental degradation, pandemic disease, and irredentist movements are just as much a part of the story as are technological innovation, digital communication, global supply chains, cultural exchange, the promotion of human rights, and the rise of cosmopolitan values. This course aims to equip you with a conceptual toolkit for thinking critically and holistically about the many dimensions of globalization. By examining how globalization connects and shapes the everyday lives of people around the world, including our own, we will establish a foundation both for your advanced coursework in Global Studies and for your lifelong education as a globally aware professional and citizen.

79-276 Beyond the Border
Intermittent: 6 units
In this course we will consider the historical emergence and transformation of the U.S.-Mexico border, as much as an idea as a physical boundary. Our explorations will be far-ranging: from the initial encounters of Christopher Columbus and Hernán Cortés with indigenous populations, to social, cultural and political dynamics of the borderlands in subsequent centuries; from the experiences and practices of cross border migrants, to contemporary immigration debates and policies surrounding migration, border control and walling, and the deportation of unauthorized migrants.

79-277 From Venice to Chicago: How "The Ghetto" Came to America
Intermittent: 6 units
This course will explore the genealogy of the term "ghetto". For most Americans, "ghetto" probably makes them think of poor urban neighborhoods, or of Jews living under Nazi oppression. Most do not know that the first ghetto was established 500 years ago, to keep Jews separate from Catholics. After quickly reviewing how ghettos spread throughout early modern Europe, the course will shift its focus to the Americas. We will examine when and how the term "ghetto" arrived in the United States, and how the use and application of the term changed before the 1930s. For the majority of the course we will study how "ghetto" became associated with black urban neighborhoods, and what role local, state, and federal governments played in forming postwar American ghettos. By the end of the course students should better understand the origins of current urban policy and will be prepared to critique and make arguments about how urban policy is often used as a political tool.

79-278 How (NOT) to Change the World
Intermittent: 9 units
Everyone, it seems, wants to "change the world." Aspiring to enact positive change is what motivates me as a professor and, I suspect, what has drawn many of you to pursue higher education. But what form do our noble aspirations take in practice? What assumptions do we bring with us when we set out to change the world and with what (unintended) consequences? How do others go about pursuing change and how might we engage with their efforts? In this course, we will critically examine a diverse set of attempts to bring about change, taking time to interrogate the cultural values and social structures that shape them. These will include some of our own engagements (e.g., campus activism, volunteering abroad), those of nearby communities (e.g., regional environmental-justice activism), and some that may be more distant from our everyday lives (e.g., Indigenous resurgence). Applying concepts from anthropology and critical social theory, we will consider examples from around the world while engaging with diverse perspectives, including those of scholars, practitioners, and activists.

79-279 Comparative Study of Nationalism Case Studies: USA, Arabia, South Africa
Intermittent: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. This course, dealing with a significant historical question of the past century, will enable students to develop a deeper understanding of the origins of many contemporary states as well as problems in former colonies. Participants will work individually or in teams on research papers pertaining to their chosen countries.

79-280 Coffee and Capitalism
Intermittent: 9 units
[Note: students who have taken the mini course, 79-280, Brewing Revolution? Coffee and Social Change from Adam Smith to Starbucks, may not enroll.] What role has coffee played in connecting people and places to capitalist markets and consumer cultures? What are the economic, social, and environmental consequences of these connections? How did espresso change from an "ethnic drink" to something served at McDonalds? Why do college students (and professors!) hang out in coffee shops? This course will answer these questions and more by using coffee to learn about the history of capitalism, and capitalism to understand the history of coffee. We will follow the spread of coffee and capitalism across the globe, with excursions to places where people grow coffee (Ethiopia, Yemen, Indonesia, Brazil, and Costa Rica), and also where they drink coffee (Seattle, Tokyo, Seoul, New York, and Berlin). In the process, we will confront global problems linked to economic inequality, trade, gender relations, and environmental degradation. Course meetings will combine interactive lecture, group discussions, and mini-presentations. Assignments will include journal responses, ethnographic observations, and writing a short script that tells a story about coffee and capitalism.

79-281 Introduction to Religion
Intermittent: 9 units
Religion can be understood from the "outside," through the academic lenses of history, sociology, psychology, philosophy, etc., and from the "inside," listening to the experiences and reflections of those who practice various faiths. The course will examine major religious traditions from several perspectives, and begin to explore such topics as the relationship between religion and science, faith and reason, and religion in public life. This introduction is designed for students with a general interest in religion, as well as those contemplating a Religious Studies minor.

79-282 Europe and the World Since 1800
Intermittent: 9 units
This course will introduce students to topics of historical and contemporary relevance in European society and culture from the nineteenth-century to the present. The course will focus on issues of national and cultural identity with special attention to the situation of inhabitants who have been considered outsiders or "others." We shall examine Europe's place in shaping debates—both new and old—about topics such as: religious, ethnic, and national identity; immigration to and within Europe; Islamophobia; anti-Semitism, and marginalization of the Roma. Throughout the course we shall also consider the shifting meanings that have been assigned to the concept of Europe as well as how these meanings have been contested. In addition to class lectures, students will become familiar with these themes through the reading and discussion of historical and anthropological texts, current political and cultural debates, music and film.

79-283 Hungry World: Food and Famine in Global Perspective
Intermittent: 9 units
The science and technology of the Green Revolution in the second half of the 20th century were heralded as a miracle. Agricultural science promised seeds, peasants, companies, governments, scientists, economists, exporters, and planners would work together to support growing populations, especially in the post-colonial world. The human population on Earth reached 6 billion by the year 2000; 7.6 billion were estimated around 2017. The United Nations predicts 8.6 billion by 2030. Awareness of living in this unique period of human history brought new debates among scholars, practitioners, and planners thinking about the critical role of agriculture and development on Earth. How can we conceptualize, hope, and plan for best possible outcomes for a human population that depends on agriculture and development? How has the legacy of the Green Revolution encouraged (or betrayed) public enthusiasm for innovative fixes? This interdisciplinary course will use methods and case studies drawing on History, Historical Demography, Anthropology, Cultural Studies, Regional Studies, Geosciences and Agricultural Sciences, and International Economic Development. If students wish to pursue a particular thematic or regional interest, there will be room in this course to explore particular cases in depth.

79-286 Archaeology: Understanding the Ancient World
Intermittent: 6 units
This course will familiarize students with archaeology as a field, including the techniques and methods archaeologists use to test hypotheses using archaeological data. Secondary objectives are to provide students with a framework for understanding the many archaeological sites that are open to the public across the United States and around the world and to explore problems having to do with the method and practice of archaeological investigation.

79-287 The Mummy's Curse: Uses and Abuses of Archaeology
Intermittent: 6 units
Popular representations of ancient civilizations often present fantastical versions of the past. This course will examine popular topics such as cursed mummies, ancient aliens, lost cities, and other alternative archaeologies to understand how they intersect with academic understandings of archaeology and human history. Students will explore how archaeologists and others answer questions about the past, and how we can evaluate competing interpretations.

79-288 Bananas, Baseball, and Borders: Latin America and the United States
Intermittent: 9 units
This course will use readings, film/video, and popular music to examine the tumultuous and paradoxical relationship between Latin America and the United States from the early 1800s to the present, with an emphasis on Mexico, Central America, and the Caribbean during the Cold War era (1945-1989) and its aftermath (1989-2014). During the Cold War years, the United States intervened frequently in Latin America; following the Cold War, a new geopolitics emerged shaped by trade policies, immigration, and illicit drug trades. We will study relationships between U.S. and Latin American governments ("state-state" relations), but we will also consider many other kinds of people and institutions including artists, athletes, businessmen, coffee farmers, consumers, corporations, Hollywood studios, journalists, migrant workers, musicians, rebels, scientists, and tourists. Evaluation will be based on class discussions, quizzes, mini-presentations, and written analysis of historical documents.

79-289 Animal Planet: An Environmental History of People and Animals
Intermittent: 9 units
Why do modern societies go to great lengths to protect some animals and slaughter others? How do people use animals to demarcate boundaries among themselves and between "humans" and "nature?" What are the environmental ramifications of domestication? What role do animals play in visual culture? These are some of the questions that we will seek to answer as we explore the role of human—animal relationships in making the modern world (ca. 1400-present). We will pay particular attention to visual representations of animals across time and cultures. Evaluation will be based on active participation in class discussions, submission of weekly field notes, and a final assignment focused on visual representations of people and animals.

79-290 The Slave Passage: From West Africa to the Americas
Intermittent: 6 units
"The Slave Passage" begins among flourishing, technologically advanced, and globally connected regions of Western Africa before the advent of the trans-Atlantic slave trade. It tells the painful story of African captives during the Middle Passage, piecing together the historical record to recognize their suffering aboard the slaving vessels and their multiple strategies of resistance. Students will study slave narratives, slave ship logs, and autobiographies of former enslaved people, as well as analyze films and theater performances depicting the Middle Passage and New World enslavement.

79-291 Globalization in East African History
Intermittent: 6 units
Most Americans would identify slavery and colonialism when thinking of Africa's relationship to the rest of the world. While these two institutions have been critically important in shaping Africa's present condition and recent history, they only constitute a fraction of Africa's past and its interaction with the wider world. This course traces globalization to ancient times and seeks to understand it from an African perspective.

79-293 Inward Odyssey
Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. Inward Odyssey will explore world history by examining it through the outward-looking eyes of travel writers, on the assumption that travelogues, though supposedly written about the "other," in fact provide crucial insights about the mindset of the culture that produced them, and often serve as a vehicle for cultural self-exploration or even self-criticism. In terms of content, this course is intended to overlap with World History, Islam and the European World, and US-Arab Encounters. However, this course is intended to be a skills course, designed not to teach students about specific historical periods, but rather to give students the tools they need to conduct their own critical explorations into the historical past.

79-294 Islam on the Main Street in the West since the 18th Century
Intermittent: 9 units
This course is offered only at Carnegie Mellon in Qatar. This introductory course to the humanities and social sciences through the prism of religion and faith, aims at: 1. analyzing the interaction between these central disciplines and at appreciating the significance of Western and Islamic humanism and applying it to the present context of cultural globalism, confrontation and dialogue; 2. becoming familiar with some important literary texts of the modern era; 3. learning how to articulate one's thoughts in a cogent manner. The discussion will stress how religion, a powerful instrument of socialization may, under some circumstances, foster intolerance and inequality or openmindedness and tolerance. Understanding this process may lead to a new appreciation of classical Western writings.

79-295 Archaeology of Technology
Intermittent: 6 units
Archaeology of Technology is a new course that surveys the archaeology of invention and the "immaterial". We live in an increasingly immaterial world, in which many of the artifacts we value are digital, and our relationships are built beyond the confines of face-to-face interactions. This course will explore the relationship between people and the artifacts they create by addressing one big question of equal concern to innovators, archaeologists, and historians alike: Why and how do some inventions spread like wildfire and dramatically transform society?

79-296 Religion in American Politics
Intermittent: 6 units
"Separation of church and state" is an expression widely used but poorly understood. Thomas Jefferson's phrase, which does not actually appear in the Constitution, reminds us that religious institutions are kept separate from government in America, even though religious commitments and motivations have always played an important part in American politics. This course will provide an historical perspective on the role of religion in public life from the late 18th century to the present, including religion's influence on political parties and public policies, and the boundaries set by the Constitution on such activity.

79-298 Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal
Intermittent: 6 units
This course will examine the ways that social media and the ubiquity of mobile phones with good cameras and Internet access are changing how information about development and human rights is gathered, analyzed, and disseminated. We will ask: What are the new possibilities opened up by these technologies? What are the potential pitfalls—e.g., privacy concerns, risks to sources, or the false confidence that we are now able to know everything about what is happening in the world? What are the biggest technical, cultural, and political challenges in this domain? Who is responding to these challenges and what are they doing? And perhaps most importantly, to what extent can advances in technology ameliorate problems that are fundamentally political in nature?

79-299 From Newton to the Nuclear Bomb: History of Science, 1750-1950
Intermittent: 9 units
This course provides an introduction to the history of modern science in Europe and North America, from the Enlightenment to the mid-twentieth century. Our goal is to understand scientific theories and practices on their own terms and as products of their own contexts, rather than as a progression of developments moving inevitably toward the present. The course seeks to explore both how and why science has become the dominant way of knowing about the natural world, as well as how scientific activity intersects with the history of religion, war, commerce, and the state. Most classes will involve active discussion of texts written by scientists, including Darwin, Einstein, McClintock, Laplace, Joule, Lovelace, and Paley.

79-300 Guns in American History: Culture, Violence, and Politics
Intermittent: 9 units
This course will describe and analyze aspects of the development of law and public policy related to guns in the United States from the colonial era to the present. Students will be expected to synthesize perspectives from social history, ethnography, public health, criminology, policy analysis, and legal scholarship. They will also engage the critical examination of popular culture and media representations of gun cultures and gun violence. Particular emphasis will be placed on changing views about the authority of the government to intervene in the production and ownership of guns, as well as the best way to balance individual and collective interests in a pluralistic society. Assignments may include reading quizzes, in-class debates, policy position papers, and film/documentary reviews.

79-301 History of Surveillance: From the Plantation to Data Capitalism
Intermittent: 6 units
Our awareness of surveillance has been dramatically heightened over the past few years. From Edward Snowden's revelations about the U.S. National Security Agency's data collection infrastructure to the extent to which companies like Facebook and Google monetize our personal information, surveillance has become one of the most controversial political issues of our time. In this course, we will place these developments in context, examining the long history of surveillance in the United States. We will begin with the 18th-century plantation "overseer," who was charged with ensuring the productivity and obedience of slaves under his watch. We will then move on to explore the emergence of commercial surveillance in the 19th century, which sought to gather intelligence on the credit worthiness and moral worthiness of businessmen in a rapidly growing, and increasingly impersonal, economy. Next, we will examine the shifting focus of surveillance from the late 19th century to the present, as it expanded from immigrants and criminals to include industrial workers, political radicals, civil rights activists (most notably Martin Luther King), the poor, and ultimately, all of us. Today, anyone who has a cell phone in their pocket, surfs the Internet, keeps up with friends through social networks, makes purchases with a credit card, uses membership cards, travels, or even just spends time in public spaces ought to assume that their movements, purchasing habits, communication metadata, social connections, and Internet browsing histories are being recorded, stored and analyzed for a variety of governmental and commercial purposes. In the final week of the course, we will debate the implications of these incursions into our public and private lives.

79-302 Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems
Intermittent: 6 units
[Note: students who have already taken this course under its former title 79-302, Drone Warfare and Killer Robots: Ethics, Law, Politics, and Strategy, may not enroll.] Unmanned aerial vehicles (drones) have become a central feature of the United States' global counterterrorism strategy since September 11, 2001, and autonomous weapons systems (often called "killer robots" by critics) are increasingly being integrated into military arsenals around the world. According to proponents, drones and autonomous weapons systems are much safer than manned systems, so accurate that they can be used to target individuals and detect threats in real time, and efficient and inexpensive enough to be used for long-term surveillance and protection missions around the globe. According to critics, the use of such systems is problematic because of the obfuscation of historically accepted chains of accountability and responsibility, and the difficulty of translating complex ethical decision making processes into computer code. This course will evaluate these issues through the lenses of law, politics, morality, history, and military strategy.

79-303 Pittsburgh and the Transformation of Modern Urban America
Intermittent: 6 units
This course will focus on the transformations, both positive and negative, of Pittsburgh and the Pittsburgh region in the period from 1945 through the present. It will explore the following themes: the redevelopment of the city in the Pittsburgh Renaissance; urban renewal and its consequences; the collapse of the steel industry and its impacts; the development of an Eds/Meds service economy; air, land and water environmental issues; and the city's changing demography.

79-304 African Americans in Pittsburgh
Intermittent: 6 units
This course will examine the development of Pittsburgh's African American community from the Great Depression and World War II through the era of deindustrialization during the late 20th and early 21st centuries. The course will emphasize not only the ways that a variety of external socioeconomic, cultural, and political forces shaped the history of black people in western Pennsylvania, but also the diverse strategies that African Americans devised to give meaning to their own lives and how these changed over time. Students will read both primary and secondary accounts of Pittsburgh's African American history; write short analytical papers on specific topics or themes; and engage in regular classroom discussions of assigned readings.

79-305 Moneyball Nation: Data in American Life
Intermittent: 9 units
From conducting clinical trials and evaluating prisoners' parole cases to drafting professional ballplayers, we increasingly make decisions using mathematical concepts and models. This course surveys the development of—and resistance to—such tools by grounding them in the recent cultural history of the United States. Focusing on baseball, medicine, and the law, we'll explore how and why Americans have come to believe mathematical and computational methods can solve complicated problems, even in seemingly unrelated moral, political, and social domains. The course encourages students to think critically about the wider implications of these transformations by situating their development historically.

79-306 Fact into Film: Translating History into Cinema
Intermittent: 9 units
From the very beginning, film has provided a window into the past. But how useful are the images we see through that window? For every person who reads a work of history, thousands will see a film on the same subject. But who will learn more? Can written history and filmed history perform the same tasks? Should we expect them to do so? How are these two historical forms related? How can they complement each other? This course will draw examples from across the history of film in order to examine how the medium of film impacts our understanding of facts and events, the ways that film transfers those facts to the screen, and how that process affects the creation of historical discourse. Films may include such titles as The Fall of the Roman Empire, The Gunfight at the O.K. Corral, Saving Private Ryan, World Trade Center, Enemy at the Gates, Lagaan and Hero.

79-307 Religion and Politics in the Middle East
Intermittent: 9 units
This course looks at the historic relationship among Islam, Judaism and Christianity and what they have to say about the nature of government, the state's treatment of religious minorities, and relations among states in the Middle East. We will consider the impact of religion on domestic and foreign policy in selected Middle Eastern countries and communities, the role of religion in fueling conflicts, the phenomenon of religious fundamentalism, the challenge and opportunity this presents to the United States, and the potential for religion to help advance Middle East peace. We will take advantage of the unprecedented upheavals roiling the Middle East since 2011 and use contemporary social media to contact people on the ground in the states we are studying to produce "updates" as to where religion and politics seem to be intersecting at this time.

79-308 Crime and Justice in American Film
Intermittent: 9 units
Films dealing with criminal activities and criminal justice have always been popular at the box office. From the gangsters of the Thirties and the film noir of the Fifties to the more recent vigilante avenger films of Liam Neeson, the film industry has profited from films about crime and its consequences. How those subjects are portrayed, however, tells us a great deal about larger trends in American history and society. Every imaginable type of criminal activity has been depicted on screen, as have the legal ramifications of those acts. But these films raise profound questions. What is the nature of crime? What makes a criminal? Are there circumstances in which crime is justified? How do socioeconomic conditions affect the consequences? How fair and impartial is our justice system? Perhaps most importantly, how do depictions of crime and justice in popular media influence our answers to these questions? This class will utilize a variety of films to discuss the ways in which popular media portrays the sources of crime, the nature of criminals, the court and prison systems, and particular kinds of criminal acts. Films to be screened may include such titles as The Ox-Bow Incident, Out of the Past, 12 Angry Men, Young Mr. Lincoln, Brute Force, The Equalizer, Jack Reacher and Minority Report. By thoroughly discussing these films and related readings we will be able to trace the various changes in attitude towards crime and justice in America over the last century.

79-309 The Chinese Revolution Through Film (1949-2000)
Intermittent: 9 units
This course is about both film and history. It is not a detailed history of film, but rather introduces some key issues of modern Chinese history and examines how that history is treated in film. Most of the films are made in China (including Taiwan and Hong Kong) but some are produced in the west. Topics that may be explored include the rise of the Communist Party, life in Maoist China, the Cultural Revolution, the Cold War/anti-imperialism, depictions of China's minority peoples, and the Reform-era under Mao's successors. Along with feature movies, we may view documentaries, propaganda films, TV shows and even music videos. In addition to providing a general history of the period, accompanying readings and assignments explore the social context and methodology of the films while developing critical skills in writing, analysis, and historical imagination.

79-310 Modern U. S. Business History: 1870 to the Present
Intermittent: 9 units
This course explores the development of American business within its economic, political, and social context from the late nineteenth century to the present. Through the lens of "history of capitalism," readings and discussions will explore the interconnections of State and Market in the twentieth century United States that shaped how, why, and where business transactions occurred. Particular attention will be paid to the institutional, social, technological, environmental, labor, and cultural context in which American commerce developed, from the rise of the modern corporation in the late nineteenth century to the emergence of a true information economy in the twenty-first. Students will encounter primary sources, scholarly secondary readings, business case studies, and cultural artifacts as they explore how business functioned and changed over time in an American context.

79-311 PaleoKitchen: Food and Cooking in the Ancient World
Intermittent: 6 units
From home cooking to haute cuisine, people are passionate about food. But what did people eat in the ancient world? This class will center around the origins of the human diet, including human dietary adaptation to diverse ecological and technological situations; social, cultural, behavioral, and ecological factors which influenced diet in ancient societies; and the origins of cuisines around the world.

79-313 "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration
Intermittent: 6 units
What is home? What does it mean to belong, or not belong? What does it mean to be mobile? Is mobility a privilege or a curse? How do experiences of migration, exile, and displacement shift one's understanding of home? This course will examine the modern patterns of migration, mobility, and displacement, with a particular focus on the US and Europe in the 20th and 21st centuries. We will engage with anthropological and historical analyses of global migrations of people, capital, and ideas; social inequalities; and new forms of political control (surveillance, "profiling," militarization of borders, and race-related forms of rejection and violence). The course will rely on seminar discussions and interactive lectures¿a combination of lecture and discussion, which will productively challenge the students to engage with the material in a critical manner and will help them contextualize and enrich the knowledge they gain from the course readings.

79-314 The Politics and Culture of Memory
Intermittent: 9 units
What is the relationship between an individual person and collective memories? How do societies "remember"? This course proposes an interdisciplinary approach to the relationship between memory and history. It explores various ways in which societies have mobilized their remembrances of the past for political and economic ends in the present; how and whose memory began to matter in a global 20th century; and how individual testimonies have highlighted the role of body, experience, trauma, and nostalgia for writing new, more inclusive and heterogenous histories. We will analyze how the politics of memory intermesh at a local and global scale, via a set of case studies that focus on: the use and erasure of the past in post-1945 Western and Central Europe; political violence, civil war, and reconciliation in post-1990 Guatemala; and the role of remembrance and testimony for claims of moral retribution in the aftermaths of colonialism (the Mau Mau in Kenya). This class will follow the format of a seminar. The professor will give short lectures each week in order to introduce the readings and place them within larger debates, but the course will mainly be discussion-oriented.

79-315 Thirsty Planet: The Politics of Water in Global Perspective
Intermittent: 9 units
Water is necessary for all forms of life on Earth. The purpose of this course is to introduce students to social and political aspects of water, using in-depth case studies that draw on a variety of perspectives. Examples of regional water projects we'll study include traditional tank irrigation in South India; international negotiations along the Nile River; and the U.S. Government in negotiation with native activists and fisheries on the Columbia River. In addition to regional variety, readings will explore a variety of themes, for example, water and gender; water and armed conflict; and water and private companies versus public management. By the end of this course, students should be able to articulate their own answers to these questions: How have global organizations and participants characterized, enacted, and addressed problems of water supply and delivery for those who need it most? How do particular regions reflect global trends in water resource development, and how might these diverge from global trends? How have social and environmental studies in the literature of development come to understand the problem of water? One set of readings is assigned each week. Students should be prepared to discuss each week's readings in a thoughtful way during class meeting time.

79-316 Photography, the First 100 Years, 1839-1939
Intermittent: 9 units
Photography was announced to the world almost simultaneously in 1839, first in France and then a few months later in England. Accurate "likenesses" of people were available to the masses, and soon reproducible images of faraway places were intriguing to all. This course will explore the earliest image-makers Daguerre and Fox Talbot, the Civil War photographs organized by Mathew Brady, the introduction in 1888 of the Kodak by George Eastman, the critically important social documentary photography of Jacob Riis and his successor, Lewis Hine, the Photo-Secession of Alfred Stieglitz, the Harlem Renaissance of James VanDerZee, the precisionist f64 photographers Ansel Adams, Imogen Cunningham, and Edward Weston, and other important photographers who came before World War II. The class will be introduced to 19th century processes, such as the daguerreotype, tintype, and ambrotype, as well as albumen prints, cyanotypes, and more.

79-317 Art, Anthropology, and Empire
Intermittent: 9 units
This seminar will explore the anthropology and history of aesthetic objects, as they travel from places considered "primitive" or "exotic," to others deemed "civilized" or "Western." First, we will consider twentieth-century anthropological attempts to develop ways of appreciating and understanding objects from other cultures, and in the process to reconsider the meaning of such terms as "art" and "aesthetics." Then we will discuss several topics in the history of empire and the "exotic" arts, including: the conquest, colonization and appropriation of indigenous objects; the politics of display and the rise of museums and world fairs; the processes by which locally-produced art objects are transformed into commodities traded in international art markets; the effects of "exotic" art on such aesthetic movements as surrealism, etc.; and the appropriation of indigenous aesthetic styles by "Western" artists. Finally, we will consider attempts by formerly colonized populations to reclaim objects from museums, and to organize new museums, aesthetic styles, and forms of artistic production that challenge imperialism's persistent legacies.

79-318 Sustainable Social Change: History and Practice
Intermittent: 9 units
If you wanted to change the world, who would you ask for guidance? Mahatma Gandhi? Rachel Carson? Nelson Mandela? In this interdisciplinary course, we will examine the history of efforts to create sustainable social change. Through a series of targeted case studies, we will examine the successes and failures of notable leaders, past and present, who strove to address social problems nonviolently and to create lasting improvements in fields such as education, healthcare, and human rights. In keeping with the example of the people we will be studying, we will bring our questions and our findings out of the classroom through a variety of creative, student-driven experiments in sustainable social change.

79-319 India Through Film
Intermittent: 6 units
Bollywood films attract hundreds of millions of viewers, not just in India but throughout the world. The name "Bollywood" makes it seem that the Indian film industry is a junior partner, merely an echo of Hollywood. But more films are made in Mumbai every year than in Los Angeles. And Mumbai is only one of many film hubs in India. The rich diversity of Indian cinema speaks to the equally rich history of India itself. This course uses Indian movies to examine several key themes in India's history. We will focus on the twentieth century and on questions of democracy, diversity, and development. This course includes a mandatory film screening on Wednesday evenings beginning at 6:30pm.

79-320 Women, Politics, and Protest
Intermittent: 9 units
This course examines the history of women's rights agitation in the United States from the early nineteenth-century to the present. It investigates both well-known struggles for women's equality—including the battles for women's voting rights, an Equal Rights Amendment, and access to birth control—and also explores the history of lesser-known struggles for economic and racial justice. Because women often differed about what the most important issues facing their sex were, this course explores not only the issues that have united women, but also those that have divided them¿keeping intersectionality and women's diversity at the center of the course.

79-322 Stalin and the Great Terror
Intermittent: 9 units
Joseph Stalin has been vilified and praised, damned and worshipped. He left behind a mixed and complex legacy. He created an industrialized modern economy in the Soviet Union and won a great and painful victory over the Nazis. At the same time, he built a police state, sent millions to labor camps, and destroyed the possibilities for socialist democracy. When he died, thousands of Soviet citizens wept at his funeral. This course will combine elements of biography and social history to examine Stalin, the man, and Stalinism, the phenomenon. Using history and film, we will explore one of the most complicated and influential dictatorships of the 20th century.

79-323 Family, Gender, and Sexuality in European History, 500-1800
Intermittent: 9 units
The medieval and early modern periods witnessed a transformation in the cultural and social understandings of gender. During this period, the mutable sexual categories of the pre-modern world evolved into the definitions of masculinity and femininity recognizable today. This course examines these changes in the understanding of gender and the family in Europe in the medieval and early modern periods, drawing upon readings in gender history, marriage and the family, and the history of sexuality. We will explore the ideal of Christian marriage and family and examine how the "ideal" compared to the reality on such issues as marriage practices, family, gender roles, and sexuality. We will also explore the fashioning of female and masculine gender norms and the construction of the male and female sense of self over time. In the process, we will examine the larger historiographical issue of the use of gender as a tool of historical analysis.

79-324 #MeToo: Naming and Resisting Gender Violence
Intermittent: 6 units
#metoo represents a sea change in society's response to gender-based violence. But what is sexual harassment, exactly? When does something cross over into being inappropriate? Would you always know violence when you see it? Chances are, you wouldn't. Focusing on the U.S., this class dives into where we are, and how we got here. It addresses gender-based violence as a public health & human rights issue. It will delineate the legal and social definitions of gender violence, explore how those definitions function both positively and negatively, and examine the long history of protest that has culminated in this moment. Come join the conversation!

79-325 U.S. Gay and Lesbian History
Intermittent: 6 units
US Gay and Lesbian History offers an overview of the changing context and circumstances of sexual minorities in American culture. From early constructions of moral opprobrium, criminal deviance or medical pathology, the LGBT community emerged in the twentieth and twenty-first century as a political constituency and a vital part of contemporary society. Students should be aware that this course will necessarily address issues of intimate relations and sexuality as well as broader historical issues.

79-326 German History through Film
Intermittent: 9 units
This course offers both a history of German cinema and a survey of 20th-century Germany as seen through German films. As film history, the course introduces students to movies spanning the silent era, Nazi films, the West German New Wave, socialist cinema, and post-unification movies. We will consider stylistic and technical trends as well as dramatic content. As a course in German history, the course sets major movies from each era against a backdrop of political, social, and cultural developments. We will also analyze the portrayal of World War II and the Third Reich in films made after 1945. We will view approximately 18 films, mostly in class but several outside of class. Readings will include works on the history of German film and a textbook on 20th-century German history. Writing will consist of three 5-page essays and one 8-10 page paper.

79-327 Modern Girlhood: Historical and Contemporary Perspectives
Intermittent: 6 units
Through primary documents, film and popular media, material culture, and interdisciplinary scholarship from the emerging field of girl(hood) studies, this course will examine historical conceptions of girlhood and accounts of girls' lives, to contemporary concerns and representations. In seeking to understand the meaning and experience of "modern" girlhood, our focus will primarily be on the 20th and 21st century American experiences, though at times we may look to perspectives from earlier periods and elsewhere in the world. Because there is no single experience or representation of girlhood, we will pay attention to the ways that girlhood is lived and constructed differently across social, cultural, geographic, and chronological perspectives.

79-328 Photographers and Photography Since World War II
Intermittent: 9 units
Invented in 1839, photography was a form of visual expression that immediately attracted a large public following. Starting around 1900, photography was practiced with two dominant strands. One of these firmly believed in the power of photographs to provide a window on the world, and was led by Lewis Hine, whose documentary photographs for the National Child Labor Committee helped to ameliorate living and working conditions for thousands of immigrant children. The other strand adhered to the philosophy of Alfred Stieglitz who adamantly affirmed that photographs were first and foremost reflections of the soul and were art objects, equal to painting, drawing and sculpture. These two schools of thought guided photographers throughout the twentieth century. This course explores in depth the tremendous range of photographic expression since World War II and examines in particular the contributions of significant image-makers such as Helen Levitt, W. Eugene Smith, Robert Frank, Diane Arbus, Garry Winogrand, Charles "Teenie" Harris, Cindy Sherman, Carrie Mae Weems, Nan Goldin, James Nachtwey, and many others. Classes include a slide lecture, student presentation, and video segments that introduce a focused selection of images by major photographers in an attempt to understand their intentions, styles, and influences. As available, students will be expected to make one or more visits to photography exhibitions on view in Pittsburgh (locations to be announced at the first class.)

79-329 "High Crimes and Misdemeanors": The Constitution and Impeachment
Intermittent: 6 units
A few years ago, the word "impeachment" drew talk of President Bill Clinton, White House interns, and definitions of the word, "is". Since President Donald Trump's inauguration in early 2017, the prospect of impeachment charges has become a regular media concern. In this course, we will examine the basis for the option of impeachment - the Constitutional power of the legislature to remove the President or other federal officials from office for "treason, bribery, or other "high crimes and misdemeanors." While Presidents may be the most high-profile subjects of impeachment, we will also examine the other 17 federal officers that have been impeached in the past, as well as a number of state officials who have been impeached, including Louisiana Governor Huey Long in 1929 and Illinois Governor Rod Blagojevich in 2009.

79-330 Medicine and Society
Intermittent: 9 units
This course examines the history of American medicine, public health, medical research and education, disease patterns, and patients' experiences of illness from the colonial period to the present. Students read the voices of historical actors, including physicians, patients, policy makers, and researchers. In analyzing these voices, students will learn what was at stake as Americans confronted diseases and struggled to explain and cure them. Readings include a range of primary sources as well as fiction and non-fiction accounts of medicine and health in America.

79-331 Body Politics: Women and Health in America
Intermittent: 9 units
[Note: Students who have taken 79-178, Freshman Seminar: Body Politics: Women and Health in America, may not enroll.] This course takes a topical, intersectional approach to the history of U.S. women's health in the nineteenth and twentieth centuries. It is less about governmental politics, although we do some of that. Rather, it sees bodies as cultural texts through which power is built and contested. The course covers topics such as the history of anatomy, menstruation, reproductive rights, body image, mental health, sexuality, violence, childbirth, and menopause. We explore how science and American culture both have constructed these issues over time (some of it is super whacky!), while also examining women's organizing around them. This course is open to all students.

79-333 Sex, Gender & Anthropology
Intermittent: 9 units
This course introduces students to an anthropological perspective on the relationship between sex (biological) and gender (cultural). In order to understand the various debates we will examine the ideas of manhood, womanhood, third genders and sexuality in cross-cultural perspective. The focus will be primarily on non-western cultures and will examine the construction of status, sexuality, and gender roles within the broader context of ritual, symbolism, marriage, and kinship. Utilizing film, the popular media, and anthropological case studies, this course will provide students with ways to understand and question how and why we express ourselves as "men," "women," and "other."

79-334 Climate Change and Climate Justice: Global Perspectives
Intermittent: 6 units
There remains no credible doubt that human activities are a leading cause of climate change, but profound questions persist over what measures to take, whom to hold accountable, and how to help those affected. What does an effective and just response look like when those who are most responsible for climate change are also often the most protected from its consequences? Who gets to participate in international negotiations and whose cosmologies or values are recognized there? How do debates about climate change relate to those concerning social policy? In this mini-course, we will examine these questions through the lens of Climate Justice. Both a transnational movement and an analytical orientation, Climate Justice compels us to consider how climate change reflects (and exacerbates) systemic inequalities within and between societies. Our exploration will engage case studies and perspectives from different parts of the world, including climate-related health disparities in the US, Indigenous Peoples' calls for climate reparations, island nations facing displacement, and efforts by various parties to influence scientific and popular knowledge.

79-336 Oil & Water: Middle East Perspectives
Intermittent: 6 units
This course provides an introduction to the field of global environmental history, while using regional case studies from the geographic region of the Middle East. It highlights key issues in global history, seeking ways to examine Middle East history from a global historical perspective. Several themes in environmental history will receive special attention, including: agricultural systems; water resources; climate variability; the temporalities of natural resources; and narratives of 'development.' In addition, we will examine the historiography, or changing assumptions over time, of historians and other scholars who have studied the environmental resources of the Middle East.

79-338 History of Education in America
Intermittent: 9 units
Americans have long understood schools both as mechanisms for inculcating communal values and as instruments for social reform. Schools have been alternatively described as pillars of democratic society and as authoritarian institutions for managing deviance. Institutions of education - whether schools, colleges, or universities - figure prominently in discussions of inequality and discrimination, opportunity and meritocracy. This course provides an introductory historical survey of American educational ideas and institutions. From debates in the 17th and 18th centuries over the proper balance of religious and secular education to fierce battles today over the role of the federal government, citizens have been politically mobilized through their concerns about education. By understanding the complicated history of American educational ideas and institutions, this course prepares students to engage critically with ongoing debates about the curriculum, vouchers, charter schools, and national standards.

79-339 Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)
Intermittent: 6 units
How have American films portrayed juvenile delinquency and the juvenile justice system? What does filmmakers' portrayal of juvenile delinquency tell us about American culture and society? Do films vividly capture or badly distort the "realities" of crime and the operations of the justice system? This course uses feature films (to be viewed in advance of class) from the 1920s to the early 1960s, as well as various sociological, psychological, and historical readings, to explore these issues. The course is run as a colloquium, with students playing central leadership roles in launching and guiding class discussions. The course will have a take-home midterm exam (essay), a final exam (essay), and a few short, written assignments linked to students' required oral presentations in class.

79-340 Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)
Intermittent: 6 units
How have American films portrayed juvenile crime, drug use, gang violence, and law enforcement responses (especially police and prisons) to juvenile crime and violence? How have American films portrayed individual juvenile delinquents, their families, and the communities in which they live? Do films vividly capture or distort the "realities" of juvenile crime and the operations of law enforcement? This course uses feature films from the late 20th and early 21st centuries, as well as social science and historical readings, to explore these issues. The course is run as a colloquium, with students playing central leadership roles in launching and guiding class discussions.

79-341 The Cold War in Documents and Film
Intermittent: 9 units
This course is based on use of historical documents and films to study problems that reshaped the world during and after the Cold War. We will examine how documentary and feature films depicted the most important events of the Cold War, such as the Korean War, the construction of the Berlin Wall, the Cuban missile crisis, and others. In addition to films, sources will include documents, lectures and readings.

79-342 Introduction to Science and Technology Studies
Intermittent: 9 units
This course provides an introduction to Science and Technology Studies, a vibrant interdisciplinary field that examines the ways that science and technology interact with contemporary politics, culture, and society. Using theories and methods from history, philosophy, anthropology, and sociology, we will examine topics including: the nature of scientific and technical knowledge; the formation of new fields of interdisciplinary expertise (e.g., atomic science, artificial intelligence, or genetic engineering); the emergence of risk societies; systems of classifications and categories and their impact on ideologies of race, sex, and gender; the possibility of objectivity; and the public understanding of science.

79-343 Education, Democracy, and Civil Rights
Intermittent: 9 units
What is the relationship between education and democracy? By examining a series of case studies at the intersection of education and the civil rights movement, this course will prepare students to approach contemporary educational debates as historically-informed critical thinkers. The controversy surrounding charter schools, vouchers, the common core, and the role of standardized testing cannot be understood outside the long history of debates regarding the relationship between education and democracy. Are schools meant to perpetuate the status quo? How did both traditional and more radical forms of education advance the struggle for civil rights? What role have students played in advancing civil rights and democracy? While exploring these questions, we will also partner with local high school students and teachers to bring our learning beyond the classroom.

79-344 Public History: Learning Outside the Classroom
Intermittent: 6 units
Museums and other non-academic institutions reach large audiences with an array of history offerings, including exhibitions, films, publications, performances, oral history, workshops, lectures, events, research, reenactments, lectures, social media, webinars, online, radio and television programming. These educational tools are calculated to engage diverse audiences. Museums and educational nonprofits are also actively collecting and preserving artifacts and archival materials. This course will focus on Pittsburgh history as students examine best practices in Public History. The class will study the inner workings of a large history museum's collection, exhibition, conservation and education programs. Students will participate in field trips and behind-the-scenes tours, virtual explorations, and "hands-on history" outside the classroom at the Heinz History Center and other Pittsburgh attractions. This course will especially interest students considering non-traditional careers in history, education, communications, and nonprofits. MAXIMUM ENROLLMENT IS 15. ALL CLASSES WILL BE HELD ONCE PER WEEK OFF CAMPUS, STARTING AT THE HEINZ HISTORY CENTER IN THE STRIP DISTRICT (1212 SMALLMAN STREET).

79-345 Roots of Rock & Roll
Intermittent: 9 units
This course is about open source, collaborative innovation and the impact of social and technological change on American music. We will spend the first 8 weeks on early "remix" music (slave songs, Anglo-Appalachian ballads, ragtime, and Depression era blues and country). After studying Bessie Smith, Woody Guthrie, Lead Belly, Hank Williams, and other early artists, we'll spend the last 7 weeks on revolutionaries like Chuck Berry, Bob Dylan, Jimi Hendrix, and Janis Joplin. The format is informal lecture and discussion. Assignments include reading two books plus some articles, weekly music listening, short papers, and a final project. NB: This course may be taken pass-fail (with submission of appropriate form).

79-346 American Political Humor
Intermittent: 9 units
This course takes a cultural approach to U.S. history since the Civil War, as seen by the nation's most astute and influential critics: its political humorists. Besides immortals like Mark Twain and contemporaries like Jon Stewart and Stephen Colbert, we will (re)discover the satirical yet hilarious voices of H.L. Mencken, Will Rogers, Lenny Bruce, Dick Gregory, Richard Pryor, Nora Ephron, Dave Chapelle, and others through essays, recordings and films. At its sharpest edges, humor addresses issues of class, gender and race in American life, and provokes alternative thinking about mass culture, consumerism, and conformity. Assignments include short analytical essays and a final paper.

79-348 Abraham Lincoln
Intermittent: 9 units
This course explores Lincoln's historical importance and his changing status as an American icon. We will not only learn about his life, we will address controversies about him (such as his attitudes and motives regarding slavery and racism). Readings will include a short biography, a book about his struggles with mental illness, a book about his friendship with Frederick Douglass, and Lincoln's own speeches and writings. His skills as a precise and succinct writer will be an ongoing focus; hence, assignments will emphasize the drafting, revising, and polishing of short essays, rather than the memorization of facts.

79-349 United States and the Holocaust
Intermittent: 6 units
This course will challenge you to explore profoundly disturbing historical material. We will examine aspects of history on both sides of the Atlantic with regard to Hitler, the Nazis and America's response in the 1930s and 1940s. This course will compel you to think not only about what happened and why, but also about the implications for us today as individuals and as Americans. Films, a meeting with a survivor or child of survivor as well as the inclusion of survivor accounts in the readings will serve to strengthen the learning impact.

79-350 Early Christianity
Intermittent: 9 units
This course examines the origins of Christianity in historical perspective. Using both Christian and non-Christian sources from the period, we will examine how and why Christianity assumed the form that it did by analyzing its background in the Jewish community of Palestine, its place in the classical world, and its relationship to other religious and philosophical traditions of the time. We will also examine historically how the earliest Christians understood the life and message of Jesus, the debates about belief and practice that arose among them, and the factors influencing the extraordinary spread of the movement in its earliest centuries. This course satisfies one of the elective requirements for the Religious Studies minor.

79-352 Christianity Divided: The Protestant and Catholic Reformations, 1450-1650
Intermittent: 9 units
At the dawn of the sixteenth century, most western Europeans shared a common religious identity as members of the Roman Catholic Church. Within less than two decades, this consensus began to crumble, and the very fabric of western culture was irrevocably altered. By 1550, Europe was splintered into various conflicting churches, confessions, sects, and factions, each with its own set of truths and its own plan for reforming the church and society at large. This period of rapid and unprecedented change in western history is commonly known as the Reformation. Though this term has traditionally referred to the birth of Protestantism, it also encompasses the simultaneous renewal and reform that occurred within Roman Catholicism. This course will survey the Reformations of the sixteenth century, both Protestant and Catholic, examining the causes of the Reformation, the dynamics of reform, and its significance for western society and culture. In the process, we will analyze such on-going problems as religious persecution and the accommodation of dissent, the relationship between religion and politics, and the interactions between ideology and political, social, and economic factors in the process of historical change.

79-354 Kids and Schools in the 20th Century
Intermittent: 6 units
This course examines the history of children's experiences in American K-12 schools, both public and private, at three critical moments in the 20th and early 21st centuries. We will first examine the emergence of Progressivism as a perceived antidote to the impacts of industrialization, urbanization, and the immigrant experience on children and youth in the early 1900s. We will then study the retreat from Progressive educational ideas in the wake of the Cold War and "Space Race" with the Soviet Union in the decades following World War II. Finally, we will analyze the impacts on American schoolchildren of the "Excellence" and "No Child Left Behind" movements that began around the turn of the 21st century and and continue today. To ground class discussions, we will use both secondary and primary historical sources, including policy and curricular documents, documentary film, and first-person accounts of both children and teachers in schools.

79-355 Fake News: "Truth" in the History of American Journalism
Intermittent: 6 units
Scandal, conspiracy, and partisan propaganda have been among the stuff of media ever since newspapers first appeared in America, and now they figure prominently in electronic media as well. The question "What is truth?" is not just a matter of philosophical speculation, but an essential issue at every level of American life, from individuals on social media to citizens, journalists, and politicians responsible for sustaining a democratic society. This course is literally "ripped from the headlines," examining contemporary conflicts over credibility in print and online, in the context of historical experience. My goal is to help you think in new ways about how to assess when news really is "fake" and when it's just "an inconvenient truth."

79-356 Neuroscience and the City
Intermittent: 9 units
How do we, as human beings, experience the urban environment? We explore the underlying psychological and neural basis of our perceptions as they create the experience of historical change.

79-359 Truth, Lies, and Propaganda: A Historical Inquiry
Intermittent: 9 units
For many commentators, the election of Donald Trump in November 2016 marks the beginning of the "post-truth" era, in which reality is no longer knowable, or even relevant. While this narrative certainly captures the unease that many Americans feel, it is historically inaccurate. There never was a time in the past when we could readily discern truth from falsehood without difficulty. The goal of this course is to examine the social history of truth. We will explore the concept of truth in philosophy and science; the evolution of methods for discovering facts about the world; the centrality of trust in knowledge production; and the innumerable ways that facts have been questioned, manipulated, discredited, purposefully ignored, and fabricated over the past several centuries. The course will include case studies from science, law, politics, war, art, journalism, and history.

79-363 The Rise of Modern Golf, 1860 to the Present
Intermittent: 6 units
Aristocratic pastime or the people's game? This course will examine the emergence of golf as both a professional and amateur sport and as a popular leisure activity between 1860 — when Prestwick Golf Club in Scotland hosted the first (British) Open — and the present day. Students will read and discuss historical, sociological, and literary texts, and view several documentary and feature films as well. The course will have a take-home midterm exam (essay), a final exam (essay), and a few short, written assignments linked to students' required oral presentations in class.

79-364 From Midwife to Obstetrician: The Transformation of Modern Childbirth
Intermittent: 6 units
At-home births, epidurals, C-sections: women's experiences with childbirth have varied widely over time. Many of these differing experiences stem from societal developments that first occurred in Europe during the seventeenth and eighteenth centuries. Focusing specifically on England and the United States, we will identify the factors (e.g., human agents, ideologies, etc.) that influenced major changes in the childbirth process and examine how these changes affected mothers and childbirth practitioners of the time. Additionally, we will consider what implications this historical study holds for interpreting contemporary debates surrounding women's health issues, including but not limited to childbirth. Throughout this course, we make liberal use of primary sources to develop arguments about the large-scale changes that occurred between 1600 and the present. Through assigned readings, class discussions, and diverse course assignments, students will develop an informed perspective on the transformation(s) of childbirth.

79-367 Disastrous Encounters
Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. Disastrous Encounters explores the complex interaction between human beings and their environment by examining incidents in which those disasters have proven destructive or fatal to humankind. By the end of the class students will be able to: Explain the scientific principles behind "natural" disasters, including cyclonic weather, global climate change, volcanoes, earthquakes, tsunamis, river flooding, famines, and diseases. Analyze to what extent a given disaster is in fact "natural" at all, but rather was either caused by or exacerbated by human actions. Draw connections between different types of disasters, recognizing that major disasters often produce predictable secondary disaster effects. Read documents critically, especially in terms of the author's agenda and the author's likely biases. Write strong analytical essays.

79-368 Un-natural Disasters: Societies and Environmental Hazards in Global Perspective
Intermittent: 6 units
In the wake of Hurricane Katrina, Neil Smith famously observed that "there is no such thing as a natural disaster." This course takes a cue from Smith by examining the social production of disasters in the past and present, from acute environmental events like typhoons and earthquakes to disasters of "slow violence" like chronic exposure to toxic pollution and food insecurity. Examining case studies from around the world, we will explore how these different forms of disaster collide with inequalities of race, class, and gender - and in the process challenge us to rethink the relationship between nature and society.

79-369 Disasters in American History: Floods and Hurricanes
Intermittent: 6 units
In this course we will investigate the historical roles played by people in creating the conditions for disastrous floods and hurricanes in the United States, examining the material causes of "natural disasters" and analyzing how Americans have been affected differently according to race and class. By the end of the course, we will have examined some of America's largest flood and hurricane disasters in their historical contexts, and we will use this knowledge to think about disasters that Americans face now and in the future.

79-370 Disasters in American History (2):Epidemics & Fires
Intermittent: 6 units
This course investigates the historical roles played by people in creating the conditions for disastrous outbreaks of disease and fire in the United States, examining the material causes of "natural disasters" and analyzing how Americans have been affected differently according to race and class. By the end of the course, we will have examined some of America's largest epidemics and wildfires in their historical contexts, and we will use this knowledge to think about disasters that Americans face now and in the future.

79-371 African American Urban History
Intermittent: 9 units
Popular perceptions of poor and working class people occupy a prominent place in discussions of today's African American urban community in the unfolding Age of Donald Trump. In the contemporary quest to build livable urban communities, however, journalistic, public policy, and academic analysts often discuss the black poor and working class as "consumers" rather than "producers," as "takers" rather than "givers," and as "liabilities" instead of "assets" in the present moment of the nation's history. Effective public policies, movement strategies, educational programs, media campaigns, and sensitive philanthropic decisions require deeper and more thoughtful perspectives on the history of urban race and class relations in the past. Focusing on the development of African American urban history from its colonial beginnings through today's "Black Lives Matter Movement," this course will emphasize the many ways that people of African descent shaped American and African American urban life through their roles as workers, community-builders, and social justice activists. In addition to weekly classroom discussions of assigned readings, students will write a series of short essays (based upon a mix of secondary and primary sources) on selected topics/themes in the development of African American urban life, culture, and politics.

79-372 Cities, Technology, and the Environment
Intermittent: 6 units
This course will explore the interaction of cities, technology and the natural environment over time. In doing so it will consider major issues confronting cities today including landscape and site changes; water supply, wastewater disposal and flooding; solid waste disposal; transportation and suburbanization; energy changes; and the impact of deindustrialization. These themes will be approached through a combination of class discussions, lectures, and visiting speakers. Class participation is expected, and will comprise a portion of the grade. In addition to required texts, readings will be distributed on Canvas.

79-373 Culture and Revolution: The Socialist Experiment in Soviet Russia
Intermittent: 6 units
In 1917, revolutionaries took power in Russia to create the world's first socialist society. In this great and untried experiment, they initially attempted to remake every phase of social and cultural life, from the family to art to education. Before Stalin's rise to power at the end of the 1920s, the new socialist society challenged tradition and created new possibilities. How could life be lived in a new way and better way? What values could and should replace the old traditions of patriarchy and class hierarchy? How could ordinary people be empowered to create a new culture? In this course, we will study the 1920s, a riotous decade of experimentation in cultural, sexual, and political life. Looking at literature, art, social relations, education, and law, we will examine the theories and experiments that bloomed in the wake of revolution.

79-375 Science & Religion
Intermittent: 6 units
A widely-held notion is that science and religion are perennially at "war" with one another. Debates over evolution, and more recently climate change, are often cited as examples, while predictions that science will eventually render religion obsolete are at least as old as the Enlightenment. Nevertheless, science and religion are both thriving in the twenty-first century, which raises the question of whether these two ways of seeing the world might, for some people at least, be more complementary than conflictual. We'll explore the history of the relationship between science and religion and the different "ways of knowing" employed by each. A number of common assumptions will be critically examined as we consider questions of fact and value, and the competency of both science and religion to address some of the major challenges of our day.

79-377 Food, Culture, and Power: A History of Eating
Intermittent: 9 units
This course explores food production and consumption in the modern world. This semester, we will focus on ongoing debates over how to feed a world of seven billion people on a planet undergoing major climate change. We will explore the historical roots of the problem of "feeding the world" and consider the overlapping yet competing ideas of food security and food sovereignty. What are the cultural, economic, environmental and political contexts that create opportunities and constraints for changing food systems? After exploring this big question through readings and group discussions, the second half of the semester will be devoted to individual research projects focused on the historical and cultural dimensions of food provisioning.

79-379 Extreme Ethnography
Intermittent: 9 units
Observation, participation and direct experience of "the field" are hallmarks of anthropological ways of knowing, and their representation has played a foundational role in ethnographic writing both past and present. Yet reflexive and postmodernist explorations of these topics have triggered contentious debates over the nature of anthropology as a scientific or humanistic enterprise, and over its ethical, political and epistemological value. In this seminar, we will approach such questions through an exploration of the extremes of ethnographic fieldwork and writing. We will consider such topics as: the colonial history and politics of explorers and ethnographers; liminality and the place of extreme experience—such as cultural dislocation, violence, derangement, intoxication, sex, possession, and dreaming-in fieldwork and writing; field-notes as an ethnographic genre, and their relationship to "official" published ethnography; ethnographic surrealism and surrealist ethnography; the dimensions of sensory experience (visual, auditory, olfactory, etc.) in fieldwork and ethnography; collecting and the powers of "exotic" objects; inter-subjectivity and its implications; and experimentation with alternate ethnographic forms, such as autobiography, film, diary, and poetry.

79-380 Hostile Environments: The Politics of Pollution in Global Perspective
Intermittent: 9 units
Earth is an increasingly toxic planet. Fossil-fueled industrialization, chemical engineering, and resource-intensive consumerism have generated immense wealth, but they have also left long-term, cumulative legacies of toxic pollution and ecological harm. While these legacies affect everyone, their impacts are by no means evenly distributed. In this course, we will use the tools of anthropology, political ecology, and history to examine experiences of toxic exposure in different parts of the world, including Pittsburgh. Our analyses will ask how inequalities of race, class, and gender shape exposure as well as how cultural differences create divergent understandings of ecology, health, and their interrelationship. We will consider, moreover, how these disparities shape what people know about pollution and whether/how they demand accountability for it. Cases we explore will range from acute industrial disasters (and their aftermath) to the harms experienced by other-than-human beings to the gradual, often invisible exposures that affect all of us to varying degrees.

79-381 Energy and Empire: How Fossil Fuels Changed the World
Intermittent: 9 units
Few things have changed the world as much as petroleum: cars, airplanes, fertilizers, plastics are just some of the technologies derived from oil. Moreover, the wealth and power associated with "black gold" has shaped geopolitics in the twentieth century, giving rise to so-called "petro-states." For the first five weeks, we will trace the evolution and expansion of "petrocultures" around the world. The remainder of the course will be organized around individual student research projects. The major learning objective of this course is to give students experience writing an original research paper. Students will be expected to define a research question, assemble a bibliography of sources, write and revise an analytical paper, and do an oral presentation. This course, open to all students, partially fulfills the Theoretical and Topical Core course requirement for Global Studies majors.

79-382 Law, Voting Rights, & American Democracy: Historical & Contemporary Perspectives
Intermittent: 6 units
Voter participation in free and fair elections is one of the most basic principles of the American republic, yet our country's history is fraught with examples of citizens having to fight to exercise this right. From literacy tests to poll taxes, gerrymandered districts to controversial campaign financing rules, the federal and state governments have been called upon to establish protections for citizens and, when these protections fail, determine a remedy. This course will examine various key elements of voting and elections especially relevant to the current body politic, including campaign finance and gerrymandering.

79-383 The History of Capitalism
Intermittent: 9 units
What is capitalism? How does it differ from the systems that preceded it, and how did it come to revolutionize the globe? This course will cover the development of capitalism from the 16th century to the present. We will examine the theories of Karl Marx and Adam Smith, who both attempted to theorize the new, emerging system. We will look at how the transition from feudalism to capitalism took place, and the impact of new world slavery, commodity production, and the role of women and the household. We will examine the development and demise of the factory system and deindustrialization in America's rust belt cities. We will examine "globalization," the latest dynamic phase of capitalism, and its impact on people and the environment. Finally, we will discuss the advent of robotization, and the impact of casual labor, low wages, and unemployment on democracy, the prison system, and the rise of a new technocratic elite.

79-384 Gender and Sports
Intermittent: 9 units
This course will examine how gender has fundamentally shaped the logic of organized sports for men and women during the past century and a half, especially in the U.S. A variety of competitive levels will be examined, with the focus on amateur as well as professional sports. Several sports will receive special attention, including basketball, track, tennis and golf — both men's and women's participation in each sport. The course will be in a discussion format, with reading assignments required for each class. All examinations will be in essay format.

79-385 Out of Africa: The Making of the African Diaspora
Intermittent: 9 units
The trans-Atlantic slave trade dispersed Africans in the New World and the Old, creating the African Diaspora. Generations of scholars have disputed whether descendants of enslaved Africans could have retained any of their African culture and/ or fully assimilated into New World societies. This course will combine a chronological, geographical, and a thematic approach to the creation of new Africa-inspired cultures in both Africa and the African Diaspora. It will explore societies in the Caribbean, the US South, Latin America, and Africa and address themes, such as Africanisms, African survivals, African retentions, Creole languages, and religion.

79-386 Entrepreneurs in Africa, Past, Present and Future
Intermittent: 9 units
Fifty years after Ghana, the first sub-Saharan African nation, gained its independence from colonial rule, African economies continue to rest on a fragile foundation. Entrepreneurs must play an important role in developing the African continent, because both African governments and foreign aid have overall failed. In the face of these myriad of internal and external constraints on economic development, the history of entrepreneurship and future potential for entrepreneurship is often overlooked. This course will show that sub-Saharan Africa is-and has been for centuries-a thriving place of business, despite the obstacles of war, political and economic instability, disease, and famine. It will also focus on the challenges, such as local, regional, and national integration, access to credit and capital accumulation, and debt burden that African economies faced in the past, present, and future. Lastly, it will focus on the strategies that entrepreneurs in Africa-local and foreign-have developed to circumnavigate these challenges-and the opportunities that they have created in spite of them. By taking a historical approach to the subjects of entrepreneurship, innovation, and technology in Africa, this course will define African entrepreneurship in a way that is rooted in Africans' historical experiences and use this definition to put Africa's current and future roles in the global economy into historical perspective.

79-387 General Francisco Franco: Fascism and its Legacies in Spain
Intermittent: 6 units
Francisco Franco was Europe's longest-ruling dictator. He ruled over Spain from 1939 to 1975. This course will examine the social and cultural context of the rise of Fascism in Spain. We will focus especially on Franco's seizure of power during the Spanish Civil War; the decades of his lengthy dictatorship; the social and cultural politics in transitioning Spain to democracy after his death; and the legacy of Spanish Fascism and Franco's dictatorship in contemporary Spain.

79-388 The History of Sports in the United States
Intermittent: 9 units
The course will survey the history of sports in the United States, focusing primarily on the 20th century. Topics considered will include sports and race, gender, and politics; the commercialization of sport; and collegiate sports. We will pay particular attention to the way in which sports have served as an arena for dissent. Also covered will be Pittsburgh's relation to national sports trends. By the end of the semester students will gain an understanding of the changing role of sports in the United States.

79-390 History Workshop: Computer Science
Intermittent: 9 units
This course examines the history of computing with a focus on the history of computers and computing at Carnegie Mellon University. Students will read historical accounts of computing as well as research the history of computing at Carnegie Mellon using the materials and resources of the University Archives and libraries. Students in the course will collaboratively produce a public exhibition on the history of computing as their final project.

79-392 America at War: From Vietnam to Afghanistan
Intermittent: 9 units
In this course we will look at fundamental changes in the approach of the United States to preparing for and engaging in armed conflict that have taken place since the War in Vietnam. The lowering of the voting age to eighteen and the end of conscription ("the Draft"), committed the United States to the challenge of continuing the Cold War and winning - there has been no acceptable alternative since the fall of Saigon - post-Cold War conflicts with an all-volunteer military whose members were now enfranchised. At the same time, the U.S. defense establishment continued its pursuit of advanced technologies in all facets and at all levels of warfare, evolving through various regional interventions and culminating in the Gulf War, "Operation Desert Storm," in 1991. We will examine the continuing and increasing role of hi-tech in the chaotic decade after the collapse of the Warsaw Pact and in the American-led "War on Terror" since 9/11, waged by a much smaller, highly professionalized military, and we will engage some ethical and social issues about the American Way of War in the recent past and the citizens who practice it.

79-393 Institutions of the Roman Church
Intermittent: 9 units
This course is only offered at Carnegie Mellon's campus in Qatar. This course will explore the history of the Catholic Church, with a particular focus on the church as an evolving European institution. Although we will have to deal with theological arguments at times, abstract theology will not be the focus of the course. Instead, the course will be centered on two main questions. First, how did the Catholic Church manage to persist, for nearly two millennium, as a stable institutional entity within an ever-changing European milieu? Secondly, to what degree did the Catholic Church influence and/or reflect developments within Western European culture?

79-394 Exploring History through Geography
Intermittent: 6 units
For studying the past, space can be as important as time. Digital mapping and GeoLocation technologies influence our everyday interactions and perceptions of the world around us. Historians are thinking about how these technologies can change their fields of study, too. Through the "spatial turn" in the Humanities and Social Sciences, historians are using spatial experience to think more deeply about the meaning of place and space. Visualizing spatial relationships via new technologies can offer meaningful new ways to approach historical questions. This course will consider viewpoints from the discipline of Geography and explore the impact of new methods in the Digital Humanities, including the impact of digital tools such as Geographic Information Systems (GIS).

79-395 The Arts in Pittsburgh
Intermittent: 9 units
This course will examine the arts in Pittsburgh, both historically and in the present. We will focus especially on art exhibits and musical events scheduled by the city's museums and concert halls during the semester. The "curriculum" will derive from the artistic presentations themselves, which will provide a springboard for reading assignments, seminar discussions, and research papers in the history of music and art. We will also examine the historical development of cultural institutions in Pittsburgh. The History Department will pay for students' admission to all museums and studios. However, students will be charged a supplemental fee of approximately $275 to help subsidize the considerable expense of purchasing tickets for concerts and performances by the Pittsburgh Symphony, Pittsburgh Opera, Chamber Music Society, and Renaissance and Baroque Society. Attendance at all art exhibits and musical events is required. Prerequisite: Please check your overall course schedule: you must be available to attend art exhibits on several Fridays and Saturdays, and to attend musical events on several Thursday, Friday and Saturday evenings.

79-396 Music and Society in 19th and 20th Century Europe and the U.S.
Intermittent: 9 units
This course will explore the interrelations between society and classical and popular music in the nineteenth and twentieth centuries in Europe and the United States. We will examine the importance of different musical forms in the life of society and how music contributed to the making of political consciousness, especially in the twentieth century. In addition to reading assignments, seminar discussions, and research papers in the history of music, students will be taken to performances of the Pittsburgh Symphony, Pittsburgh Opera, and Chamber Music Pittsburgh. A supplemental fee of approximately $275 will be charged to subsidize part of the considerable expense of purchasing tickets for concerts and performances. Prerequisite: Availability to attend musical events on several Friday and Saturday evenings.

79-397 Environmental Crises and the City
Intermittent: 6 units
Concern over Global Climate Change has increasingly focused on the environment of cities. our largest and most vulnerable population centers. Yet, since their origins, cities have consistently faced environmental challenges from both natural and human made factors. This course will explore some of these environmental challenges over time, examining issues including air and water pollution, floods, heat waves, earthquakes and hurricanes, disease and public health, and warfare. It will examine how these events have shaped and altered cities and urban life over time and consider issues relating to the desirability or undesirability of life in cities.

79-398 Documenting the 1967 Arab-Israeli War
Intermittent: 9 units
This course considers how historians practice their craft in interpreting great events with the Arab-Israeli war of 1967 serving as the case study. Students read recent scholarly accounts of the war and then check them against one another as well as a variety of primary source materials such as memoirs, documents, speeches, newspapers, maps, eye-witness reports and UN resolutions. We will constantly be asking if the sources support the secondary accounts or if there are other interpretations that might lead to different conclusions. We will be examining the texts for tangents left unexplored and possibly worthy of further research. Students should expect a significant reading load, frequent short assignments and a final research paper of 15-20 pages on a 1967 War-inspired topic.

79-400 Global Studies Research Seminar
Fall: 12 units
This research seminar is the capstone course for Global Studies majors. The course is designed to give you a chance to define and carry out a research project of personal interest. The first few weeks of the course will be devoted to developing a research topic and locating sources. We will then work on how to interpret and synthesize sources into a coherent and compelling thesis before you begin drafting your paper. Your research may be based on in-depth reading of a body of scholarly work, field notes from ethnographic observations, archival research, analysis of literary or visual media, or some combination of these sources. Incorporation of some non-English language sources is strongly encouraged where possible. Independent work, self-initiative, participation in discussion, and peer evaluations are required. There are several interim deadlines that will be strictly enforced in order to ensure successful completion of the course.
Prerequisites: 79-275 and Theoretical and Topical Core must be complete or concurrently enrolled. Corequisite: 79-275.

79-420 Historical Research Seminar
Fall: 12 units
The purpose of this research seminar is to help students conceptualize, design, organize, and execute a substantial research project that embodies and extends the knowledge and skill set they have been developing as History majors at Carnegie Mellon. The identification, collection and interpretation of relevant primary source data are integral parts of this intellectual task. Students will strive to hone written and oral presentation skills, deepen their command of research methodologies and strategies, and sharpen their abilities as a constructive critic of others' research. The seminar seeks to develop these intellectual skills through a combination of in-class, student-led discussions of everyone's research-in-progress, and regular individual consultations with the instructor.
Prerequisite: 79-200 Min. grade C

79-449 EHPP Project Course
Fall: 12 units
The Ethics, History and Public Policy Project Course is required for the Ethics, History and Public Policy major and is taken in the fall semester of the senior year. In this capstone course, Ethics, History and Public Policy majors carry out a collaborative research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis for a chosen client. The students develop an original research report based on both archival and contemporary policy analysis and they present their results to their client and a review panel.

79-470 Simulating Conflict Resolution
Intermittent: 3 units
This course is only offered at Carnegie Mellon's campus in Qatar. This pass-fail, 3-credit course for the Qatar campus is designed to prepare students for a capstone event: an international conflict resolution exercise, to be held in the 2018 Spring semester, that simulates a current Middle Eastern crisis. The course will consist of two parts. First, students will meet weekly with an instructor for 1 hour/week to discuss the historical and modern Middle East, so that they will be prepared to participate meaningfully in the simulation. For these classes, students will be expected to complete and discuss readings prepared by the instructor. Secondly, students will participate in the simulation exercise in late spring, taking the role of one of the Middle Eastern actors (these will be decided ahead of time) and role-playing their nation's response to the specific crisis scenario. Finally, after the simulation, students will submit to the instructor a reflection paper on what they learned from participating in the event. Suggested pre- or co-req: Conflict Resolution (80-242 or 70-321).

79-491 Independent Study
Intermittent
An Independent Study is meant for students with a special interest in an area not covered by a formal history course. Readings and other work are negotiated between the student and an individual faculty member.

79-503 Senior Thesis I
Fall: 9 units
Seniors may write a thesis with permission of the Undergraduate Advisor and a designated faculty member who will supervise its completion.

79-505 Social & Political History Internship
All Semesters
The Social & Political History program strongly encourages students to locate internship opportunities in Pittsburgh or elsewhere that complement their historical interests (as, for example, in a museum or historical society) or areas of policy research that link closely with their historical interests (as, for example, in a government agency or non-profit organization). To earn academic credit for their internship, students will be required to maintain a weekly journal; write a short critical reflection on how the internship connects to their academic interests; and share their experience with other Social & Political History majors. The Academic Advisor will assist students with matching their interests to local organizations. SPH students can earn up to 9 units in each internship. However, the internship credits they earn will not count toward fulfillment of the course requirements (93 units) for the SPH major.

79-506 Global Studies Internship
Fall and Spring
This course provides Global Studies majors with a chance to explore global connections in Pittsburgh. Majors, working in close consultation with the Global Studies director and advisor, will arrange an internship with a non-governmental organization (usually in Pittsburgh) whose mission has a global reach. This could include an organization that supports projects in other countries, works with immigrants in the Pittsburgh area, or participates in international policy making/governance. We strongly encourage students to seek out opportunities that require use of a second language. Students will be required to maintain a weekly journal; write a short critical reflection on how the internship connects to academic work; and share their experience with other Global Studies majors. Global Studies advisor and director will assist students with matching their interests to local organizations and identifying an on-site supervisor available to collaborate in the ongoing and final evaluation of the student's work.
Prerequisite: Students must be Global Studies majors and obtain permission for the proposed internship from the Global Studies advisor.

The Major in Information Systems

Joe Mertz, Faculty Director

Gary DiLisio, Principal Academic Advisor

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Information Systems (IS), found within the Dietrich College of Humanities and Social Sciences, is an internationally recognized undergraduate major for students who want to design and implement effective solutions to meet organizational, societal and management needs for information and decision support.

In today's complex, interconnected world, the effective creation, distribution, and use of information via technology is central to daily life. Computer based information systems facilitate, enable and often define the relationships between corporations and consumers, buyers and suppliers, businesses of all sizes, social networks, and citizens and their governments. Understanding these relationships and effectively addressing the collection, flow, and distribution of information is vital to running a modern organization, enterprise or government agency.

Information Systems involves the effective design, delivery, use and impact of information and communications technologies in organizations and society. The importance of information technology and information systems to organizations and the need for well-educated professionals in the field is the basis for the Information Systems curriculum at Carnegie Mellon. Whether implementing applications, providing management or decision support, managing complex systems projects, or helping organizations design business processes or cope with rapid change, IS professionals fill an essential need across all sectors of society.

Information systems students at Carnegie Mellon learn to use, manage and deploy information technologies to address real problems or opportunities. They develop a solid foundation in computing, communications, as well as software development principles, languages, and methods. Since Information Systems generally operate within organizations, IS students study social sciences and organizational theory. IS students learn how to right-size information technology solutions to meet real-world economic and organizational constraints. Information Systems students also learn, through hands-on experience, the importance of professional communications, problem analysis, critical thinking and teamwork. Building on the multi-disciplinary strengths of the university and the Dietrich College of Humanities and Social Sciences, graduates in Information Systems are ideally suited to take a leading role in shaping our information-based future.

The flexible nature of the program encourages students to explore their own interests through program electives, study in a contemporary content area or through optional second majors and minors.

IS students are well prepared to pursue graduate work in a wide range of fields. For students interested in master's degree-level graduate work at Carnegie Mellon, there are many possibilities, including accelerated Masters degree programs in Information Systems Management, Human Computer Interaction, Information Security Policy and Management, Engineering Technology and Innovation Management, and Business Administration.

IS graduates continue to be in high demand in the information-age workplace. There has been a strong job market for IS students in recent years, and national trends indicate that this is likely to continue. IS majors often take jobs in consulting companies, major software firms, large corporations, and start-up companies. Internship opportunities closely parallel the job market.

In addition to the Dietrich College General Education Requirements and basic prerequisites in Mathematics, Statistics and Computer Science, IS students must complete the Professional Core, the Disciplinary Core and a focused Content Area. In the Professional Core (consisting of six courses), students learn the basic skills necessary to analyze, design, implement and test high-quality, cost effective information systems. Two of the Professional Core courses are project-based experiences in which small teams of students develop and deliver solutions to real information problems.

In the Disciplinary Core (consisting of three courses), students study key areas fundamental to understanding and solving problems in information systems: professional communications; quantitative analysis and research methods; and organizations, policy, and social science.

IS students also complete three courses within one Content Area. The content areas are designed to provide students an opportunity to gain additional depth in a focused area. Currently, twelve content areas are available: (1) Business / Enterprise Systems, (2) Computing and Information Systems & Technology, (3) Social and Global Systems, (4) Quantitative Analysis, (5) Game Design, (6) Animation and Special Effects, (7) Media Design, (8) Design for Learning, (9) Sonic Arts, (10) Innovation and Entrepreneurship, (11) Intelligent Environments, (12) Physical Computing. Content areas (5) through (12) are offered through CMU's Integrative Design, Arts, and Technology (IDeATe) (http://www.cmu.edu/ideate) initiative combining arts and technology.

Study Abroad Options in Information Systems

Given the importance of globalization, we encourage students to consider expanding their international experience by spending a semester studying abroad. The IS program is very flexible in allowing students to pursue these opportunities. With careful planning, study abroad is possible during most semesters. Students interested in study abroad should talk with the IS Academic Advisor to help plan an appropriate course of study. With prior approval, study abroad courses may be applied to major requirements.

Information Systems as Additional Major or Minor

Information Systems is not available as either an additional major or minor.

Curriculum

The Information Systems major is offered only as a Bachelor of Science (B.S.) degree. In addition to major requirements outlined below, all Information Systems students must fulfill the General Education requirements for the Dietrich College of Humanities and Social Sciences. A total of 360 units is required for the degree.

Requirements are subject to revision. Advisor approval is required for each student's major curriculum plan. Any proposed course substitutions to courses required for the IS major must be approved in advance by the IS Academic Advisor.

Prerequisites

Information Systems requires completion of prerequisite courses in Mathematics, Statistics and Computer Science. All prerequisites must be successfully completed prior to the start of Fall semester, junior year.

Mathematics and Statistics

Complete one of the following calculus sequences:

		Units
21-111	Differential Calculus	10
21-112	Integral Calculus	10

OR

		Units
21-120	Differential and Integral Calculus	10
21-256	Multivariate Analysis (Required for advanced business courses)	9

OR

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation (Required for advanced computer science courses)	10

AND also complete:

		Units
36-200	Reasoning with Data	9

Computer Science

Three Computer Science courses are required. To maintain normal progress toward the Information Systems degree, students must complete 15-121

Introduction to Data Structures prior to the start of Spring Semester, sophomore year.

Students entering the program as freshmen will have the option to complete a Computer Science Placement Test. Depending on appropriate Advanced Placement credit and/or results of the Computer Science Placement Test, entering students may place directly into 15-112 or 15-121. 15-110 is taken as the first Computer Science prerequisite unless a student places directly into 15-112 or 15-121. Most students entering the program will begin the sequence with 15-110.

		Units
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-121	Introduction to Data Structures	10

Note: Students cannot receive credit for both 15-104 Introduction to Computing for Creative Practice and 15-110 Principles of Computing.

Professional Core

The Professional Core consists of six courses (five core courses and one core elective).

Complete all five of these courses:

		Units
67-250	The Information Systems Milieux (Spring Semester Only)	9
67-262	Database Design and Development (Fall Semester Only)	9
67-272	Application Design and Development (Spring Semester Only)	9
67-373	Information Systems Consulting Project (Spring Semester Only)	12
67-475	Innovation in Information Systems	12

* Departmental approved courses are available as substitutions for 67-475. Please discuss with IS advisor.

Professional Core Elective

Plus, complete 6 to 12 units chosen from the following options:

		Units
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
67-202	The Softer Side of Software	6
67-211	Business Oriented Sys:History, Des & Dev-Lens of CoBOL Programming Language	6
67-240	Mobile Web Design & Development	9
67-261	Information Design Fundamentals	9
67-265	Design Fundamentals I: Shaping Interactions and Experiences	9
67-279	Introduction to Geographical Information Systems	6
67-306	Special Topics: Management of Computer and Information Systems	6
67-308	Innovation Studio: Health Care Information Systems	9
67-309	Special Topics: Information Assurance and Security	6
67-317	Mobile Web Development and Usability Testing	9
67-324	Accelerating Innovation and Entrepreneurship	9
67-327	Web Application Security	6
67-328	Mobile to Cloud: Building Distributed Applications	9
67-329	Contemporary Themes in Global Systems	9
67-330	Technology Consulting in the Community	9
67-338	Information & Grid Design	9
67-344	Organizational Intelligence in the Information Age	9
67-353	IT & Environmental Sustainability	6
67-364	Practical Data Science	9
67-442	Mobile Application Development in iOS	9
88-223	Decision Analysis	12
88-275	Bubbles: Data Science for Human Minds	9

OR Any Computer Science OR related courses above 15-121 with prerequisite of 15-112 or higher.

OR Any Human-Computer Interaction course (05-xxx).

OR other *pre-approved* 67-2xx. 67-3xx or 67-4xx which may be offered from time to time. Students wishing to apply such courses to their Professional Core requirement must complete a course substitution application through the IS Academic Advisor.

OR other *pre-approved* courses offered by the Engineering & Public Policy Department (19-xxx).

NOTE: 67-1xx may not be applied to this requirement.

Disciplinary Core

Complete one course (9 units) from each of the three Disciplinary Core categories.

Professional Communications

Information systems professionals communicate with a wide range of people in most organizations and often facilitate communications between diverse groups of stakeholders. Consequently, the most successful professionals typically are those with strong communication skills. These courses help students see that the structure and presentation of information affects how well (and how easily) it can be understood and used.

Complete one course. It is recommended that this requirement be completed by the end of junior year:

		Units
05-341	Organizational Communication	9
36-315	Statistical Graphics and Visualization	9
51-261	Design Center: Communication Design Fundmntls: IxD for Communications	9
or 51-262	Design Center: CD Fundamentals: Design for Interactions for Communications	
67-202	The Softer Side of Software	6
67-261	Information Design Fundamentals	9
67-265	Design Fundamentals I: Shaping Interactions and Experiences	9
67-338	Information & Grid Design	9
70-321	Negotiation and Conflict Resolution	9
70-340	Business Communications	9
70-341	Team Dynamics and Leadership	9
70-342	Managing Across Cultures	9
70-350	Acting for Business	9
70-483	Advertising and Marketing Communications	9
76-270	Writing for the Professions	9
76-272	Language in Design	9
88/70/85-341	Team Dynamics and Leadership	9

Quantitative Analysis and Research Methods

This area focuses on decision making and data analysis — essential to development of useful information systems. this area exposes students to analytic methods in the social sciences and quantitative methods for approaching complex methods.

Complete one course (9 units). It is recommended that this requirement be completed in the sophomore year:

		Units
21-257	Models and Methods for Optimization	9
21-325	Probability	9
36-202	Statistics & Data Science Methods	9
36/70-208	Regression Analysis	9
36-217	Probability Theory and Random Processes	9
36-218	Probability Theory for Computer Scientists	9
36-225	Introduction to Probability Theory	9
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
67-364	Practical Data Science	9
67-445	Seminar in IS: Intelligent Agents	9
70-257	Optimization for Business	9
80-305	Choices, Decisions, and Games	9
80-405	Game Theory	9

88-223	Decision Analysis	12
88-251	Empirical Research Methods	9
88-275	Bubbles: Data Science for Human Minds	9

Organizations, Policy, and Social Science

The focus of this area is on how organizations function in modern social and economic environments. Students will develop a greater understanding of how social policy and technology influence organizations and how they operate.

Complete one course (9 units):

		Units
08-200/19-211	Ethics and Policy Issues in Computing	9
15-390/70-421	Entrepreneurship for Computer Science	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
67-308	Innovation Studio: Health Care Information Systems	9
67-315	A Web For Everyone	9
67-344	Organizational Intelligence in the Information Age	9
67-353	IT & Environmental Sustainability	6
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70/85/88-341	Team Dynamics and Leadership	9
70-342	Managing Across Cultures	9
70-415	Introduction to Entrepreneurship	9
70-416	New Venture Creation	9
70-437	Organizational Learning and Knowledge Management	9
80-249	AI, Society, and Humanity	9
80-341	Computers, Society and Ethics	9
88-223	Decision Analysis	12
88-275	Bubbles: Data Science for Human Minds	9

Content Area

Complete a minimum of 27 units from one of the Content Areas below. No Content Area course may also be used to fulfill a Disciplinary Core or Professional Core requirement.

Business/Enterprise Systems

This content area broadens a student's knowledge in the business, economics and policy aspects of large scale information systems.

		Units
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
67-240	Mobile Web Design & Development	9
67-261	Information Design Fundamentals	9
67-306	Special Topics: Management of Computer and Information Systems	6
67-308	Innovation Studio: Health Care Information Systems	9
67-309	Special Topics: Information Assurance and Security	6
67-315	A Web For Everyone	9
67-317	Mobile Web Development and Usability Testing	9
67-324	Accelerating Innovation and Entrepreneurship	9
67-328	Mobile to Cloud: Building Distributed Applications	9
67-331	Technology Consulting in the Global Community	6
67-344	Organizational Intelligence in the Information Age	9
67-353	IT & Environmental Sustainability	6
67-442	Mobile Application Development in iOS	9
70-332	Business, Society and Ethics	9
70-366	Intellectual Property and E-Commerce	6
70-371	Operations Management	9
70-395	Funding Entrepreneurial Ventures	9
70-437	Organizational Learning and Knowledge Management	9
70-438	Commercialization and Innovation	9
70-443	Digital Marketing and Social Media Strategy	9
70-449	Social, Economic and Information Networks	9
70-460	Mathematical Models for Consulting	9
70-465/	Technology Strategy	
70-471	Supply Chain Management	9
73-359	Benefit-Cost Analysis	9
73-469	Global Electronic Markets: Economics and the Internet	9
76-391	Document & Information Design	12
76-487	Web Design	12

Computing and Information Systems & Technology

This content area allows students to focus on current and emerging technologies.

		Units
05-391	Designing Human Centered Software	12
05-410	User-Centered Research and Evaluation	12
05-430	Programming Usable Interfaces	15
05-431	Software Structures for User Interfaces	15
05-432	Personalized Online Learning	12
05-433	Programming Usable Interfaces OR Software Structures for Usable Interfaces	6
05-499	Special Topics in HCI	Var.
16-311	Introduction to Robotics	12
16-362	Mobile Robot Algorithms Laboratory	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
60-415	Advanced ETB: Animation Studio	10
67-240	Mobile Web Design & Development	9
67-315	A Web For Everyone	9
67-327	Web Application Security	6
67-328	Mobile to Cloud: Building Distributed Applications	9
67-364	Practical Data Science	9
67-442	Mobile Application Development in iOS	9

* Any Computer Science OR related courses above 15-121 with prerequisite of 15-112 or higher.

Social and Global Systems

This content area exposes students to key themes in globalization and global systems management, policy, international business, and technology.

		Units
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
67-329	Contemporary Themes in Global Systems	9
67-331	Technology Consulting in the Global Community	6
67-353	IT & Environmental Sustainability	6
70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-430	International Management	9
70-443	Digital Marketing and Social Media Strategy	9
70-480	International Marketing	9
73-372	International Money and Finance	9
76-318	Communicating in the Global Marketplace	9
76-386	Language & Culture	9
79-318	Sustainable Social Change: History and Practice	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
88-411	Rise of the Asian Economies	9

Additionally, other *pre-approved* courses offered by the Engineering & Public Policy Department (19-xxx) may be used to fulfill the Social and Global Systems Content Area.

Quantitative Analysis

Students will learn to apply analytic and quantitative methods for approaching complex, ambiguous problems.

		Units
21-257	Models and Methods for Optimization	9
21-292	Operations Research I	9
36/70-208	Regression Analysis	9
36-217	Probability Theory and Random Processes	9
or 36-225	Introduction to Probability Theory	
36-218	Probability Theory for Computer Scientists	9
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-410	Introduction to Probability Modeling	9
or 36-46x Topics in Statistics		
67-364	Practical Data Science	9
67-445	Seminar in IS: Intelligent Agents	9
70-257	Optimization for Business	9
70-460	Mathematical Models for Consulting	9
70-462	Uncertainty and Risk Modeling	9
73-274	Econometrics I	9
73-374	Econometrics II	9
88-223	Decision Analysis	12
88-251	Empirical Research Methods	9

Integrative Design, Arts, and Technology (IDeATe) Content Areas:

An IDeATe content area consists of a minimum of 27 units which may include one Portal Course (other than 15-104 Introduction to Computing for Creative Practice) plus 2 courses from one of the areas below. Course information can be found on the IDeATe website (https://ideate.cmu.edu/undergraduate-programs).

Game Design (IDeATe)

In this content area, students will learn both theory and skill in the key areas of games: dramatic narrative and character development, visual and sound synthesis, special effects and performance capture, programming and engine development, interface and interaction architecture development, game assessment and redesign.

Animation and Special Effects (IDeATe)

The interconnected components of performance capture, rendering, 3D and 2D animation, and special effects will be covered in this content area.

Media Design (IDeATe)

The digital mediation of experiences content area explores the interconnected development of technology and content in new media systems and the meaning that arises from the resulting forms. Students learn to design mediated experiences across different platforms, from mobile to large-scale installations.

Design FOR LEARNING (IDeATe)

Students in this content area will combine their diverse skills for the design of effective new media systems for learning; from games for learning to tangible learning tool kits and remote learning systems. They will leverage new technologies, media arts knowledge, and learning science principles to create engaging experiences with measurable real world impact.

SONIC ARTS (IDeATe)

This content area will explore the processes and products of digital sound and music. Students will receive basic training in key areas: principles of computer music, hybrid instrument building, concepts in sound design. 62-150 IDeATe Portal: Introduction to Media Synthesis and Analysis (10 units) is the required portal course for this content area and will serve as one of the courses for this content area.

Innovation and Entrepreneurship (IDeATe)

Students in this content area will develop the knowledge and skills to lead and innovate in creative industries. Their interdisciplinary, hands-on coursework will emphasize the conceptualization of innovative products and the structuring of innovation processes.

Intelligent Environments (IDeATe)

The focus of this content area is on spaces that support efficiency and high quality of experience, addressing both the integrated development of such environments and the resulting experience.
The required portal course for this content area is 62-150 IDeATe Portal: Introduction to Media Synthesis and Analysis (10 units) or 16-223/60-223 IDeATe: Introduction to Physical Computing (10 units) and will serve as one of the courses for this content area.

Physical Computing (IDEATE)

The barriers between computing devices and their users have slowly dissolved. The physical world is becoming a key interface for computing and the internet of things is becoming the next generation of connectivity. Students in this content area will explore the technical, experiential, and semantic issues of this evolution.

Sample Curriculum

Freshman		**Sophomore**	
Fall	**Spring**	**Fall**	**Spring**
67-100 Information Systems Freshman Workshop	67-250 The Information Systems Milieux	67-262 Database Design and Development	67-272 Application Design and Development
15-110 Principles of Computing	15-112 Fundamentals of Programming and Computer Science	15-121 Introduction to Data Structures	Disciplinary Core Course
21-111 Differential Calculus	21-112 Integral Calculus	Disciplinary Core Course	Elective Course
Freshman Seminar	76-101 Interpretation and Argument (or other approved first-year writing options)	Elective Course	Elective Course
36-200 Reasoning with Data	79-104 Global Histories	Elective Course	Elective Course
99-101 Computing @ Carnegie Mellon			
Elective Course			

Junior		**Senior**	
Fall	**Spring**	**Fall**	**Spring**
Professional Core Elective Course	67-373 Information Systems Consulting Project	67-475 Innovation in Information Systems (or other approved substitutions)	Content Area Course
Disciplinary Core Course	Content Area Course	Content Area Course	Elective Course
Elective Course	Elective Course	Elective Course	Elective Course
Elective Course	Elective Course	Elective Course	Elective Course
Elective Course	Elective Course	Elective Course	Elective Course

Academic Policies

Transfer into Information Systems

Most IS students are admitted directly into Information Systems as incoming freshmen. Only Information Systems major students are permitted to enroll in the Professional Core courses (67-250 and above), and IS students have enrollment priority in IS electives.

Students in high academic standing may apply to be admitted to the Information Systems major as transfer students. Transfers into Information Systems will always be subject to availability of space in the major. Applications will be considered based on the following criteria:

- Strong record of academic performance at Carnegie Mellon (minimum QPA of 3.4)
- Relevance and clarity of personal statement
- Interview with IS Academic Advisor. Current Dietrich students must also interview with their Academic Advisory Center (AAC) advisor while non-Dietrich students will only be required to meet with the IS Academic Advisor.
- Relevance of courses completed to date

- Completion of 15-112 Fundamentals of Programming and Computer Science with final grade of 'A' or 'B'
- Relevance of prior experiences and projects

Application materials must be submitted no later than the last day of classes of the fall or spring semester. Current Dietrich students will submit materials to the Academic Advisory Center while non-Dietrich students will submit all materials directly to Information Systems in Hamburg Hall 3031.

Students accepted as transfers to the IS program would normally be expected to complete the usual prerequisites and begin the Professional Core courses during the next available semester.

Students interested in applying for transfer to the Information Systems major should contact the IS Academic Advisor for information regarding availability, application procedures and deadlines. Potential applicants to the IS major should be working toward a sensible alternative major, so that their success at Carnegie Mellon is not predicated on admission to the IS program.

Double Counting of Courses

"Double Counting" refers to instances when a course taken to fulfill one requirement counts simultaneously toward a requirement in another major or minor program. Double Counting is permitted in the Dietrich College on a very limited basis. Information Systems students may double count no more than two courses used to fulfill any Information Systems major requirement (beyond the Dietrich College General Education requirements and Prerequisite courses) with any combination of dual degrees, additional majors, minors or graduate degree programs. Only one course may double count with any minor. No course can count for more than one requirement within the major. Students must also adhere to any policy restrictions on double counting enforced by the academic department of the student's additional major or minor.

Course Repeats

Per university policy, when a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. This is the case regardless if the first grade for the course is a passing or failing grade.

Undergraduate students who wish to repeat a course already passed must obtain approval from the student's Dean or Department Head. When a student takes a course s/he has already passed, only one set of units will count towards graduation requirements.

Faculty

CHADI AOUN, Associate Teaching Professor – Ph.D., Univeristy of New South Wales; Carnegie Mellon, 2015–

ANIS CHARFI, Associate Teaching Professor – Dr.Ing., Technische Universitat Darmstadt; Carnegie Mellon, 2015–

SUSAN HAGAN, Associate Teaching Professor – PhD., Carnegie Mellon University; Carnegie Mellon, 2004–

C.F. LARRY HEIMANN, Teaching Professor – Ph.D., Washington University (St. Louis); Carnegie Mellon, 1998–

DIVAKARAN LIGINLAL, Teaching Professor – Ph.D., University of Arizona - Tucson; Carnegie Mellon, 2009–

SELMA LIMAM MANSAR, Teaching Professor – Ph.D., National Polytechnic Institute of Grenoble; Carnegie Mellon, 2007–

JOSEPH S. MERTZ, Faculty Director, Teaching Professor (joint Appointment with Heinz College) – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1997–

SARA MOUSSAWI, Assistant Teaching Professor – Ph.D. , City University of New York; Carnegie Mellon, 2016-–

DANIEL PHELPS, Associate Teaching Professor – Ph.D., Florida State University; Carnegie Mellon, 2007–

JERIA QUESENBERRY, Associate Teaching Professor – Ph.D., Pennsylvania State University; Carnegie Mellon, 2007–

RAJA SOORIAMURTHI, Teaching Professor – Ph.D., Indiana University; Carnegie Mellon, 2007–

SAVANID (NUI) VATANASAKDAKUL, Associate Teaching Professor – PhD., University of New South Wales; Carnegie Mellon, 2018–

RANDY S. WEINBERG, Teaching Professor; Information Systems – Ph.D., University of Minnesota; Carnegie Mellon, 1998–

The Major in Information Systems Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

67-100 Information Systems Freshman Workshop
Fall: 1 unit
This class provides an overview of the Information Systems Program for freshman students. The Program's academic advisor facilitates discussion of the field of IS, the curriculum, and careers, as well as co-curricular experiences such as internships and study abroad. Guest lecturers include the IS faculty, IS alumni, the IS career consultant, and various campus representatives. Discussions will include students' progress in their first semester, as well as guidance in course planning, for creating their Spring semester schedule of classes, and their overall four-year plan.

67-102 Concepts of Information Systems
Fall: 9 units
This course is an introduction to the world of Information Systems (IS). It introduces the core concepts of IS and its importance in the modern world around us. The course provides a general overview on the implications of information systems on organizations, by describing what an information system is; presenting some IS applications and discussing the implications of information systems on social and human aspects. The course also provides an initiation to essential information systems skills such as team work and project management.

67-202 The Softer Side of Software
Intermittent: 6 units
Even the best technologist has to rely on soft skills in their lives and jobs-whether they want a team member to take their constructive feedback or an angel investor to understand why their product is better than the competition. Classes will cover delivering engaging presentations, writing emails co-workers want to read, conducting meetings and workshops, delivering criticism and more. This mini course requires students to participate in a combination of short readings, in-class simulations, theater exercises, individual and group projects to practice soft skills. This course has some space available to students outside of the Information Systems program.

67-211 Business Oriented Sys:History, Des & Dev-Lens of CoBOL Programming Language
Fall: 6 units
Using computers to process business information began in the early 1960's. This course examines the technology evolution of business systems from the basic transaction processing of early business systems to today's event driven, web-based, big data systems. Students explore the unique aspects of business systems such as longevity, maintainability, good information reporting practices, and development methods. Lecture material includes important historical milestones, business systems terminology, and business oriented problem-solving approaches. Students will apply lessons learned in the lectures to programming assignments where they will gain a practical understanding of data representations, persistent storage structures, and algorithms common to business systems. The programming assignments use CoBOL, a standardized language designed for business systems development. Some minimal programming experience in any language is necessary. Good listening skills and class interaction are required.

67-240 Mobile Web Design & Development
Fall and Spring: 9 units
The Mobile Web Design and Development course provides a solid web design and development foundation focusing on responsive and user-centered design, and client-side components. Students explore the current standards and best practices of web design. Throughout the course, students work with HTML5, CSS3, Twitter Bootstrap, and Javascript, and learn how the various web components function together. The course utilizes a hands-on approach to guide students through learning and understanding the design and development process. This course is primarily designed for students with minimal technical experience. By the end of the course, students will be able to plan, design, and implement a basic functioning mobile web site/ app.
Prerequisites: 15-104 Min. grade C or 15-112 Min. grade C

67-250 The Information Systems Milieux
Spring: 9 units
Information systems (IS) are changing work practices, reshaping organizations, transforming cultures, and giving new meaning to the ways we see the world. This course is designed to help students understand the role of IS in the enterprise and the means by which these systems are created, utilized and maintained. The course will focus on enterprise information architecture including the components of enterprise strategy, business, application, information, and infrastructure layers. This course provides not only a framework for understanding information systems, but also a language to identify their dynamic complexities and interdependencies.

67-261 Information Design Fundamentals
Fall: 9 units
Information Design Fundamentals builds from a foundation in visual composition and typographic layout, to visual/verbal communication through the interplay of images, text, and typeface. Students apply this core understanding to information design problems that consider both qualitative and quantitative data developed for descriptive and strategic purposes that take the form of timelines, maps, hierarchies, and networks. While exercises concentrate on mastery of the tools and usability testing, projects importantly incorporate user studies methods as the first design step in order to help users perform tasks that meet their goals in ways that minimize barriers

67-262 Database Design and Development
Fall: 9 units
Data driven decision making is a core process of organizations. In this class students will study the principles of database management systems, their design, and development. Recent alternatives to the classical relational model will also be examined. This course is a required professional core course and is open only to sophomores in the IS major who have completed 67-250 or equivalent.
Prerequisites: (15-121 or 15-122 or 15-112) and 67-250

67-265 Design Fundamentals I: Shaping Interactions and Experiences
Fall: 9 units
This is an introductory course in interaction design, user experience, and the process of designing for people and technologies. The course introduces students to basic human-centered design research and concept development in the development of digital, service, and user experiences. Students also develop component skills in user interface design. Coursework promotes design thinking and practice for application in tech fields. Offered only on the Qatar campus.

67-272 Application Design and Development
Spring: 9 units
This course provides students with the concepts and techniques to design and develop software applications, and to understand the design process. Students will learn the importance of user-centered design and will develop a prototype of a web application as a course project. In the process of developing the application, students will learn how to design and create relational databases, how to acquire competency in new programming languages quickly, how to use the Model-View-Controller pattern to develop software applications, how to ensure technical quality in software development, and how to apply principles of user-centered design. This course is a required professional core course and is open only to sophomores and juniors in the IS major who have completed 67-250 or equivalent.
Prerequisites: (15-122 or 15-121) and 67-262

67-276 Building Better Web Applications
Fall: 3 units
This class introduces students to new technologies that will help improve web application performance and responsiveness. Classes will begin with a time of instruction followed by hands-on activities to reinforce learning principles.
Prerequisite: 67-272

67-279 Introduction to Geographical Information Systems
Intermittent: 6 units
Geographical Information Systems (GIS) allow us to visualize information that uses location. Through displaying layers of information in computer generated maps, we can see, analyze, understand and explore spatial patterns and relationships in new and novel ways. People in many different fields use Geographical Information Systems in their work: for visualizing the environment, human development, demographics, traffic and transportation, public health and many more. In this course, students will learn the basics of GIS through hands-on experience with popular mapping tools. Sources of data, principles of coordinate and projection systems and elementary geo-analysis techniques will be included. Upon completion of the course, students will have the background to begin using GIS techniques in their own areas of interest and will be prepared for further study in advanced GIs courses.

67-306 Special Topics: Management of Computer and Information Systems
Intermittent: 6 units
The course provides the overall knowledge of how Information Technology departments are managed in organizations of all sizes. It is about the technology people, the necessary best practice processes, and how innovation occurs transforming organizations in the way they operate and compete.

67-308 Innovation Studio: Health Care Information Systems
Intermittent: 9 units
Healthcare information systems are intended to improve patient outcomes while reducing the cost of clinical care. However, with the highest per person healthcare expenditures, the United States ranks low in healthcare quality compared to other countries. Although healthcare information systems are improving, challenges persist because information workflow, human interface design, and interoperability are not emphasized. In this course, students will learn to solve real-world healthcare information systems challenges in a team-based format.

67-309 Special Topics: Information Assurance and Security
Intermittent: 6 units
Special Topics: Information Assurance is an introduction course for Information Systems students that focuses on information security concepts. This course will be a broad introduction to many aspects of information security that affect computer systems, your everyday life on the internet, your activities - and those of others, and the practices of all organizations using and building information systems. You will learn an introduction to the practice of securing information systems, how organizations manage risk to their information assets, what threats there are to the security of an information systems, strategies for organizational resilience, applicable US cyber laws, and how organizations respond to real incidents. You will hear about some of the major cyber incidents that have shaped the way security is performed by organizations on the internet today, and you will participate through class discussions and homework analyzing important recent cyber issues, real incidents, and internet-scale events. By the end of the class you will be able to analyze systems for security using the language of security professionals and analyze the implications of real world attacks on security systems by applying core information security concepts.
Prerequisites: (15-112 or 15-110) and 67-250

67-315 A Web For Everyone
Spring: 9 units
This course provides a strong foundation in user-centered design and the engineering of web accessibility. The student will gain expertise in methodologies and toolkits for designing, prototyping, and evaluating a web site ensuring that the content is equally accessible to people with disabilities. Upon successful completion of this course, the student will be able to discuss standards and metrics for use in web development projects and be proficient in different stages of the project life cycle including data gathering methods, analysis techniques, requirements specifications, application of universal design principles, prototyping, and testing for usability and WCAG (Web Content Accessibility Guidelines) compliance. A term-long individual project will involve analysis of an organization's website for compliance with WCAG 2.1 guidelines, design and development of an improved prototype, and usability studies of the prototype
Prerequisites: 67-272 or 67-240

67-317 Mobile Web Development and Usability Testing
Intermittent: 9 units
Designing for mobile web applications enables businesses to harness the explosive growth and new opportunities on the mobile internet, besides enabling innovation in many ways. This course emphasizes a 'mobile first' approach to responsive web design, development, and user experience. Students gain a deep understanding of the mobile web development process, the grammar of building mobile web sites, emerging web standards, and state-of-the-art mobile usability testing methods. They gain first-hand exposure to developing with HTML5 and CSS3 and applying heuristic methods and testing tools such as Morae and Tobii eye tracker, to achieve an enhanced mobile user experience. Recent reports state that 80 percent of mobile websites in the US get traffic from other regions of the world. The course will address the need for facilitating a 'global' user experience, through independent student projects that target a 'global or social' theme and deliver a complete solution involving design, development, and usability testing of a localized and responsive web site.
Prerequisites: (15-122 or 15-121) and 67-272

67-319 Global Technology Consulting Groundwork
Spring: 3 units
This course is by invitation only for participants in the Technology Consulting in the Global Community program. For information on the program and how to apply, see http://cmu.edu/tcingc.

67-324 Accelerating Innovation and Entrepreneurship
Fall: 9 units
Mastering innovation processes and incorporating entrepreneurial methods into one's career is a cornerstone of success. Whether one endeavors into a startup or large company, successfully incorporating innovation and entrepreneurship will propel a career in software development, consulting, financial services, and many others. Innovation and entrepreneurship is a discipline with established tools and methods that must be properly harnessed in order to translate ideas into commercial successes. This course will expose and educate students to the discipline of innovation and entrepreneurship that will be portable to most any career and industry focus. After the completion of this course students will be able to understand and differentiate among "right sized" innovation and entrepreneurial methodologies

67-327 Web Application Security
Fall: 6 units
This is a technical course designed to help students learn how to exploit web applications and to be better able as developers to defend against such exploits. The course covers the process of hacking a web application, starting with initial mapping and analysis, followed by identifying common logic flaws in web apps, database and network exploits, command and SQL injections, and the like. This hands-on course requires students to be familiar with a popular web application framework or language (such as Ruby on Rails, PHP, Django/Python, ASP.NET or the like). Prerequisite: 67-272 or permission of instructor.
Prerequisite: 67-272

67-328 Mobile to Cloud: Building Distributed Applications
Fall: 9 units
Web 2.0, Mashups, Mobile Apps, and Cloud Computing are just a few of the new terms people are using to describe emerging technologies for building complex, distributed applications. Protocol standards, web services, open-APIs, increasingly more powerful mobile devices, and the Internet have enabled new possibilities for weaving complex applications using globally-distributed data and computing resources. Application development has largely left any single computer, and is distributed across a wide range of hardware and software platforms. This class will explore these developing technologies and models for structuring their complexity, while building projects that go from mobile to the cloud. Prerequisite: 67-272 (with "C" or higher) or permission of instructor.
Prerequisite: 67-272 Min. grade C

67-329 Contemporary Themes in Global Systems
Fall: 9 units
Globalization and outsourcing of information systems (IS) is a mainstay of the business environment. The decision to outsource software services to providers in distant places has many risks and thus careful management of critical success factors is essential. Likewise, products and services are being developed and delivered by teams of people in diverse locations working together. Management of these sourcing models and human capital relationships will be an increasingly important skill for students expecting to fully participate in the emerging IS marketplace of the 21st century. This course introduces the effective fundamentals of global project management and the mechanics of sourcing arrangements including offshore outsourcing. Students will also examine the effects of human diversity and cross-cultural considerations in the creation, use and management of information systems.

67-330 Technology Consulting in the Community
Spring: 9 units
In this course, the student develops technical consulting and management skills while collaborating on-site with a community leader of a non-profit community organization or school. This service-learning course has students analyze a complex organization, then design and implement a work plan that will expand the organization's capacity to use information technology. Student consultants do not merely provide IT support, nor do they focus on system development. Rather they focus on solving organizational problems using IT solutions. In doing so, they may develop a system, or adapt open source or commercial tools as appropriate to the situation. Throughout the semester, students develop a consulting report. They learn how to use this working document to collaborate with others and to think through and communicate a strategic technology plan. Students also experience how urban community organizations function, seeing the valuable benefits these organizations provide to society. Prerequisites: 76101 and (15121 or 70451) At least sophomore standing.
Prerequisites: 70-451 or 15-121 or 15-122

67-331 Technology Consulting in the Global Community
Fall
This course is by invitation only for participants in the Technology Consulting in the Global Community program. Admitted ONLY BY Permission of Instructor

67-335 Introduction to Data Analysis
All Semesters
This course teaches the basic techniques and practical skills required to make sense out of a variety of data, with the help of the most acclaimed software tools in the data science world: pandas, numpy, scipy, scikit-learn, etc. Thanks to a new set of software tools that allows to easily process and analyze data at scale, we are now able to extract invaluable insights from the vast amount of data generated daily. As a result, both the business and scientific world are undergoing a revolution which is fueled by one of the most sought after job profiles: the data scientist.

67-338 Information & Grid Design
Fall: 9 units
Whether you create, oversee, or want practice in solving problems through grid systems for websites, responsive applications, slide presentations, or data visualizations, this course provides the skills needed to communicate using the interplay of image, text, and typography in grid environments.

67-339 User-Centered Web Design
All Semesters: 9 units
User-Centered Web Redesign builds on the student's knowledge of design fundamentals, adding a stronger focus on user studies and usability testing. Our object of study is the redesign the website created as the final projects in Database Design and Development in order to synthesize design thinking as a system that not only functions on the back end but also on the front. Students engage in user studies by first developing an hypothesis of the user that they test through interviews and observations, leading to a revised hypothesis that more fully appreciates the user's goals, tasks, and internal barriers. Students will use these insights to develop site architecture through card sorting for organization, stress testing for navigation, and label testing for language use. The architecture of the site will then be explored for the visual/verbal communication design needed to help users perform tasks that meet their goals, which students will confirm through usability testing. Students will not only gain a stronger understanding of why "I am not the user," they will also gain insights concerning the complex features that inform a fully functional site.
Prerequisites: 67-265 and 67-262

67-344 Organizational Intelligence in the Information Age
Fall: 9 units
Across all organizations people find that the actions they take affect, and are affected by, the technology, norms, procedures, culture, and members of the organization. In order to navigate through this organizational world, agents need a better understanding of social and organizational intelligence. How do organizations (and the people who populate them) acquire and then process information? In what ways have new technologies affected the norms, procedures, and culture of organizations? How do leaders successfully guide their organizations through a world where new information and new technologies are constantly being produced? This course is about information assessment and analysis in organizations, and the way organizations are transformed by technology. This course is for Sophomores, Juniors, and Seniors.

67-352 Electronic Business
Intermittent: 9 units
The objective of this course is to give students a good understanding on how e-business is conducted and managed including opportunities, limitations, issues, and risks. E-business applications require certain technological infrastructures and other support mechanism in areas of business-to-consumer, business-to-business, and consumer-to-consumer. Topics will cover the technologies, skills and business concepts that surround the emergence of electronic business and the impacts of applying these information technologies to different commercial processes from both an operational and strategic perspective. The course will also explore the problems surrounding electronic business such as security, privacy, intellectual property rights, legal liabilities and global issues. The course provides a contemporary exposure to concepts and practices associated with a new and dynamic digital environment in the real business world. The information technologies associated with the delivery of Internet sites as well as internal operations will be discussed. After completion of this course, students are expected to have appropriate level of knowledge, skills, and concept of the digital operations in a modern business world.
Prerequisites: 67-272 or 67-371

67-353 IT & Environmental Sustainability
Intermittent: 6 units
Sustainable living and sustainable development are serious challenges facing individuals, communities, organizations and countries around the world. Addressing these challenges is a multidisciplinary effort. In particular, while Information and Communications Technologies have been among the most transformative developments in recent decades, they have the potential to address some of society's most urgent needs. For examples, intelligent use of IS/IT can help enable smarter cities, more efficient transportation systems, smarter energy systems, more efficient logistics and 'greener' product life cycle design. In this course, students will reflect on the challenges of sustainability and the potential role IS/IT may play in enabling adaptation and mitigation of these challenges.

67-354 Information Systems and Sustainability
Intermittent: 9 units
Environmental, economic, and societal challenges are affecting the sustainability of many communities around the globe. Given its multidisciplinary foundation, IS presents an important potential for enabling adaptation and mitigation to these challenges. IS innovation could also play a prominent role in transforming unsustainable problem spaces into sustainable and resilient systems. What is needed is sustainability minded IS professionals to lead such transformation. This course introduces students (future IS leaders) to the fundamentals of sustainability in the 21st century. It includes topics on Green IS, Smart Cities, and the Information Economy. The course invites students to proactively reflect on sustainability issues and their effects on policy and leadership. In such reflection, students are encouraged to consider various case-based scenarios where they evaluate challenges to sustainability and developed innovative, strategic, practical, and rigorously supported IS based solutions.
Prerequisite: 67-250

67-357 Healthcare Analytics and Big Data
Intermittent: 9 units
The objectives of this course are: (1) to provide a sound understanding of how healthcare analytics helps to re-engineer the complex processes that drive return on investment and lower medical costs and (2) how the big data revolution is accelerating value and innovation in healthcare. Topics in healthcare business intelligence (BI) to be covered include how data quality and data governance improve the quality of healthcare, architectural implications of BI, technology management, and how BI facilitates evidence-based medicine and effective clinical decision support. Besides gaining hands-on lab experience with BI technologies and tools used in real-world healthcare organizations, students will also work on a group project to understand better the challenges that big (and unstructured) data present to traditional clinical database systems.
Prerequisites: (70-451 or 67-250) and 15-121 and 36-201 and 67-272

67-364 Practical Data Science
Spring: 9 units
From empirical, to theoretical, to computational science, we are at the dawn of a new revolution—-a fourth paradigm of science driven by data. Like archaeological remnants, data, by its very nature, is a marker of what happened in the past. How can data be used to better understand this past and what is happening in the present? How can data be leveraged to forecast what will happen in the future? Better still, how can data be used to mold what should happen in the future? In this course we will study descriptive, predictive, and prescriptive methods by which data can be used to gain insight and inform actions of people and organizations. The real excitement of data science is in the doing. This is an application oriented course requiring skill in algorithmic problem solving. We will use Python based data science tools. While prior programming experience with Python will be helpful the course will strive to be self-contained. If you have not programmed in Python before, you need to be comfortable programming in some language (e.g., Ruby, R, Java, C++) and will need to come up to speed with the Pythonic way of problem solving.
Prerequisites: (36-201 Min. grade C or 36-200 Min. grade C) and 15-112 Min. grade C

67-373 Information Systems Consulting Project
Spring: 12 units
Information Systems (IS) Consulting Project is a junior level team-based course that focuses on working as a team to build a solution to meet the needs of a client. With your teammates, you will work with an actual client to design, build, and deliver an information system solution while following a disciplined software project life cycle approach. By term's end, your team must provide a sustainable solution that fits the client's objectives, organization constraints and capabilities
Prerequisite: 67-272

67-390 Independent Study in Information Systems
Fall and Spring
Independent studies are opportunities to engage in research with an IS faculty member to advance your learning in certain areas of interest. Information Systems students may enroll in independent study for 3, 6, 9, or 12 units of academic credit by obtaining an IS faculty sponsor who will oversee the academic component of the coursework, monitor progress, and assign a final grade.

67-391 Independent Study in Information Systems
Fall and Spring
Independent studies are opportunities to engage in research with an IS faculty member to advance your learning in certain areas of interest. Information Systems students may enroll in independent study for 3, 6, 9, 12 units of academic credit by obtaining an IS faculty sponsor who will oversee the academic component of the coursework, monitor progress, and assign a final grade.

67-440 IDeATe Mobile Application Design & Development
Spring: 9 units
TBD

67-442 Mobile Application Development in iOS
Fall: 9 units
This course provides students with the concepts and techniques to design and develop mobile applications with iOS and to understand the design and development process involved. Students will develop a series of smaller iOS applications in weekly lab sessions as well as larger application as part of a course project. In the process of developing these applications, students will develop a strong understanding of the Swift programming language, iOS application development, mobile-centered design, and how to ensure technical quality in software development. This course is open only to juniors and seniors in the IS major who have completed 67-272.
Prerequisite: 67-373

67-445 Seminar in IS: Intelligent Agents
Spring: 9 units
The purpose of this seminar is to study behavioral interactions with and perceptions of intelligent agents. This research seminar is intended for junior and senior students in Information Systems and other university departments who wish to engage in research at the intersection of Information Systems, Artificial Intelligence, and Psychology. All students are expected to have some prior knowledge in Statistics (36-201 or 36-309 or similar courses). For each topic, students will be reading, analyzing, discussing, and presenting several papers. This discussion-based course has two main objectives: 1) to facilitate in-depth discussions of current research articles and essential topics in this domain, and 2) to build and expand students' research skills through in-depth analysis of papers, critiques, presentations and discussions.
Prerequisites: 36-201 or 36-309

67-475 Innovation in Information Systems
Fall: 12 units
This course is a senior level team-based capstone experience that aims to capture the challenge and excitement of creating a solution that adds value - whether a process, product or service - and to provide students with an opportunity to experience the innovation process. In this course, we will focus on exploring various types of innovation (e.g. design thinking, blue ocean, business innovation, etc.). This course will also help you develop a new set of tools aimed at framing challenges, addressing the right problems, and thinking outside of the box to solve present and future business challenges. The purpose of this course is not merely to create a new app but to identify a real problem or business need, and to apply structured tools in order to solve the problem. To substantiate their thinking, teams will talk to stakeholders and users; observe people in their native environments; consider real physical, technical, and social constraints; and understand how to identify and resolve users' needs and pain points.
Prerequisite: 67-373

67-476 Innovation in Information Systems: Health Care
Spring: 9 units
Healthcare information systems are intended to improve patient outcomes while reducing the cost of clinical care. However, with the highest per person healthcare expenditures, the United States ranks low in healthcare quality compared to other countries. Although healthcare information systems are improving, challenges persist because information workflow, human interface design, and interoperability are not emphasized. In this course, students will learn to solve real-world healthcare information systems challenges in a team-based format. Juniors and Seniors

67-490 Practicum in Information Systems
Intermittent
This course is offered only at Carnegie Mellon's campus in Qatar. The practicum in information systems allows students interested in applying skills acquired in the field of information systems in the context of a working environment. Students will complete a project and be accountable to a stakeholder that is external to their program of study. They may shadow and observe practices in the field of information systems, and also perform tasks as assigned. A hands-on experience is expected. By completing this course, students practice desirable skills for employability, such as time management, project management, team work, and professional development.

67-509 Independent Study in Information Systems
Fall and Spring
Independent studies are opportunities to engage in research with an IS faculty member to advance your learning in certain areas of interest. Information Systems students may enroll in independent study for 3, 6, 9, or 12 units of academic credit by obtaining an IS faculty sponsor who will oversee the academic component of the coursework, monitor progress, and assign a final grade.

Institute for Politics and Strategy

Kiron K. Skinner, Director and Taube Professor
Location: Porter Hall 223E
www.cmu.edu/ips

Founded in 2015, the Institute for Politics and Strategy (https://www.cmu.edu/ips) (IPS) is a university-wide institute for research and undergraduate and graduate education in the fields of political science, international relations, national security, and grand strategy. IPS is dedicated to the study of politics through the discipline of political science with support from other social sciences. In this way, IPS carries on a respected tradition of interdisciplinary political science at Carnegie Mellon University (CMU). IPS also builds upon the university's rich heritage of applying basic science to issues of public policy.

International Relations and Politics is the flagship academic program in IPS. The name of the major signifies that those studying IRP learn about international relations and domestic politics from the standpoint of the discipline of political science. The IRP major preserves and expands CMU's tradition in political science, while at the same time, taps into and contributes to CMU's strengths in other social sciences that combine analytical and empirical methods. IRP recently launched an innovative initiative to incorporate decision science in political science. Thus, students learn to apply the burgeoning science of judgment and decision making to understanding political actors' strategies and foibles, the strengths and weaknesses of formal methods of policy analysis (i.e., cost, risk, benefit, analysis), and the factors shaping public responses to politics and policies. IRP provides a rich set of courses and programmatic offerings that have made it an attractive course of study for students from all of CMU's colleges.

Basic science is the foundation for the public policy activities of IPS. Analytical social science and interdisciplinary research and teaching are used to better understand, explain, anticipate, and solve public policy problems.

The CMU traditions of analytical political science and applied social science are reflected in the degree programs and entities that IPS supports and oversees. The academic programs included in the Institute for Politics and Strategy are:

- B.S. International Relations and Politics Major (primary and additional);
- B.S. Economics and Politics (primary and additional);
- International Relations and Politics Minor;
- Cybersecurity and International Conflict Minor;
- Politics and Public Policy Minor;
- Accelerated Master of Science in International Relations and Politics; and
- Master of Information Technology Strategy.

The Economics and Politics major is offered jointly between the Undergraduate Economics Program (UEP) and IPS. Students are equal members of both academic units and receive advising from both units. The major will appeal to any student interested in the design, evaluation, and political implementation of policy.

The IRP minor shares core courses with the IRP major. The minor in Politics and Public Policy has a greater focus on domestic politics and public policy than either the IRP major or minor. The minor in Cybersecurity and International Conflict analyzes the role of cyber warfare and cybersecurity in international politics – past, present, and future.

The Accelerated Master of Science in International Relations and Politics (IRP/AMP) (http://www.cmu.edu/ips/masters%20degrees) is open only to Carnegie Mellon undergraduate students. Students should have an undergraduate major, additional major, or minor in IPS, they should have participated in the Carnegie Mellon University Washington Semester Program, or they should have special approval from the faculty admissions committee. Current undergraduates will apply for the IRP/AMP during the junior year. The primary focus of the IRP/AMP is international security, along with coursework in political institutions.

The Master of Information Technology Strategy (MITS) (http://www.cmu.edu/mits) program provides graduate students with core interdisciplinary competencies in cybersecurity. The master's program is a joint initiative of the College of Engineering, the Institute for Politics and Strategy, and the School of Computer Science. The Institute for Software Research, a department in the School of Computer Science, is the administrative home for MITS.

IPS administers these initiatives:

- The Center for International Relations and Politics;
- The Carnegie Mellon University Washington Semester Program; and
- The Institute for Strategic Analysis.

The Center for International Relations and Politics (CIRP) is a university hub for scholarly and policy-oriented activities on domestic and international issues. CIRP (http://www.cmu.edu/ir) supports and promotes student and faculty research and hosts national and international thought leaders through its Policy Forum (https://www.cmu.edu/ir/cirp-policy-forum). The CIRP Journal (https://www.cmu.edu/ir/cirp-journal) is an opportunity for undergraduate and graduate students to publish their work in international relations and political science. Students from across campus contribute scholarly analyses of current problems facing the United States and the international system and perform interviews with the nation's thought leaders. The CIRP Journal is published in print and online format about twice per academic year.

The Carnegie Mellon University Washington Semester Program (CMU/WSP) (http://www.cmu.edu/ips/cmuwsp) is a semester-long program for undergraduates interested in taking courses and interning in Washington. The minor in Politics and Public Policy may be earned by completing CMU/WSP and taking an additional core course in the Institute for Politics and Strategy.

Founded in 2013, the Institute for Strategic Analysis (http://www.cmu.edu/isa) facilitates and supports CMU faculty members interested in bringing their scientific research to bear upon problems of national security. These problems include terrorism, artificial intelligence, cyber challenges, war avoidance, intelligence, and the intersection of energy and security. ISA facilitates strategic engagements between CMU faculty and leaders in the defense and intelligence community as they seek mutually beneficial ways to have basic research inform national security policy.

Bachelor of Science in International Relations and Politics

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Offered through the Institute for Politics and Strategy (IPS), the Bachelor of Science in International Relations and Politics (IRP) analyzes the role of politics at the national, regional, international, and transnational levels; examines political and institutional arrangements within and among these levels; and investigates the grand strategy of nation-states.

Statesmen, scholars, and policy makers often define grand strategy as the combination of diplomatic, economic, military, and political factors used by leaders to defend their respective nation-states. The IRP major investigates the way in which leaders and citizens construct grand strategy and national security policy more generally; the impact of domestic and international forces on states' security and economic policies; and the significance of alliances, coalitions, and international institutions for world politics. Although the study of grand strategy and political institutions is the flagship initiative of the major, students are also able to study the effects of culture, economics, and society on the international system through a rich set of elective courses.

Thinking systematically about international and domestic politics is the core objective of the IRP major. To this end, the major has required courses in mathematics and statistics that help to sharpen students' ability to undertake scientific analysis in the required substantive and historical courses. The major is rooted in the discipline of political science but also utilizes the interdisciplinary strengths of decision science, economics, and political history. Thus, students pursuing this major will use the analytic tools of game theory, economic and statistical analysis, qualitative analysis, rational choice theory, and theories of behavioral decision making as they study alliances, coalitions, institutions, and political strategy.

The name of the major signifies that those studying IRP learn about international relations and domestic politics from the standpoint of the discipline of political science. Also, the major taps into and contributes to CMU's strengths in other social sciences that combine analytical and empirical methods. IRP includes an innovative initiative that incorporates decision science in political science. It enables students to apply the burgeoning science of judgment and decision making to understanding political actors' strategies and foibles, the strengths and weaknesses of formal methods of policy analysis (e.g., cost, risk, benefit, analysis), and the factors shaping public responses to politics and policies.

Recognizing the influence of language and culture on politics, students are required to complete the intermediate (200) level, or its equivalent, in a modern language other than English. Advanced-level study is strongly encouraged.

Open to all Carnegie Mellon undergraduates, the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/ips/cmuwsp) allows students to study public policy and intern in Washington for one semester. Courses taken through CMU/WSP will count toward the elective sequence in politics and public policy for IRP majors.

IRP majors interested in developing their research skills are encouraged to apply for a research position with the Center for International Relations and Politics or work directly with a member of the IPS faculty. Students are also encouraged to join student organizations focused on domestic or international politics. Becoming involved in the Institute for Politics and Strategy, as well as attending lectures and events sponsored by the Center for International Relations and Politics (https://www.cmu.edu/ir) will provide additional opportunities for students. Students are also encouraged to submit their work for publication in the CIRP Journal (https://www.cmu.edu/ir/cirp-journal), an online and print publication that analyzes current problems facing the United States and the international system.

In addition to the primary major in International Relations and Politics, IPS offers an additional major. Minors in International Relations and Politics, Cybersecurity and International Conflict, and Politics and Public Policy are also available. IPS also offers a Bachelor of Science in Economics and Politics jointly with the Undergraduate Economics Program.

Double Counting: Students may double count a maximum of four courses with another major or minor.

Curriculum

Core Courses

Students must complete all of the following core courses.

84-104	Decision Processes in American Political Institutions	9
84-250	Writing for Political Science and Policy	9
84-265	Political Science Research Methods	9
84-275	Comparative Politics	9
84-326	Theories of International Relations	9
84-369	Decision Science for International Relations	9
84-450	Policy Forum	6
36-202	Statistics & Data Science Methods	9
84-110	Foundations of Political Economy	9
or 73-102	Principles of Microeconomics	

Mathematics Requirement

Excluded from all double counting rules. Students must complete one of the following courses.

21-120	Differential and Integral Calculus	10
or 21-112	Integral Calculus	

Language Requirement

Students are required to complete the intermediate (200) level or the equivalent in a modern language other than English. Advanced level study is strongly encouraged. Students who successfully pass a language placement exam on campus, at the intermediate II level or higher, are required to take an advanced language course to satisfy the language requirement.

Electives

International Relations and Politics students will fulfill the elective requirement by pursuing either **option 1** or **option 2** listed below:

Option 1: take 45 units (five courses) from the elective lists below. At least three courses (27 units) must be from the Institute for Politics and Strategy (84-xxx). Most courses listed below are 9-unit courses, but some are fewer. When courses offered for fewer than 9 units are chosen, students should note that a minimum of 45 units is required, and should plan to take one or more additional courses as appropriate.

OR

Option 2: complete the majority of their electives via the Carnegie Mellon University Washington Semester Program (CMU/WSP) politics and public policy elective sequence. Any elective units not fulfilled during CMU/WSP may be completed through coursework from the Institute for Politics and Strategy (84-xxx) elective list.

The Washington Semester Program (CMU/WSP) Politics and Public Policy sequence includes:

- Policy Forum (12 units) - This course will count as the Policy Forum (84-450) Core Course Requirement.
- Internship Seminar 84-360 CMU/WSP Internship Seminar (12 units)
- CMU/WSP Elective Seminars (24 units total)

A list of CMU/WSP elective seminars may be found in the Politics and Public Policy elective list below.

Grand Strategy and Political Institutions

66-221	Topics of Law: Introduction to Intellectual Property Law	9
79-298	Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal	6
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
80-135	Introduction to Political Philosophy	9
80-321	Causation, Law, and Social Policy	9
80-335	Social and Political Philosophy	9
84-309	Political Behavior	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-320	Domestic Politics and International Affairs	9
84-321	Autocrats and Democrats	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	6
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-363	Comparative Legal Systems	9
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-366	The American Presidency	9
84-370	Global Nuclear Politics	9
84-372	Space and National Security	9
84-373	Emerging Technologies and the Law	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6
84-405	The Future of Warfare	9
84-414	International and Subnational Security	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

Economics and Society

19-452	EPP Projects	12
70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-430	International Management	9
73-103	Principles of Macroeconomics	9
73-328	Health Economics	12
73-332	Political Economy	9
79-386	Entrepreneurs in Africa, Past, Present and Future	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-249	AI, Society, and Humanity	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
84-308	Political Economy of Latin America	9
84-310	International Political Economy	9
84-311	International Development: Theory and Praxis	9

84-312	Gender and Development in Sub-Saharan Africa	6
84-313	International Organizations and Law	9
84-315	Contemporary Debates in Human Rights	9
84-318	Politics of Developing Nations	9
88-411	Rise of the Asian Economies	9

International Cultures

76-318	Communicating in the Global Marketplace	9
76-386	Language & Culture	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-224	Mayan America	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-233	The United States and the Middle East since 1945	9
79-257	Germany and the Second World War	9
79-259	France During World War II	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-275	Introduction to Global Studies	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-291	Globalization in East African History	6
79-307	Religion and Politics in the Middle East	9
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-314	The Politics and Culture of Memory	9
79-318	Sustainable Social Change: History and Practice	9
79-320	Women, Politics, and Protest	9
79-338	History of Education in America	9
79-342	Introduction to Science and Technology Studies	9
79-343	Education, Democracy, and Civil Rights	9
79-377	Food, Culture, and Power: A History of Eating	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-385	Out of Africa: The Making of the African Diaspora	9
79-398	Documenting the 1967 Arab-Israeli War	9
85-375	Crosscultural Psychology	9
300 or 400- level language course		

CMU/WSP Politics and Public Policy

84-330	The Shading of Democracy: The Influence of Race on American Politics	6
84-331	Money, Media, and the Power of Data in Decisionmaking	6
84-332	Effects of US Policy on Businesses: Perspectives of Asian Americans	6
84-333	Power and Levers for Change in Washington, DC	12
84-334	Presidential Power in a Constitutional System	6
84-336	Implementing Public Policy: From Good Idea To Reality	12
84-337	Biomedical Science Research, Policy, and Governance	6
84-340	Making Change: How Organized Interests Work in Washington	12
84-343	Language and Power: How to Understand and Use Political Speech	6
84-346	Legal Issues in Public Administration	6
84-348	Advocacy, Policy and Practice	6

NOTE: Some courses have additional prerequisites.

SAmple four year plan

These sample curricula represent a plan for completing the requirements for the B.S. in International Relations and Politics. International Relations and Politics students are encouraged to spend a semester studying and interning in Washington, DC, through the CMU/WSP (http://www.cmu.edu/ips/cmuwsp), and/or study abroad. The plan below demonstrates that a semester off-campus fits well into the curriculum. As with most majors in the Dietrich College, the International Relations and Politics major can be completed in as few as two years of undergraduate study, not that it must be. Students may declare the B.S. in International Relations and Politics as early as the second semester of the freshman year and should consult frequently with the deputy director (see above) about their course of study.

Freshman		**Sophomore**	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	First-Year Writing (FYW)	84-326 Theories of International Relations	84-250 Writing for Political Science and Policy
79-104 Global Histories	Freshman Seminar	36-202 Statistics & Data Science Methods	84-265 Political Science Research Methods
21-120 Differential and Integral Calculus*	Language Course	Language Course	Language Course
84-104 Decision Processes in American Political Institutions **	84-110 Foundations of Political Economy	IRP Elective	IRP Elective
Language Course	84-275 Comparative Politics	Gen Ed or Elective	IRP Elective
99-101 Computing @ Carnegie Mellon			

*If required to start with 21-111 in fall of freshman year, complete 21-112 in spring of freshman year.

**This course should be taken as the first course in the International Relations and Politics major sequence. It is intended for students in the first or second year.

Junior		**Senior**	
Fall	**Spring**	**Fall**	**Spring**
84-369 Decision Science for International Relations	CMU/WSP or STUDY ABROAD*	IRP Elective	84-450 Policy Forum**
Language Course or Elective	Elective	Elective	Elective
IRP Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

*All students are strongly encouraged to participate in the CMU/WSP (http://www.cmu.edu/ips/cmuwsp) and/or in a study abroad program. Spring semester of the junior year is a popular semester to study off-campus. However, International Relations and Politics majors may instead choose to participate in the CMU/WSP or study abroad in spring of sophomore year, fall of junior year, or fall of senior year. Students should consult the deputy director when planning their curricular program.

**Students who participate in the CMU/WSP (https://www.cmu.edu/ips/cmuwsp) will complete the Policy Forum while studying in Washington, DC. Students who do not participate in the CMU/WSP will take the Policy Forum in the spring of the senior year in Pittsburgh.

Additional Major

Students who elect International Relations and Politics as an additional major must fulfill all of the requirements of the International Relations and Politics major.

Bachelor of Science in Economics and Politics

Politics and economics are deeply interconnected. Political institutions and decision-making impact economic growth, income distribution, and many other aspects of economic life. Both fiscal and monetary policies affect the economy, but these policies are often employed with political considerations in mind and can influence political activity. Conversely, economic outcomes shape political preferences and policy choices. The overlap between these two disciplines is endless. For example, while the United Nations is often thought of in purely political terms, the Security Council can and does impose sanctions on countries- an example of an economic policy used for political change.

The Economics and Politics major is offered jointly between the Undergraduate Economics Program (https://www.cmu.edu/tepper/programs/undergraduate-economics) (UEP) and the Institute for Politics and Strategy (https://www.cmu.edu/ips) (IPS). Students are equal members of both academic units and receive advising from both units. The major will appeal to any student interested in the design, evaluation, and political implementation of policy. It will be especially attractive to students considering careers in politics, government agencies, political and business consulting, lobbying, or the law.

The B.S. in Economics and Politics is an interdisciplinary major. The major will develop the political context and underpinnings of economic policy making. It will explore how political institutions resolve the tradeoffs and disagreements associated with policymaking and how they can facilitate or impede desirable economic outcomes.

IPS strengths lie in topics like national security, grand strategy, and globalization. Economic policy is just one facet of grand strategy, through which an administration pursues domestic and international goals. This major will also address key issues such as the complementarity between the multilateral economic institutions such as the IMF and World Bank and the use of economic coercion, and enable students to understand economic statecraft more broadly. Whether coercion is successful depends not just on the levers of power but on also on variations in authoritarian regime structure, and complex linkages in the international economy. This is also important for our understanding of the relationship between international economics on human rights practices, extending even to how treaty commitments can facilitate compliance with a global initiative to combat climate change. And, not least important, there is broad recognition that the viability of the “Euro Zone” depends on whether the political-economic agreements necessary to mitigate institutional weaknesses are politically feasible or destined to failure.

Economics and Politics is available as both a primary and additional major.

Curriculum

Students must earn a grade of "C" or better in all courses taken in the Department of Economics (73-xxx).

Prerequisites

Students must complete all of the following courses.

21-120	Differential and Integral Calculus	10
or 21-112	Integral Calculus	
36-200	Reasoning with Data	9

Foundations (48 units)

Students must complete all of the following courses.

21-256	Multivariate Analysis	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-275	Comparative Politics	9
73-210	Economics Colloquium I	3

Core (63 units)

Students must complete all of the following courses.

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9
84-265	Political Science Research Methods	9
84-326	Theories of International Relations	9
84-310	International Political Economy	9

Communication (9 units)

Students must complete one course from the following list.

73-270	Professional Communication for Economists	9
84-250	Writing for Political Science and Policy	9

Electives (27 units)

Majors are required to take 27 units (three courses) from the elective lists below. At least one course (9 units) must be taken from Economics (73-xxx) and at least one course (9 units) must be taken from the Institute for Politics and Strategy (84-xxx). Students may complete electives through coursework in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/ips/cmuwsp) Politics and Public Policy elective sequence.

Economics Electives

73-328	Health Economics	12
73-332	Political Economy	9
73-338	Financial Crises and Risk	9
73-352	Public Economics	9
73-353	Economic Foundations of Regulation: Applications to Financial Markets	9
73-359	Benefit-Cost Analysis	9
73-365	Firms, Market Structures, and Strategy	9
73-367	Technology Jobs and the Future of Work	9
73-372	International Money and Finance	9
73-415	Data Driven Business and Public Policy Decision Making	9
73-421	Emerging Markets	9
73-427	Sustainability, Energy, and Environmental Economcs	9

Politics and Strategy Electives

84-308	Political Economy of Latin America	9
84-309	Political Behavior	9
84-311	International Development: Theory and Praxis	9
84-313	International Organizations and Law	9
84-318	Politics of Developing Nations	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	6
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-363	Comparative Legal Systems	9
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-366	The American Presidency	9
84-369	Decision Science for International Relations	9
84-370	Global Nuclear Politics	9
84-372	Space and National Security	9
84-373	Emerging Technologies and the Law	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6
84-405	The Future of Warfare	9
84-414	International and Subnational Security	9

CMU/WSP Politics and Public Policy Electives

84-330	The Shading of Democracy: The Influence of Race on American Politics	6
84-331	Money, Media, and the Power of Data in Decisionmaking	6
84-332	Effects of US Policy on Businesses: Perspectives of Asian Americans	6
84-333	Power and Levers for Change in Washington, DC	12
84-334	Presidential Power in a Constitutional System	6
84-336	Implementing Public Policy: From Good Idea To Reality	12
84-337	Biomedical Science Research, Policy, and Governance	6
84-340	Making Change: How Organized Interests Work in Washington	12
84-343	Language and Power: How to Understand and Use Political Speech	6
84-346	Legal Issues in Public Administration	6
84-348	Advocacy, Policy and Practice	6

Additional Electives

19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-425	Sustainable Energy for the Developing World	9
70-365	International Trade and International Law	9
70-430	International Management	9
79-280	Coffee and Capitalism	9
79-318	Sustainable Social Change: History and Practice	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-321	Causation, Law, and Social Policy	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
88-366	Behavioral Economics of Poverty and Development	9
88-419	International Negotiation	9
88-444	Public Policy and Regulation	9

CAPSTONE (15-21 units)

Students must complete all of the following courses.

84-450	Policy Forum 12 units if taken during CMU/WSP, 6 units if taken in Pittsburgh	6
73-497	Senior Project or Senior Honors Thesis	9

SAMPLE Four Year Plan

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	73-210 Economics Colloquium I	73-240 Intermediate Macroeconomics
36-200 Reasoning with Data	73-103 Principles of Macroeconomics	73-230 Intermediate Microeconomics	Communication Course (84-250 or 73-270)
73-102 Principles of Microeconomics	84-275 Comparative Politics	73-265 Economics and Data Science	84-265 Political Science Research Methods
84-104 Decision Processes in American Political Institutions	Freshman Seminar	84-310 International Political Economy	73-274 Econometrics I
76-101 Interpretation and Argument	79-104 Global Histories	84-326 Theories of International Relations	Economics & Politics Elective 1
99-101 Computing @ Carnegie Mellon		Open 1	

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
Economics & Politics Elective 2	Open 5	73-497 Senior Project or Senior Honors Thesis	84-450 Policy Forum May also be taken during the CMU/WSP
Economics & Politics Elective 3	Open 6	Open 10	Open 14
Open 2	Open 7	Open 11	Open 15
Open 3	Open 8	Open 12	Open 16
Open 4	Open 9	Open 13	Open 17

Economics and Politics students are highly encouraged to participate in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/ips/cmuwsp) during the junior year. Study abroad is also encouraged.

Minor in Cybersecurity and International Conflict

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The minor in cybersecurity and international conflict analyzes the role of cyber warfare and cybersecurity in international politics—past, present, and future. Cyber attacks by nation-states and their proxies have the potential to reshape how wars are fought in the twenty-first century. As such, the complexity and policy challenge of cyber-engagements is immense and altogether without precedent. The minor addresses the role of deterrence, dissuasion, and attribution in cyber conflict, while also studying the nuances of key components of modern warfare—from the security dilemma to escalation management.

Courses in this minor focus on the existing gaps in our understanding of cybersecurity and international conflict, such as whether or not cyberspace is offense or defense dominant and which factors are most important in determining the answer to this, and other relevant questions, including how nation-states, their primary adversaries, and a bevy of nonstate actors engage online and in the virtual and information environments. Accordingly, the minor exposes students to basic technology concepts, methods of attack and defense, potential strategy and goals for cyber-engagement, and response and forensics for cyber-engagements.

Alongside conventional methods of warfare, cybersecurity has rapidly developed into a centerpiece of state's ability to project power and impose its will in order to achieve its national priorities and strategic objectives. As the United States and other emerging cyber powers craft and implement doctrine in this nascent domain, there is likely to be a rapid increase in activity, from efforts to disrupt the online activities of global terrorist networks like the Islamic State to near daily raids on foreign networks designed to cripple states' cyberweapons before they can be deployed.

In the shifting landscape of cyber capabilities, how will laws, authorities, and policies keep pace? What are the implications and consequences of actions that may be considered "short of war" by some countries but "above the threshold" of conflict by others? Will a more aggressive defensive posture with respect to cybersecurity inadvertently increase the risk of conflict with states that sponsor malicious hacking groups? What is the proper balance between offense and defense in cybersecurity and how are cyber operations best integrated into a country's overall military strategy?

Unlike other kinds of conflicts, the attribution of attacks presents significant challenges. Indeed, in many cases, it can be difficult to determine whether the attacker is a nation-state, a nonstate actor, a criminal gang, or a lone hacktivist. Investigators must combine technical and traditional methods to identify potentially responsible parties and to understand their intent. If the aggressor's identity cannot be confirmed, how can a counterattack be launched? Some attackers may seek to mount "false flag" attacks and deception, for example, that misdirect defenders to counter-attack in the wrong direction. Additionally, what are appropriate responses to attacks made on civil infrastructure and private business operations, such as in the areas of financial services, transportation, energy, entertainment, and health care? In other words, what are the appropriate rules of engagement for national systems, infrastructural systems, businesses, and individuals? When, for example, is a counterattack or a "kinetic" response permissible?

These questions have major implications for the study of war and peace. More than at any time in the past, those who seek to start war may be harder to find and their motives more difficult to discern. Many of the technical challenges posed by cyberspace activities will be addressed in the School of Computer Science's new security and privacy concentration for SCS students. The SCS program, available to non-SCS students as a minor, requires a high degree of math and quantitative training. The cybersecurity and international conflict minor proposed herein tackles the social-scientific dimensions of cybersecurity with a focus on the implications of the cyber age for modern statecraft, warfare, elections (local, state, and national), and politics, more generally.

CURRICULUM
60 units

Foundational Course

Students must take one of the following two foundational courses (9 units):

84-275	Comparative Politics	9
84-326	Theories of International Relations	9

Core Courses

Students must take all of the following core courses (24 units):

84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-405	The Future of Warfare	9

Elective Courses

Students must take three courses from the following list of elective courses (27 units). At least one course (9 units) must be taken from the Institute for Politics and Strategy and have an 84-number.

79-298	Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal	6
79-301	History of Surveillance: From the Plantation to Data Capitalism	6

79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
80-249	AI, Society, and Humanity	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-323	War and Peace in the Contemporary Middle East	9
84-325	Contemporary American Foreign Policy	9
84-370	Global Nuclear Politics	9
84-372	Space and National Security	9
84-373	Emerging Technologies and the Law	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-414	International and Subnational Security	9
17-200	Ethics and Policy Issues in Computing	9
17-303	Cryptocurrencies, Blockchains and Applications	Var.
17-331	Information Security, Privacy, and Policy	12
17-333	Privacy Policy, Law, and Technology	9
17-334	Usable Privacy and Security	9
17-702	Current Topics in Privacy Seminar	3

Students are permitted to double count a maximum of two courses between the minor in Cybersecurity and International Conflict and another major or minor.

Minor in International Relations and Politics

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The International Relations and Politics (IRP) minor analyzes the role of politics at the national, regional, international, and transnational levels; examines political and institutional arrangements within and among these levels; and investigates the grand strategy of nation-states.

Statesmen, scholars, and policy makers often define grand strategy as the combination of diplomatic, economic, military, and political factors used by leaders to defend their respective nation-states. The IRP minor investigates the way in which leaders and citizens construct grand strategy and national security policy more generally; the impact of domestic and international forces on states' security and economic policies; and the significance of alliances, coalitions, and international institutions for world politics. The study of grand strategy and political institutions is the flagship initiative of the minor.

In the tradition of Carnegie Mellon University, political science is studied and taught in an interdisciplinary manner. Utilizing the interdisciplinary strengths of the social sciences at CMU, IRP students study political phenomena through the perspectives of decision science, economics, and political history. Students pursing the minor will be asked to develop an understanding of game theory, economic and statistical analysis, qualitative analysis, rational choice theory, and theories of behavioral decision making as they study alliances, coalitions, institutions, and political strategy. Recognizing the influence of language and culture on politics and international relations, students are encouraged to study a modern language other than English.

The International Relations and Politics minor is offered through the Institute for Politics and Strategy. A maximum of two courses may double count between the minor in International Relations and Politics and another major or minor.

Curriculum

54 units

Core Courses

Students must take all three core courses (27 units):

84-104	Decision Processes in American Political Institutions	9
84-275	Comparative Politics	9
84-326	Theories of International Relations	9

Economics Requirement

Students must complete one of the following courses. Excluded from all double counting rules.

84-110	Foundations of Political Economy	9
73-102	Principles of Microeconomics	9

Electives

Students select three courses (27 units) from any of the elective sequences below. Two courses (18 units) must be taken from the Institute for Politics and Strategy and have an 84-number.

Grand Strategy and Political Institutions

66-221	Topics of Law: Introduction to Intellectual Property Law	9
79-298	Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal	6
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
80-135	Introduction to Political Philosophy	9
80-321	Causation, Law, and Social Policy	9
80-335	Social and Political Philosophy	9
84-309	Political Behavior	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-320	Domestic Politics and International Affairs	9
84-321	Autocrats and Democrats	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	6
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-363	Comparative Legal Systems	9
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-366	The American Presidency	9
84-369	Decision Science for International Relations	9
84-370	Global Nuclear Politics	9
84-372	Space and National Security	9
84-373	Emerging Technologies and the Law	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6
84-405	The Future of Warfare	9
84-414	International and Subnational Security	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

Economics and Society

19-452	EPP Projects	12
70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-430	International Management	9
73-103	Principles of Macroeconomics	9
73-328	Health Economics	12
73-332	Political Economy	9
79-386	Entrepreneurs in Africa, Past, Present and Future	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-249	AI, Society, and Humanity	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
84-308	Political Economy of Latin America	9
84-310	International Political Economy	9

84-311	International Development: Theory and Praxis	9
84-312	Gender and Development in Sub-Saharan Africa	6
84-313	International Organizations and Law	9
84-315	Contemporary Debates in Human Rights	9
84-318	Politics of Developing Nations	9
88-411	Rise of the Asian Economies	9

International Cultures

76-318	Communicating in the Global Marketplace	9
76-386	Language & Culture	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-224	Mayan America	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-233	The United States and the Middle East since 1945	9
79-257	Germany and the Second World War	9
79-259	France During World War II	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-275	Introduction to Global Studies	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-291	Globalization in East African History	6
79-307	Religion and Politics in the Middle East	9
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-314	The Politics and Culture of Memory	9
79-318	Sustainable Social Change: History and Practice	9
79-320	Women, Politics, and Protest	9
79-338	History of Education in America	9
79-342	Introduction to Science and Technology Studies	9
79-343	Education, Democracy, and Civil Rights	9
79-377	Food, Culture, and Power: A History of Eating	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-385	Out of Africa: The Making of the African Diaspora	9
79-398	Documenting the 1967 Arab-Israeli War	9
85-375	Crosscultural Psychology	9
300 or 400 level language class		

Minor in Politics and Public Policy

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Rooted in the discipline of political science, the minor in Politics and Public Policy investigates U.S. public policy issues and other matters of domestic politics while providing students hands-on and practical learning experiences. Students pursuing the Politics and Public Policy minor must participate in the Carnegie Mellon University Washington Semester Program for one semester during their undergraduate experience.

From embassy headquarters to nongovernmental organizations, think tanks to advocacy organizations, and consulting firms to media outlets, Washington, DC, is a focal point for many international and public policy activities. Open to all Carnegie Mellon undergraduates, the Carnegie Mellon University Washington Semester Program (CMU/WSP) allows students to study public policy and intern in Washington for one semester. Undergraduates from any course of study who would value firsthand policy experience are invited to apply to the Carnegie Mellon University Washington Semester Program and declare a minor in Politics and Public Policy.

In this semester-long program, students live, work, and study in Washington, DC, coming into direct contact with political, business, and community leaders and learning about the most pressing policy issues of the day.

Students earn 48 units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field of interest within Washington, DC, while taking classes taught by Carnegie Mellon faculty. The Institute for Politics and Strategy sponsors events and policy-oriented opportunities in Washington for students participating in the program to further enrich their experience and enhance their understanding of how Washington functions as a hub of international and public policy decision making.

The minor in Politics and Public Policy is offered through the Institute for Politics and Strategy. A maximum of two courses may double count between the minor in Politics and Public Policy and another major or minor.

Curriculum 57 units

Core Seminars

Students must take the following two courses while participating in the CMU/WSP (24 units):

84-360	CMU/WSP Internship Seminar	12
84-450	Policy Forum	6
84-450	Policy Forum	6

Elective Seminars

Students must take 24 units from the below list of elective seminars offered in the CMU/WSP. Offerings vary by semester. (24 units):

84-330	The Shading of Democracy: The Influence of Race on American Politics	6
84-331	Money, Media, and the Power of Data in Decisionmaking	6
84-332	Effects of US Policy on Businesses: Perspectives of Asian Americans	6
84-333	Power and Levers for Change in Washington, DC	12
84-334	Presidential Power in a Constitutional System	6
84-336	Implementing Public Policy: From Good Idea To Reality	12
84-337	Biomedical Science Research, Policy, and Governance	6
84-340	Making Change: How Organized Interests Work in Washington	12
84-343	Language and Power: How to Understand and Use Political Speech	6
84-346	Legal Issues in Public Administration	6
84-348	Advocacy, Policy and Practice	6

Foundational Course

Students select one course from the following list of courses offered at Carnegie Mellon University's Pittsburgh or Qatar campus. Students may take this course before or after participating in the CMU/WSP. (9 units):

84-104	Decision Processes in American Political Institutions	9
84-275	Comparative Politics	9
84-326	Theories of International Relations	9

Economics Requirement

Students must complete one of the following courses. Students may take this course before or after participating in the CMU/WSP. Excluded from all double counting rules.

84-110	Foundations of Political Economy	9
73-102	Principles of Microeconomics	9

Carnegie Mellon University Washington Semester Program

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From embassy headquarters to nongovernmental organizations, think tanks to advocacy organizations, and consulting firms to media outlets, Washington, DC, is a focal point for many international and public policy activities.

Undergraduates from any course of study who would value firsthand policy experience are invited to apply to the Carnegie Mellon University Washington Semester Program (CMU/WSP), sponsored by the university's Institute for Politics and Strategy. In this semester-long program, students live, work, and study in Washington, DC, coming into direct contact with political, business, and community leaders and learning about the most pressing policy issues of the day.

Students earn 48 units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field of interest within Washington, DC, while taking classes taught by Carnegie Mellon faculty. The Institute for Politics and Strategy sponsors events and policy-oriented opportunities in Washington for students participating in the program to further enrich their experience and enhance their understanding of how Washington functions as a hub of international and public policy decision making.

Students should contact the IPS deputy director for more information or to discuss how the CMU/WSP may fit into their curriculum. Students who participate in the CMU/WSP may qualify for a minor in Politics and Public Policy (https://www.cmu.edu/ips/undergraduate%20degrees/minors/minor-in-politics-and-public-policy.html).

Curriculum

All students enroll in the following core seminars (24 units).

Core Seminars		
84-360	CMU/WSP Internship Seminar	12
84-450	Policy Forum	6
84-450	Policy Forum	6

Students enroll in 24 units from the below list of elective seminars. Offerings vary by semester.

Elective Seminars		
84-330	The Shading of Democracy: The Influence of Race on American Politics	6
84-331	Money, Media, and the Power of Data in Decisionmaking	6
84-332	Effects of US Policy on Businesses: Perspectives of Asian Americans	6
84-333	Power and Levers for Change in Washington, DC	12
84-334	Presidential Power in a Constitutional System	6
84-336	Implementing Public Policy: From Good Idea To Reality	12
84-337	Biomedical Science Research, Policy, and Governance	6
84-340	Making Change: How Organized Interests Work in Washington	12
84-343	Language and Power: How to Understand and Use Political Speech	6
84-346	Legal Issues in Public Administration	6
84-348	Advocacy, Policy and Practice	6

Accelerated Master of Science in International Relations and Politics

The accelerated Master of Science in International Relations and Politics (IRP/AMP) is open only to Carnegie Mellon undergraduate students. Students should have an undergraduate major, additional major, or minor in the Institute for Politics and Strategy, they should have participated in the Carnegie Mellon University Washington Semester Program, or they should have special approval from the faculty admissions committee.

Students interested in applying for the IRP/AMP should consult with the Institute for Politics and Strategy (IPS) Deputy Director in the sophomore or junior year for details and advice on shaping undergraduate coursework to qualify for the program. Current undergraduates will apply for the IRP/AMP during the junior year. Detailed information on the IRP/AMP curriculum is available on the Institute for Politics and Strategy website (http://www.cmu.edu/ips/masters%20degrees).

Intellectual Rationale

At the end of the Cold War, there was widespread belief among democratic elites that the end of history finally had arrived. They predicted that the United States (indeed the West, if not the world) would benefit from the peace dividend resulting from the dissolution of the Soviet Union and the undisputed role of the United States as the world's predominant power. But the spread of democracy across Eastern Europe and Latin America as the Cold War ended has been met with highly unanticipated reversals. Relations among nation-states are in flux. In the twenty-first century, the United States has been engaged in continuous Middle East and South Asian wars, intense territorial disputes among the great powers (US, China, and Russia) are redefining the international landscape, civil wars routinely spill over into larger regional conflicts, and cyber warfare and terrorism intersect in deadly ways.

For the generation of students we are now teaching, war has been a constant in their lifetime. Accordingly, the primary focus of the International Relations and Politics Accelerated Master's Program (IRP/AMP) is *international security*.

Perhaps at no time since the interwar period of the twentieth century has there been so much uncertainty about what path the international system will take and how states will internally organize themselves. During this current period of uncertainty, transformation, and chaos, there is no denying President Barack Obama's dictum: The United States is the world's indispensable nation. In other words, the United States is the main nation-state actor that helps to organize and enforce norms in the anarchic international system. It is a system marked by the absence of any authority above states or any commonly agreed-upon authority for the use of force – the opposite of domestic society. Perforce, understanding domestic political institutions must be a component of the accelerated master's program.

It is important to comprehend how the political institutions of other nations function because domestic political processes of all sorts help to shape international relations. Theorists of international relations no longer contend, as they did a half century ago, that politics stops at the water's edge. International security will be the area of concentration in this accelerated master's program. Courses in political institutions also will be integral to IRP/AMP because they will enrich students' scientific understanding of political processes.

Faculty

KIRON K. SKINNER, Taube Professor of International Relations and Politics; Institute Director – Ph.D., Harvard University; Carnegie Mellon, 1999–

IGNACIO ARANA, Assistant Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2016–

COLIN P. CLARKE, Assistant Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2014–

BARUCH FISCHHOFF, Howard Heinz University Professor in the Institute for Politics and Strategy and Department of Engineering and Public Policy – Ph.D., The Hebrew University of Jerusalem; Carnegie Mellon, 1987–

Executive Committee

KIRON K. SKINNER, Taube Professor of International Relations and Politics; Institute Director – Ph.D., Harvard University; Carnegie Mellon, 1999–

KATHLEEN CARLEY, Professor – Ph.D., Harvard University; Carnegie Mellon, 1984–

BARUCH FISCHHOFF, Howard Heinz University Professor in the Institute for Politics and Strategy and Department of Engineering and Public Policy – Ph.D., The Hebrew University of Jerusalem; Carnegie Mellon, 1987–

Lecturers

MOLLY DUNIGAN, Lecturing Faculty in the Institute for Politics and Strategy – Ph.D., Cornell University; Carnegie Mellon, 2014–

GEOFFREY MCGOVERN, Lecturing Faculty in the Institute for Politics and Strategy – Ph.D., Binghamton University, J.D., Harvard University; Carnegie Mellon, 2013–

Post-Doctoral Fellows

JOHN J. CHIN, Post-Doctoral Fellow in the Institute for Politics and Strategy – Ph.D., Princeton University; Carnegie Mellon, 2016–

DANIEL HANSEN, Post-Doctoral Fellow in the Institute for Politics and Strategy – Ph.D., Michigan State University; Carnegie Mellon, 2018–

DANI NEDAL, Post-Doctoral Fellow in the Institute for Politics and Strategy – Ph.D., Georgetown University; Carnegie Mellon, 2018–

DANIEL M. SILVERMAN, Post-Doctoral Fellow in the Institute for Politics and Strategy – Ph.D., The Ohio State University; Carnegie Mellon, 2017–

Fellows

RASHALL BRACKNEY, Fellow in the Institute for Politics and Strategy – Ph.D., Robert Morris University; Carnegie Mellon, 2018–

FRED CRAWFORD, Fellow in the Institute for Politics and Strategy – J.D., Georgetown University; Carnegie Mellon, 2017–

DALE CROWELL, Fellow in the Institute for Politics and Strategy – M.A., Catholic University of America; Carnegie Mellon, 2018–

MARCIELA DEGRACE, Fellow in the Institute for Politics and Strategy – Ph.D., Harvard University; Carnegie Mellon, 2018–

JOSEPH E. DEVINE, Associate Dean of Undergraduate Studies; Fellow in the Institute for Politics and Strategy – Ph.D., Carnegie Mellon; Carnegie Mellon, 1978–

THOMAS KARAKO, Fellow in the Institute for Politics and Strategy – Ph.D., Claremont Graduate University; Carnegie Mellon, 2015–

KIM SMACZNIAK, Fellow in the Institute for Politics and Strategy – J.D., Harvard University; Carnegie Mellon, 2017–

SACHIKO TAKAYASU, Fellow in the Institute for Politics and Strategy – M.B.A., The Ohio State University; Carnegie Mellon, 2018–

BEVERLEY WHEELER, Fellow in the Institute for Politics and Strategy – D.Ed., Harvard University; Carnegie Mellon, 2012–

JULIE WILSON, Fellow in the Institute for Politics and Strategy – J.D., American University; Carnegie Mellon, 2017–

SEAN ZEIGLER, Fellow in the Institute for Politics and Strategy – Ph.D., Duke University; Carnegie Mellon, 2019–

Adjunct Faculty

SOPHIE LE BLANC – Ph.D., University of Delaware; Carnegie Mellon, 2017–

MICHELLE GRISÉ – Ph.D., Yale University, J.D.,University of Michigan; Carnegie Mellon, 2019–

MARIA MCCOLLESTER – Ph.D., Boston College; Carnegie Mellon, 2020–

FORREST E. MORGAN – Ph.D., University of Maryland; Carnegie Mellon, 2017–

ISAAC R. PORCHE III – Ph.D., University of Michigan; Carnegie Mellon, 2017–

CHAD C. SERENA – Ph.D., University of Pittsburgh; Carnegie Mellon, 2016–

SUSAN SOHLER EVERINGHAM – M.A., University of California, Los Angeles; Carnegie Mellon, 2017–

Institute for Politics and Strategy Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

84-104 Decision Processes in American Political Institutions
Fall: 9 units
This is an interdisciplinary introduction to the study of politics and government in the United States. It familiarizes the student with the basic structures and processes of American government, but moves beyond the purely descriptive into the realm of the analytical. The main theoretical tools are spatial models of political decision-making, and models of collective action problems. The position taken in this course is that understanding American philosophical ideas about authority, power, and freedom is as central to demystifying the U.S. form of democracy as is understanding how decision-making institutions function. Thus, on one side, this course looks at how American political thought is infused into political institutions and society. On the other side, it investigates institutional arrangements using rationalistic theories. In addition, scientific writings at the intersection of psychology and economics are used to probe the possibility of gaining explanatory leverage on U.S. politics from the perspective of behavioral decision-making theories.

84-110 Foundations of Political Economy
Spring: 9 units
Political Economics studies the interplay between economics and politics. Politicians, for example, may deviate from welfare-maximizing policies due to political pressures. Conversely, the economic and political consequences of policy decisions can shape the choices of future governments. The course will provide a broad, accessible introduction to the key issues in micro and macroeconomics, international economics, and financial markets, emphasizing those most valuable to understanding the interaction of politics and economics. The course will examine core economic concepts to illuminate how economies work, what constraints governments face, and what the welfare implications are of policy choices. From there, the course will expand to illustrate the political and ideological influences on monetary policy and central banking, the political factors shaping economic crises, the international factors influencing the implementation of domestic polices, and political influences on economic integration.

84-198 Research Training: Institute for Politics and Strategy
Fall and Spring
This course is part of a set of 100-level courses offered by Dietrich College departments as independent studies for second-semester freshmen, and first- or second-semester sophomores, in the College. In general, these courses are designed to give students some real research experience through work on a faculty project or lab in ways that might stimulate and nurture subsequent interest in research participation. Faculty and students devise a personal and regularized meeting and task schedule. Each Research Training course is worth 9 units, which generally means a minimum for students of about 9 work-hours per week. These courses are offered only as electives; i.e., they cannot be applied toward a college or major requirement, although the units do count toward graduation as elective units. Additional details (including a roster and descriptions of Research Training Courses available in any given semester) are available in the Academic Advisory Center. Prerequisites/ restrictions: for Dietrich College students only; only for second-semester freshmen, or first- or second-semester sophomores; minimum cumulative QPA of 3.0 (at the time of registration) required for approved entry; additional prerequisites (e.g., language proficiency) may arise out of the particular demands of the research project in question.

84-250 Writing for Political Science and Policy
Spring: 9 units
The aim of this course is to equip students with the essential skills necessary to successfully write academic research papers and theses in political science, and professional documents such as policy memos, op-eds, political speeches, briefs, and PowerPoint slides. Students thus learn fundamentals of writing for political science and public policy. Key topics include principles of rhetoric, evidence-based argumentation, citation, concision, and framing. Students also learn how to cite properly using citation management software EndNote and construct powerful tables and figures using quantitative datasets. This is a writing-intensive course in which students practice writing, edit peers' writing, read about how to write, and analyze examples of stellar writing. A final project entails writing a draft senior thesis proposal.

84-265 Political Science Research Methods
Spring: 9 units
This course provides an overview of research methods in political science. Students will learn to think like social scientists and develop skills required by the discipline. The course emphasizes the nature of causality and how causal claims can be made in the social sciences. The goal for the class is for students think critically about the strengths and weaknesses of various methodological approaches and identify the methodological tools that are most appropriate for answering different research questions. Furthermore, students will increase their ability to consume political science research from a variety of subfields while also learning to design and present their own research.
Prerequisites: 70-207 or 36-220 or 36-247 or 36-207 or 36-201 or 36-200

84-275 Comparative Politics
Spring: 9 units
This course is an introduction to the subfield of Political Science called Comparative Politics. Scholars in this subfield -comparativists- use comparative methods to study and compare domestic politics across countries. In this course, we aim to learn about how political systems differ, discuss why they differ and explore the consequences of such variation. The course is divided into four sections. In the first part, we will examine the main theories and methods used to conduct research in the subfield, and discuss the development and consolidation of the modern state. In the second section, we will examine political regimes, including variation among democracies and nondemocracies. In the third unit, we will study some of the countries' central political institutions. We will compare presidentialism to parliamentarism, and examine legislatures, electoral systems, and political parties. In the final segment, we will scrutinize political mobilization and conflict. We will discuss interest groups, nationalism, social movements, protests, populism, clientelism, revolutions, civil wars, terrorism, and globalization. Throughout the course, the discussion will focus mainly on the Americas and Europe, but not exclusively. Students will be required to apply the comparative methods discussed in the course to make in-class presentations about different countries.

84-308 Political Economy of Latin America
Spring: 9 units
For most of its history, Latin America has been home to numerous political and economic experiments. Revolutions, coups, military dictatorships, democratic and authoritarian regimes have coexisted with dramatic oscillations on economic policies regarding the size and functions of the state and the role of the market. Governments have experimented with a range of strategies to attain development, using the region as a laboratory of politico-economic theories. In this course, we will examine how the complex relationship between politics and economic policies helps us to explain the current level and range of economic development in the region. The course is divided into three main sections. The first part will focus on Latin American history from its conquest to the end of the First World War (1492-1918). The second portion will cover from the aftermath of the First World War to the end of the Cold War. The third segment will center on the macro processes that have characterized the region since 1990, with an emphasis on the existing challenges to democratic and economic consolidation. In a final paper, students will discuss how current events connect to the region¿s historical complex marriage between politics and economics. Students will be encouraged to submit their papers to the CIRP Journal (https://www.cmu.edu/ir/cirp-journal), Panoramas (http://www.panoramas.pitt.edu) or similar academic magazines.

84-309 Political Behavior
Intermittent: 9 units
The goal of this course is to understand how citizens engage with and influence the political system. This course is devoted to the study of how people behave when interacting with other citizens, politicians, and political institutions. We will primarily focus on the behavior of non-elite political actors using examples from the United States, other developed democracies, as well as developing countries. We will address questions such as what influences people to vote or abstain in an election, how people decide between candidates, how trust and cooperation develop within and across ethnic groups, and how citizens respond to political violence and terrorism. The course will integrate game theoretical perspectives with insights from psychology to help students gain a deeper understanding of the interplay between citizens' political goals and the political system in which they operate.

84-310 International Political Economy
Fall: 9 units
This course explores how political institutions, process, and actors influence economic interactions both domestically and internationally. During the semester, we will address two key questions: 1) how do governments collaborate to regulate, and stabilize, the trans-boundary flow of capital, goods, and services?; 2) what are the distributional effects of the current world economic order? In exploring these question from diverse theoretical lenses, we will discuss topics ranging from monetary and exchange rate policies, intentional trade, and global integration of production to the role of multinational corporations, social movements and civil society organizations, as well as institutions for corporate social responsibility, in the global economy. By the end of the course, students will be prepared to compare and contrast the theoretical propositions, and policy recommendations, of rival schools of thought.
Prerequisites: 73-102 or 84-110 or 12-421 or 88-220 or 73-100

84-311 International Development: Theory and Praxis
Intermittent: 9 units
What is the difference between a developed country and one that is developing? How did some countries achieve a state of development, while others remain mired in underdevelopment? What is the best solution for assisting people living in developing countries? This course will explore these key questions and many more related to theoretical foundations and daily applications of international development. Because development theory and praxis are interdisciplinary in nature, this course will take a similar approach and draws upon readings from political science, economics, history, and sociology. We will also examine the various intersections of development, gender, indigeneity, race, class, and citizenship, as they are manifest in contemporary development approaches.

84-312 Gender and Development in Sub-Saharan Africa
Intermittent: 6 units
The purpose of this course is to continue a discussion on the debates, structures, and agents that inform international development in Africa but through the varied perspectives and experiences of African women. Their perspectives offer critical interventions into development discourses and practices traditionally viewed through masculine and Western lenses. In studying development from the African woman's perspective, one is better able to engage both the successes and failures of this formal process we call "development" in Africa. By examining African women and their relationship to this process, we will also see the alternative frames of feminisms and knowledges that emerge from these realities. The core questions driving this course are: (i) what are the various development ideologies and processes that have shaped contemporary Africa? (ii) How have African women adopted, rejected, and/or creolized these ideologies and processes for the purposes of changing their cultural, political, and economic conditions? The course readings come predominantly from African women, although there are texts from non-African women and men that generally serve to highlight the larger discourses taking place around a particular topic.

84-313 International Organizations and Law
Spring: 9 units
This course will take a comprehensive view on the role and function of both international organizations (IOs) and international law (IL) in world politics, and will examine its implications for both international political economy as well as security studies. It will begin with a review of classical theoretical debates regarding the function of these institutions. Do these institutions have any exogenous impact on world affairs? Do IOs meaningfully impact international cooperation? Further, it will engage with headline contemporary issues: can a non-binding international treaty such as the Paris Climate Accord meaningfully influence international climate goals? The course thus critically examines whether these institutions are effective and, if so, under what plausible conditions. It will examine a broad range of global institutions and will examine international security elements, such as how IOs and IL influence the conduct of war, human rights and civil conflict outcomes. But it will also engage with important themes in political economy, such as how institutions like the IMF relate to development or financial stability; compliance under the WTO; and whether international treaties influence international investments patterns.
Prerequisites: 36-200 or 36-201

84-315 Contemporary Debates in Human Rights
Intermittent: 9 units
What are human rights? Are human rights universal or provincial? This class will survey the origins, debates, and application of human rights around the world. As a class, we will explore the history of the term and the evolution of human rights as a set of formal and informal institutions derived from the global aspirations of the Universal Declaration of Human Rights (UDHR) and the quotidian interactions between the powerful and ostensibly powerless. By the end of this course, you should come away with both a renewed and wavering belief in the idea of human rights.

84-318 Politics of Developing Nations
Fall: 9 units
Be it on our feet, in our grocery bags or in the news, our daily lives connect us to people in the developing world. Despite such an intricate relationship, we tend to know very little about developing nations and their challenges beyond a common stereotype of poverty. What are developing nations? What is their place in the world? What challenges do those nations and their populations face? In this class, we will strive to answer those questions through readings of political science and political economy scholarship and in-class activities and discussions. We will explore the socio-economic and political issues that developing nations face and take special care to practice perspective taking (i.e. we will put ourselves in specific nations' shoes and consider situations from their point of view). We will adopt various lenses (e.g. post colonialism, liberalism, feminism) throughout the semester to inform our understanding of the various positions taken by global actors. By addressing the unequal power balance between developed and developing nations as well as among developing nations, we will enrich our world view and understanding of major global issues, such as development. We will practice those skills in class through discussions and activities (you should expect very little lecturing) and outside of class through guided readings. Your learning in the course will be assessed through various writing assignments (take home exams, a final paper, weekly responses) where you will practice composing arguments based on evidence.

84-319 U.S. Foreign Policy and Interventions in World Affairs
Intermittent: 9 units
This course will discuss the various ways in which the United States, like other countries around the world, tries to influence developments within other states by intervening in their domestic affairs. Interventions of various kinds, utilizing numerous tools, are frequently undertaken by the United States with major effects on the intervened country and subsequent U.S. foreign policy. The goal of this course is to provide a better understanding of such interventions in general and a more complete picture of this frequently neglected aspect of American foreign policy in particular. Accordingly this course will focus on explaining, among other things, why interventions of various types are done, their effectiveness in achieving their goals and their effects on the target and (occasionally) on the U.S.. It will also discuss in depth various historical cases of American interventions ranging from the early 20th century to the present, widening the depth and breadth of student knowledge on American foreign policy. The course will cover both military and non-military forms of interventions including (for example): Military interventions in civil wars, FIRCs/regime change operations (both the overt and covert types), humanitarian interventions, partisan electoral interventions, economic sanctions, external help in state-building, and drone warfare.

84-320 Domestic Politics and International Affairs
Intermittent: 9 units
This course will provide students with a broad overview of the literature which investigates the effects of political institutions, or, more specifically, the inclusiveness of political institutions, on both domestic and foreign policies. Domestic political institutions influence policies through shaping policymakers' incentives, and, in turn, outcomes of domestic and international affairs influence the political survival of policymakers and even of political institutions. With this in mind, our main objective is to develop students' ability to critically and logically analyze global patterns of governance, conflict, and cooperation. To this end, students will also be introduced to fundamentals of research design and game theory, an analytical tool to analyze strategic interactions. The substantive questions we will ask include, but not limited to, the following: how does domestic politics constrain or encourage state leaders to go to war, sign trade pacts, and develop economy?; how can citizens incentivize policymakers to achieve desirable policy goals?; how do international affairs affect our lives in the long run?; and do certain foreign policies affect citizens of democracies and non-democracies differently, and if so, why?

84-321 Autocrats and Democrats
Intermittent: 9 units
The international system is populated by countries with many different types of national governments. A common simplification of the many diverse political systems in the world is to divide them into democratic states and non-democratic states or "autocracies." This simplification misses many key differences among autocracies and causes us to overlook key similarities between autocracies and democracies. This course will cover three major areas. First, we will evaluate the strategic incentives faced by all leaders and discuss how these incentives differ by regime type. Second, we will discuss how leader responses to these incentives shape policy outcomes such as economic growth. Third, we will examine the factors that promote transitions from one regime type to another. Throughout the course, students will be asked to re-consider much of what they've thought about both democratic and non-democratic leaders. Class assignments will ask students to critically examine existing theories of political organization and apply their knowledge to real world cases, both historical and contemporary.

84-322 Nonviolent Conflict and Revolution
Spring: 9 units
Conflict and revolution are usually associated with armed struggle and violence. But over the course of the last century, nonviolent conflict has become an increasingly prominent source of institutional change and political revolution around the world, from Gandhi's salt march to Filipino "people power" to the post-Soviet "color revolutions" to the Arab Spring. What are the causes, strategies, tactics, dynamics, and consequences of nonviolent conflict, and how do these differ from violent or armed conflict? When and how do unarmed "people power" campaigns topple repressive authoritarian regimes? This course addresses these questions and in the process engages contending theories of power, revolution, and insurgency. The first half of the course introduces students to key concepts, theories, and historical patterns of nonviolent conflict. In the second half of the course, the class analyzes case studies of landmark nonviolent campaigns, both successful and failed. By the end, students will be expected to write an original 10 page analysis of an historical or ongoing nonviolent conflict.

84-323 War and Peace in the Contemporary Middle East
Spring: 9 units
This course examines the drivers of war and peace in the contemporary Middle East and North Africa (MENA) region. The course is structured around five major types of armed conflict that plague the region today - civil wars, insurgent and terrorist campaigns, enduring rivalries, regional disputes, and external interventions. We will delve into the theories of what fuels - and what resolves - each of these types of conflict, while exploring cases around the region such as the disputes in Libya, Syria, Yemen, Iraq, and Turkey, as well as broader clashes like the Arab Israeli conflict, Shi'a-Sunni conflict, and recent great power interventions in the region. The course will rely on a mixture of research articles and books as well as more diverse materials such as war reporting, films, and memoirs in order to give students a holistic understanding of these issues.

84-324 The Future of Democracy
Intermittent: 6 units
After the Cold War, Francis Fukuyama famously argued that humanity had reached the "end of history" insofar as liberal democracy had become the last viable form of government. Yet today, illiberal democracies and dictatorships persist and the world has witnessed the return of authoritarian great powers led by China and Russia. What is the future of democracy globally? How strong and secure are autocratic regimes from Iran to North Korea? Do populist movements in the United States and Europe really put democracy in the heart of the "democratic west" at risk? This course surveys the historical rise of democracy, the domestic and international causes of democratization and democratic consolidation, the rise and fall of democracy promotion, and the impact of democratic and autocratic major powers on the spread of democracy worldwide. By the end, students will be expected to write an intelligence memo on democratic prospects in a specific country or region or a policy memo with a proposal to reform democracy promotion.

84-325 Contemporary American Foreign Policy
Spring: 9 units
This course provides a survey of American foreign policy since World War I. We will cover topics such as America's entry into the Great War, the League of Nations and America's role in global self-determination movements, the perennial battles between isolationism and internationalism, the creation of a US-led world order after 1945, Cold War nuclear strategy and nuclear nonproliferation, the modern domestic politics of foreign policy, the international dimensions of the civil rights movement, US covert action, the challenges of managing unipolarity, and contemporary issues of climate change, humanitarian intervention, terrorism, and international economic policy. This is an interdisciplinary course that marries International Relations and Political Science with American, Diplomatic and Military History. We will make ample use of primary sources and some data analysis. A good grasp of 20th century American and World History, and some familiarity with International Relations Theory are not requirements but will prove helpful. By the end of the semester, students will have the requisite historical background and analytical toolkit to analyze and evaluate contemporary foreign-policy decision-making.

84-326 Theories of International Relations
Fall: 9 units
This course focuses on teaching the main approaches for the study of international relations. Although you will learn about some current international issues and about the evolution of international relations, and see how various theories would explain important past international events, the focus of this course is analytic rather than substantive. In other words, it will focus on general arguments and their underlying logic rather than on specific events and details or, for that matter, definitive answers as to 'which side is right'. As such, this course will help you to better understand the world we live in and provide you with tools for analyzing various international events. It will also acquaint you with many of the frameworks frequently used by statesmen, either implicitly or explicitly, in order to understand the world and to make policy on various issue areas. The course will begin by analyzing approaches from the three main levels of analysis: the individual, domestic (liberal and non-liberal theories) and systemic (neorealism, etc.). It will move on to discuss approaches which focus on, for example, the effects of strategic interactions between states, of international institutions and of norms and of the overall 'social environment' that states live in. The course will then conclude by discussing the future of international relations.

84-330 The Shading of Democracy: The Influence of Race on American Politics
Intermittent: 6 units
This course will explore intersections of race, political influence and the shaping of America's democracy. Discourse will focus on racial and ethnicity-related policies, practices and processes designed to influence democratic outcomes. Students will examine complex, and often pivotal occurrences that have transformed the political landscape through the works of Richard Rorty, Achieving Our Country: Leftist Thought in Twentieth-Century America; Michelle Alexander, The New Jim Crow: Mass Incarceration in the Age of Colorblindness; and, Steve Phillips, Brown Is the New White: How the Demographic Revolution Has Created a New American Majority. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-331 Money, Media, and the Power of Data in Decisionmaking
Intermittent: 6 units
This course focuses on the impact of three critical influences on policy and decisionmaking in Washington D.C.: money, in the form of political campaign dollars in particular; media, from national to local; and data that can define the policy problem and solution. The course will dive into each topic through a series of case studies of policies whose successful adoption and implementation hinged upon money, media or data. Students will come away from the course with the background and context to critically consider tough questions about the right role of these powerful influences on national policy. (Is the media "broken?" ; What is the prospect for moderating the impact of money on policy? ; Is the influence of data and facts on the wane in a hyper partisan political context?) THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-332 Effects of US Policy on Businesses: Perspectives of Asian Americans
Intermittent: 6 units
This course explores the effects of policy, advocacy, and government on the U.S. business sector, specifically from the perspective of Americans of Asian heritage and various kinds of business entities (corporations, start-ups, small business, etc.). Each student or small group of students will be assigned a particular kind of business entity and a designated Asian heritage, and the class would work through select policies, exploring how they affect the different enterprises and Asian Americans. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-333 Power and Levers for Change in Washington, DC
Intermittent: 12 units
Political and policy change often appears to sweep in at the direction of high-profile, centralized decision makers. The path to change is in truth a longer tale, driven by a diversity of actors and influencers. This course aims to more fully map out the diversity of levers that drive change in federal policymaking and implementation, examining key influences such as Congress, money, media, social movements, rhetoric and data. The course aims to give students a fuller picture of how their own particular strengths and interests are valuable to creating change, through seminar dialogue, guest speakers, and reflections on students' internship organizational structures. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-334 Presidential Power in a Constitutional System
Intermittent: 6 units
The United States Constitution vests the executive power in a president who is sworn to faithfully execute the laws and to defend the Constitution. What this means was disputed in the Pacificus-Helvidius debate in 1793, and continues to be debated in our present circumstances. This course will examine how the constitutional framework and political forces shape presidential behavior, and how they are affected by it. Special attention will be given to executive orders, signing statements, appointments and removals, and other means presidents use to accomplish their goals in a system of separated powers and a large administrative bureaucracy. Class visitors will include individuals who have written orders, shepherded nominations through Congress, argued for or against presidential actions in federal courts, worked on presidential transition teams, covered the presidency for the press, and more. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-336 Implementing Public Policy: From Good Idea To Reality
Spring: 12 units
Good public policy doesn't just "happen." Rather, successful policy is the result of thorough research, careful drafting, and successful navigation within the government or non-government organization whose leadership may ultimately promulgate it. The course begins with a brief review of government and organizational behavior in a bureaucracy, and the identification of a federal agency's current policy system as a framework to which we will turn throughout the term. Study then turns to an overview of legal research skills. Though usually the province of law students and attorneys, such skills will enable students to know when policy may be crafted "from scratch" — or where, when, and how policy must conform to larger governing legal or regulatory structures. Students will then consider a particular sub-specie of public policy, administrative law, which addresses the special circumstance of regulatory agencies and the statutory regimes that create and govern them. The course culminates with students developing and "staffing" a notional policy, modeled on the federal agency policy system studied throughout the term. This course may benefit a range of audiences: students considering government and related policy careers; future business leaders who must set standards for business practices, employee behavior, or operations within the confines of governmental regulations; prospective paralegals and attorneys; or anyone interested in exploring "what the rules are" and why. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-337 Biomedical Science Research, Policy, and Governance
Intermittent: 6 units
This course is designed for those with science backgrounds or an interest in science to explore how the biomedical sciences intersect with policy and governance on a national and international scale. Biomedical research, in addition to contributing fundamental scientific knowledge, can lead to improvements in health, reduced illness, and have the secondary impact of job creation and other economic benefits. The course will explore how the US funds biomedical science, how Congress and government agencies implement science policies, and the policy implications of new scientific fields using biomedical research topics such as emerging infectious disease, genomics, stem cell research, etc. By the end of the course, the students will be able to understand the process of policy implementation in the US government and consider the effects of policy on biomedical science. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-340 Making Change: How Organized Interests Work in Washington
Fall: 12 units
American politics has many elements and founding principles. Among them is the right of individuals- alone or in groups- to assemble and petition the government in pursuit of their interests and beliefs. This class will highlight the intersection between pressure groups, politics, and policy in Washington, DC. More specifically -based in the political science and other academic literature- the class will examine how organized interests engage and try to influence elected and public officials as they make decisions and take actions related to the nation's political and policy agenda. The class will also interact with Washington-based advocacy and lobbying organizations to see how those ideas are applied in real life scenarios. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-343 Language and Power: How to Understand and Use Political Speech
Intermittent: 6 units
Political writing is a subspecies of language with several manifestations. There is an art to the op-ed and to the editorial, to the polemical essay and to the review. Within government, there are skills particular to writing speeches and ghosting essays, preparing Congressional testimony and Federal commission reports, and to drafting policy memoranda. There are even special forms and qualities of expression for hosting award and memorial ceremonies, and for writing thank-you notes, toasts, and letters of condolence. This course is designed to teach an appreciation for the range and nature of political writing and speech in both its public and governmental forms. It also introduces students to the fundamental skills required to do effective political writing. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-346 Legal Issues in Public Administration
Intermittent: 6 units
Part I of the course will focus on legal issues in public administration and cover the relationship between the government and its employees, including the role of labor unions and collective bargaining in the federal sector. Part II will cover official immunity for government officials, "equal protection of the law" and substantive due process. Part III will cover separation of powers, federalism and judicial review of agency action. Reading assignments will include short excerpts from relevant books/periodicals. Students will also be asked to read court opinions. Although these opinions may be filled with legal jargon, at their essence, most concern the tension between individual rights and government efficiency and control. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-348 Advocacy, Policy and Practice
Intermittent: 6 units
This course examines the role that advocacy and advocacy organizations play at all stages of the policymaking and implementation process, from grassroots to professional advocacy organizations, public facing communications initiatives to internal policy-focused actions. Part of the course will focus on the history of advocacy in policy making, and case studies will be used to explore the players, outcomes, and influences of advocates when designing and implementing policy. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-360 CMU/WSP Internship Seminar
Fall and Spring: 12 units
The internship is the experiential "core" of the Washington Semester Program. Students intern three days per week, for approximately 24-25 hours, in offices from Capitol Hill to the White House and including opportunities in cabinet agencies, nonprofit institutions, museums, advocacy groups, policy think tanks, cultural institutions, and news organizations. Through the internship, students gain professional experience and make long-lasting professional and personal contacts. In addition, students meet once a week with the CMU internship faculty for a 2-hour seminar to report and reflect on their internship experiences, and address pressing current issues from the perspective of their internship organization. In addition, the weekly seminar typically includes 1-2 CMU alumni from the Washington, DC, area. Their personal and professional experiences become part of the seminar conversation, and they make themselves available to students as ongoing sources of information and advice. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-362 Diplomacy and Statecraft
Fall: 9 units
Diplomacy and statecraft are the driving forces behind foreign policy and international politics. The class first surveys the evolution of great power politics from the Peace of Westphalia to today and examines the history and practice of different types of statecraft, including coercive diplomacy, crisis management, and economic statecraft (e.g. trade, foreign aid, financial bailouts, and exchange rate policy). The class then surveys contemporary diplomatic challenges, including challenges posed by human trafficking, global climate change, nuclear proliferation, democracy promotion, and major powers such as Russia and China. Both in the classroom and in writing, students are encouraged to think, act, and write like diplomats and to appreciate diplomacy as a vocation. Throughout the course, students build skills in foreign policy memo writing, participate in various diplomatic role-playing simulations, and connect diplomatic trend lines with today's international headlines.

84-363 Comparative Legal Systems
Intermittent: 9 units
This course carries out a comparative study of the nature of courts and law, their position in political systems and the role of judges as political actors, and the potential of legal political institutions to impact society. The course is very theoretical and is organized around key themes and concepts, rather than historical detail on countries. We will examine the political and regime logic behind the origin of judicial power, competing theories about judicial decision making, the meaning and significance of judicial independence, and the potential effectiveness of courts as tools for social and political change.

84-364 Comparative Presidential Behavior: Leadership, Personality, and Decision Making
Fall: 9 units
Presidents receive universal attention for good reasons. As the most powerful politicians in the 49 countries that they govern, their behavior and decisions have enormous consequences. Given the vast amounts of energy dedicated to understanding presidents, one would expect that many questions about presidential behavior and performance have been answered. However, there is still little understanding of how presidents matter. In this course we address the pressing question of how presidents matter from a multidisciplinary and comparative perspective. We will mainly incorporate insights from political science and psychology, but also from other disciplines that study leadership (e.g., management and history).
In the first section we will discuss the comparative history, evolution, and characteristics of the presidency, examining cross-country variation of presidential powers and roles. In the second part, we will discuss theories that have addressed the role of political leaders from different disciplines and methodological approaches. In the third (and main) section, we will study the personal presidency, or how the unique background of the leaders and their personality traits are related to relevant political outcomes. In the last section, we will examine how the broader social, political, and economic context explains presidential behavior and performance.

84-366 The American Presidency
Spring: 9 units
The person elected president of the United States immediately assumes many formal and informal roles including, but not limited to, head of the Executive Branch, diplomat-in-chief, commander-in-chief, leader of party, and legislator-in-chief. Yet the president must fulfill these roles within the confines of a three-branch government and the limitations of power placed upon the office; a literal catch-22. This course therefore seeks to understand how the presidency developed to acquire its many different roles, and how the holders of the office must maneuver the intricacies and challenges of the U.S. government to influence policy and effect change. The first part of the course will study the development of the presidency from 1789 to present, interweaving the roles and responsibilities of the office as they formed and morphed throughout the course of history. The second part will survey different areas of public policy to see how the presidency has played a role in those areas through the examination of relevant cases. The course will provide students with a deep understanding of the presidency, helping them to appreciate the inherent challenges and opportunities faced by those who dare to hold the office.

84-369 Decision Science for International Relations
Fall: 9 units
Decision Science looks at choices from three interrelated perspectives: analysis, characterizing decision makers' options, in terms of expected effects on outcomes that they value; description, characterizing decision makers' beliefs and preferences; and interventions, helping decision makers to choose among the options available to them or create better ones.
The course integrates foundational research in Decision Science with applications to international relations and politics.
Prerequisites: 36-200 or 36-201

84-370 Global Nuclear Politics
Fall: 9 units
The taming of the atom is one of the defining features of the modern era. The awesome creative and destructive potential of nuclear energy has had enormous impact on great power politics, the environment, economic development, and international institutions. Limiting the risk of nuclear Armageddon is one of the dominant challenges in US foreign policy and global governance alike. In this course, we will study 1) why and how countries pursue nuclear weapons and what happens when they acquire them; 2) the national policies and international regimes that have been devised to curb their spread and use, while allowing for the diffusion of energy technology, 3) the national and transnational civil society movements that have fought to roll back the nuclear age or limit its harmful effects, and 4) the role of private actors such as scientists and corporations.

84-372 Space and National Security
Spring: 9 units
Space systems contribute a great deal to America's security, prosperity, and quality of life. This course examines how space-based services provide critical support to military and intelligence operations and contribute to national security more broadly. The course is designed to investigate several interrelated themes, weaving together relevant aspects of technology, strategy, and policy. The material is approached from both functional and historical perspectives, beginning with the basics of military and intelligence space operations and ending with an examination of the space- and cyber-related technical, strategic, and political challenges facing the nation today and in the foreseeable future.

84-373 Emerging Technologies and the Law
Spring: 9 units
This course provides a forum for students to consider the relationship between key emerging technologies and the law. In the first half of the course, each session will be dedicated to discussing the legal implications of a particular emerging technology, including autonomous vehicles, artificial intelligence, cryptocurrency and blockchain technology, stem cell therapy, quantum computing, and 3D printing. In the second half of the course, we will turn to overarching themes at the intersection of law and technology, including emerging technologies and the law of armed conflict, policing and surveillance, intellectual property, and privacy. Throughout the course, students will be asked to consider whether existing legal frameworks are sufficient to address issues related to emerging technologies.

84-380 Grand Strategy in the United States
Fall: 9 units
This course introduces students to the concept of grand strategy in the United States, broadly defined as the combination of diplomatic, economic, military, and political factors used by American presidents and their administrations to advance U.S. interests throughout the world. In the context of highly interdependent domestic and international politics, leaders must develop strategies that address a diverse range of internal, state, and non-state challenges while also dealing with the myriad challenges resulting from globalization, or the intersection of international politics, culture, markets, and technology. This course will review American diplomatic history over the ages, with a focus on both Cold War and post- Cold War American presidencies and their respective approaches to defending American national security whilst also playing a role as one of the world's leading powers. The course will conclude with an assessment of American grand strategy over the course of the past decade and how the United States manages relations with rising powers like China, revanchist states like Russia, and host of near-peer and other adversaries, including Iran and North Korea.

84-386 The Privatization of Force
Intermittent: 9 units
This course considers different forms of privatized force and security over time and across various strategic contexts, from historical mercenarism up to modern-day private military and security contractors. While going through the historical and modern material chronologically, the course considers the various issues that arise with each form of privatized force, including questions that arise regarding the state's monopoly on violence, legal and humanitarian issues, and civil-military relations. These range from theoretical concerns regarding modern definitions of the state, to practical operational-level concerns pertaining to field coordination issues between the military and private contractors in modern conflicts.

84-387 Technology and Policy of Cyber War
Spring: 9 units
This course examines underlying and emerging technologies and policies associated with cyber war and cyber threats. The technological concepts reviewed in this course include but are not limited to the internet, networks and sensors, and trends associated with "hyperconnectivity" (e.g., The Internet of Things). The course will review history, international policy, military doctrine, and lessons learned from the use of cyber operations and cyberspace in conflicts. The principle objective of this course is to introduce students to the technological and policy variables that affect the ability to manage cyber conflicts.

84-388 Concepts of War and Cyber War
Fall: 6 units
This course examines traditional theories, concepts, and practices in international relations and warfare- conventional, unconventional, and modern- and relates them to the emerging dynamics of cyber war. The principle concepts examined in this course reflect, have shaped, and continue to shape state and non-state actor behaviors and their calculations of how to prepare for and prosecute warfare. These include, among others, conventional and nuclear deterrence, offense-defense dynamics, first strike capabilities, and irregular warfare. The course will focus on theory but will leverage history, military doctrine, and cases to highlight the challenges of integrating cyber war into defense planning and practice. Students will be challenged to consider how the 2009 introduction of cyberspace as a warfighting domain- in addition to land, maritime, air, and space- affects the ways that scholars and practitioners- operating with force structures and strategic, operational, and tactical concepts that are decades, if not centuries old- conceive of and practice warfare in the 21st Century. The principle objective of this course is to introduce students to cyber war within the context of traditional, and emerging, concepts of armed and unarmed warfare. This course will focus on two core areas: 1) a discussion of traditional concepts of warfare in the physical domains; and, 2) a discussion of cyber war and its intersection with these traditional concepts.

84-389 Terrorism and Insurgency
Spring: 9 units
There are many forms of political violence but not all are created equal. Some, like terrorism, are a tactic while others, like insurgency, are a strategy. How important is it to define terrorism and insurgency? What are the differences and similarities between them? This course will go into depth to analyze both terrorism and insurgency and their various manifestations. The course will provide a historical overview of how terrorism and insurgency have evolved over time, while also focusing on groups, methods, ideologies and organizational structures. Is the terrorism conducted by Salafist groups like Al-Qaida and the Islamic State significantly different than that perpetrated by ethno-nationalist groups like the Provisional Irish Republican Army and Tamil Tigers? What are the best methods to counter-terrorism and how successful have states been- both historically and more recently- at combating the threat posed by terrorism and insurgency?

84-390 Social Media, Technology, and Conflict
Spring: 9 units
This course will examine the role that social media and technology have had on conflict and governance over the past decade. Interconnectedness has expanded dramatically and continues to expand, not only within coastal cities but also between them and their hinterlands, from city to city, and between home populations and global networks, including diaspora populations. The Arab Spring uprisings were significantly influenced by the use of cell phones, social media, and text-messaging as organizing tools. But it is not only protesters that are harnessing the power of social media and emerging technologies- insurgent groups like the Islamic State have been able to use Twitter, YouTube, Telegram and other social media platforms to their advantage. Apps have been used to both recruit and fund raise for terrorist groups, while individuals living on the other side of the world are radicalized by virulent ideologies spread through the Internet. The proliferation of so-called "fake news" and the ubiquity of social media has introduced an entirely new variable into the study of conflict and relations between individuals, small groups, non-state actors, and nation-states.

84-393 Legislative Decision Making: US Congress
Spring: 6 units
This course analyzes decision-making by the United States Congress. The course examines legislative behavior by focusing on the way Congress is organized (institutional and constitutional structure) and the ways legislators, voters, and various other parties interact (strategic constraints). Students will both learn the legislative process and explore the influence of norms, rules, expectations, incentives and, perhaps most important of all, the power of the electorate in influencing legislative outcomes and policy. Elections, voting decisions, committee assignments, political party power, and intra-branch relations across the Federal government are some of the topics into which we will delve. This course does not require any prior knowledge of the U.S. Congress, and there are no prerequisites for the course.

84-402 Judicial Politics and Behavior
Intermittent: 6 units
This course is a survey of research and insight into one of the most unique American government institutions: the judiciary. Rather than exclusively reading case law (as one would do in a Constitutional Law class), this course examines court structure, rules of law and, most importantly, judges as actors within an institutional setting. We will focus on how rules, norms, and expectations guide the decisions, actions, and range of options available to judges. Here we will study the nature of judicial decision-making and its antecedents, the organization of the judicial branch and its implications for behavior, and the strategic interactions both within courts and between the courts and the more "political" branches of government. The course will look at state and federal courts within the United States, supplemented with examples from international jurisdictions. Material from law, history, economics, political science, sociology, and psychology will be introduced throughout the semester. Although some of the literature uses empirical and/or game theoretical models, students are not expected to have mastered these tools prior to taking the course.

84-405 The Future of Warfare
Fall: 9 units
Warfare is constantly evolving. Long gone are the days of set-piece battles involving conventional military forces. In the contemporary conflict environment, hybrid actors and proxy groups wage war in an asymmetric and irregular manner, relying on ambiguity, strategic surprise and deception to accomplish their objectives. This course will examine new trends in warfare, from the onset of cyber war to the development of violent non-state actors with conventional military capabilities. Moreover, this course will explore the concept of the "gray zone," an area of neither declared nor undeclared hostilities where U.S. adversaries like Russia, China, Iran and others are gradually allocating resources. Case studies examined in this course will include Russian hybrid warfare in Crimea and Ukraine, Chinese cyberwarfare and information operations, Iranian sponsorship of proxy militias in Syria and Lebanon and a range of other emerging trends in areas such as technology, demographics, urbanization and social media, all of which are combining to radically alter the way wars are fought today.

84-414 International and Subnational Security
Intermittent: 9 units
Why do states fight wars? Why do some wars last for years while others end in days? How is it possible that powerful states may lose wars to under-resourced non-state actors? Why are some peace settlements stable, while other ceasefires crumble precipitously? Why do some states get challenged by subnational groups? By surveying the most recent quantitative research in political science, this course explores various security challenges that contemporary states face at the international level and in the intrastate political environment. We will focus in depth on the bargaining explanations for war, democratic/regime similarity/capitalist peace, deterrence, interdependence through trade, cooperation through international organizations, and civil wars. The goal of this course is to demonstrate how theoretical and empirical approaches in social sciences can be used to answer questions about war and peace. Students will acquire training in graphical literacy as well.

84-450 Policy Forum
Fall and Spring: 6 units
The Policy Forum course takes a critical look at decision making in domestic politics and US foreign policy. It does so through weekly roundtable discussions with a diverse set of thought leaders. Based on intellectually significant essays that students are expected to read in advance of each class, these discussions give students an opportunity to ask probing questions about the three branches of the US government, media, embassies, advocacy groups, international organizations, and nongovernmental organizations. This course seeks to help students understand the responsibilities and activities that leaders and decision makers carry out on behalf of their organizations. Students are instructed in how to confidently and respectfully ask critical questions of those shaping policy. The term "roundtabling" is used to describe submitting an issue for critical discussion among relevant stakeholders. Knowing how to direct a roundtable is a significant element in the professional development of anyone interested in taking part in the policy arena, and this course helps students hone this important skill. In requiring students to read important essays related to each class session and then step back from discussions with leaders to write analytical essays, this course teaches students how to develop strong arguments based on solid logic and credible evidence, an essential component in making democracy work.

84-498 Undergraduate Research
Fall and Spring
Students conduct research under the supervision of an Institute for Politics and Strategy faculty member. Students who wish to engage in research should seek out a faculty member whose interests are appropriate to the research. Prerequisite: Students must also complete an "Independent Study/Research for Credit" form, available from the Deputy Director or on the IPS website. Permission of a faculty sponsor.

84-499 Independent Study
Fall and Spring
Students conduct independent academic study under the supervision of an Institute for Politics and Strategy faculty member. Students who wish to engage in an independent study should seek out a faculty member whose interests are appropriate to the topic. Students must also complete an "Independent Study/Research for Credit" form, available from the Deputy Director or on the IPS website. Prerequisite: Permission of a faculty sponsor.

84-505 Undergraduate Internship
Fall and Spring
An internship is an approved and monitored work experience than can be related to an academic field of study through active reflection and specific learning goals. Students will be in regular contact with a faculty member in the Institute for Politics and Strategy, who will assign and evaluate academic work. Internships are available for 3, 6, or 9 units, depending on the type and amount of academic work produced. Students are responsible for finding their own internships and faculty sponsors, although assistance is available through the Deputy Director.

Department of Modern Languages

Susan G. Polansky, Department Head

Bonnie L. Youngs, Director of Undergraduate Studies

Location: Baker Hall 160
www.cmu.edu/dietrich/modlang

Studying foreign languages and their cultures is desirable and essential for understanding our complex global world. It is crucial to educate global citizens who will be sensitive to other cultures and capable of communicating in other languages. Proficiency in a foreign language by itself, or combined with other professional training, may lead to a variety of rewarding careers. Moreover, the personal experience of mastering another language is enriching and gratifying.

Modern Languages Majors

These majors are designed to lead to acquisition of communicative language proficiency and substantive knowledge of other cultures.

Drawing on the unique interdisciplinary climate of the Carnegie Mellon campus, the undergraduate majors in Modern Languages encourage the acquisition of multiple skills by students with varied backgrounds, talents, and interests. An important resource in support of these goals is the Modern Language Resource Center (MLRC), a state-of-the-art facility that provides students with access to authentic foreign language materials such as original television broadcasts, interactive video projects, Technology Enhanced Language Learning (TELL) courses, international audio and video resources, and computerized assessment tools.

Students majoring in a modern language are also encouraged to enroll, preferably during their junior year, in a study-abroad program or to spend a summer abroad at a language institute or in an internship. Semester or year-long programs are available in places such as China, France, Germany, Japan, Africa, Russia, Spain, and Latin America. The Department also sponsors summer courses in China, Germany, and Spain. Foreign film series, informal conversation tables, native-speaker conversation partners, speaking and writing assistants, and Student Advisory Committee cultural events are some of the activities organized by the Department of Modern Languages to increase students' ability in languages and knowledge of cultures.

The major in Modern Languages is designed to permit students to acquire communicative language proficiency in their language of specialization. Courses in culture and civilization offer students a solid introduction to the main currents in national literatures as well as artistic and social movements. These courses integrate study of cultures with skill development in reading, writing, and aural/oral communication. In addition, the student who majors in Modern Languages will develop a perspective on the learning and use of second languages, from both a social and cognitive point of view, within contemporary American society and in an increasingly global community. Working closely with their advisor, language majors are guided to develop personal interests by taking courses in other disciplines such as fine arts, history, psychology, philosophy, and other humanities and social sciences, which often include readings, discussions, and papers in the foreign language. The rich technological environment of the campus strongly enhances all fields of language study.

Second language proficiency is an asset which provides students with practical as well as theoretical bases for a variety of paths after graduation. Students of Modern Languages have taken paths to a wide variety of careers in government, entrepreneurship and business, law, technology and engineering firms, media, public health, health policy, and health professions, non-profit organizations, entertainment and creative arts, and education. They are also prepared to pursue graduate studies in second language-related fields (e.g. linguistics, second language acquisition, literary and cultural studies).

Specializations within Modern Languages

Six specializations are available in the Department of Modern Languages: Chinese Studies, French and Francophone Studies, German Studies, Hispanic Studies, Japanese Studies, and Russian Studies.

Language-specific faculty advisors for these majors are:

Chinese Studies - Dr. Yueming Yu, Teaching Professor of Chinese Studies
French & Francophone Studies - Dr. Bonnie Youngs, Teaching Professor of French & Francophone Studies
German Studies - Dr. Stephen Brockmann, Professor of German
Hispanic Studies - Dr. Therese Tardio, Associate Teaching Professor of Hispanic Studies
Japanese Studies - Dr. Yasufumi Iwasaki, Associate Teaching Professor of Japanese and Dr. Keiko Koda, Professor of Japanese and Second Language Acquisition
Russian Studies - Dr. Tatyana Gershkovich, Assistant Professor of Russian Studies

The Major in Chinese Studies (96-99 units)

Faculty Advisors

Dr. Yueming Yu, Teaching Professor of Chinese Studies
(yyu@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in the Chinese language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor - Dr. Yueming Yu, yyu@andrew.cmu.edu)

Students with native or near-native proficiency in listening and speaking of the language prior to entering CMU should consult with the major advisor for a different curriculum that may accelerate their completion of the requirement.

Students may double count a maximum of one course taken for the Chinese Studies major that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in Chinese Studies (39–42 units*)

Complete all four courses

		Units
82-232	Intermediate Chinese II (may be substituted by 82-235 Fables, Lengends & Stories from Ancient Chinese Civilization) *	12
82-331	Advanced Chinese I	9
82-332	Advanced Chinese II	9
82-333	Introduction to Chinese Language and Culture **	Var.

*Students who place out of 82-232/82-235 must take a minimum of 9 additional units chosen from List A Electives.

**Students must take this course for 12 units to fulfill the requirement. Students who take this course for 9 units prior to declaring their major must register for 3 units of independent study later in their studies.

2. Core Courses in Modern Languages (12 units)

Complete one 9 unit course* plus the Senior Seminar (3 units) in the spring of the senior year.

		Units
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9

82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
82-580	Senior Seminar in Modern Languages	3

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in Chinese Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

3. Core Courses in History & Society (9 units)

Complete one course after consultation with the major advisor and the designated History or Modern Languages professor.

		Units
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
82-230	Topics in Cultural Comparison	9
82-234	Topics in Chinese History	9
82-238	Topics in Chinese Culture	9

4. Chinese Studies and Interdisciplinary Electives (36 units)

Complete two courses (18 units) from List A and two courses (18 units) from List B, or two courses (18 units) from List A, one (9 units) from List B, and one (9 units) from List C.

List A. Core Chinese Studies Electives (18 units)

		Units
82-432	Popular Culture in China	9
82-433	Topics in Contemporary Culture of China *	9
82-434	Studies in Chinese Traditions *	9
82-436	Introduction to Classical Chinese	9
82-439	Modern China Through Literature *	9
82-440	Studies in Chinese Literature & Culture *	9
82-531/532	Special Topics in Chinese Studies *	Var.

*Students may repeat these courses with new topics.

List B: Chinese Studies Electives (minimum 9 units)

		Units
82-235	Fables, Legends and Stories from Ancient Chinese Civilization *if using for List B, another course on List B must be chosen from the same list, not List C.	9
82-334	Structure of Chinese	9
82-335	Chinese Culture Through Legends and Folktales	9
82-337	Mandarin Chinese for Oral Communication I	9
82-338	Mandarin Chinese for Oral Communication II	9
82-339	Business Language & Culture in China I	9
82-340	Business Language & Culture in China II	9
82-431	China and the West	9
82-432	Popular Culture in China	9
82-433	Topics in Contemporary Culture of China *	9
82-434	Studies in Chinese Traditions *	9
82-436	Introduction to Classical Chinese	9
82-439	Modern China Through Literature	Var.
82-440	Studies in Chinese Literature & Culture	9
82-436	Introduction to Classical Chinese	9
82-505	Undergraduate Internship	Var.
82-531/532	Special Topics in Chinese Studies *	Var.

* Students may repeat these courses with new topics.

List C. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the Chinese Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		Units
48-351	Human Factors in Architecture	9
48-551	Ethics and Decision Making in Architecture	9

Art		Units
60-399	Critical Studies Independent Study	9

Business		Units
70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-430	International Management	9

English		Units
76-318	Communicating in the Global Marketplace	9
76-339	Topics in Film and Media: Hollywood vs. the World	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6

History		Units
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-309	The Chinese Revolution Through Film (1949-2000)	9

Modern Languages		Units
82-230	Topics in Cultural Comparison	9
82-234	Topics in Chinese History	9
82-238	Topics in Chinese Culture	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Philosophy		Units
80-180	Nature of Language	9
80-263	Approaching Chinese Philosophy: Basic Texts and Implications	9
80-276	Philosophy of Religion	9
80-280	Linguistic Analysis	9
80-380	Philosophy of Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

Social and Decision Science		Units
88-411	Rise of the Asian Economies	9

5. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 H&SS Senior Honors Thesis I/66-502 H&SS Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in Chinese and a 3.25 QPA overall)

Sample Curriculum

This sample curriculum assumes that all prerequisites for 82-331 are fulfilled prior to the Junior year.

Junior Year		Senior Year	
Fall	**Spring**	**Fall**	**Spring**
82-331 Advanced Chinese I	82-332 Advanced Chinese II	Core Chinese Studies Elective From List A	Core Chinese Studies Elective From List A
82-333 Introduction to Chinese Language and Culture (12 units)	Core History and Society Elective	Chinese Studies Elective From List B	82-580 Senior Seminar in Modern Languages
Modern Languages core course or equivalent approved by advisor	Chinese Studies Elective From List B or Interdisciplinary Elective From List C	Chinese Studies Elective From List B or Interdisciplinary Elective From List C	Elective
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in French and Francophone Studies (93 units)

Faculty Advisor

Dr. Bonnie Youngs, Teaching Professor of French and Francophone Studies (byoungs@cmu.edu)

Prerequisites

Intermediate-level proficiency in French. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor: Dr. Michael West, mjwest@andrew.cmu.edu)

Students may double count a maximum of one course taken for the French & Francophone Studies major that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in French and Francophone Studies (27 units)

Complete all three courses.

		Units
82-303	Introduction to French Culture	9
82-304	The Francophone World	9
82-305	French in its Social Contexts	9

2. Core Courses in Modern Languages (12 units)

Complete one 9 unit course* plus the Senior Seminar (3 units) in the spring of the senior year.

		Units
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
82-580	Senior Seminar in Modern Languages	3

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in French & Francophone Studies or from another department. Examples:80-180 Nature of Language, 85-421 Language and Thought.

3. French and Francophone Studies Interdisciplinary Electives (54 units)

Complete six courses (54 units) from List A or five courses (45 units) from List A and one (9 units) from List B.

List A. French and Francophone Electives

		Units
82-415/416	Topics in French and Francophone Studies *	9
82-501/502	Special Topics in French & Francophone Studies *	Var.
82-505	Undergraduate Internship	Var.

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the French & Francophone Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		Units
48-338	European Cities in the XIX Century: Planning, Architecture, Preservation	9
48-340	Modern Architecture and Theory 1900-1945	9
48-341	Expression in Architecture	9
48-448	History of Sustainable Architecture	9

English		Units
76-239	Introduction to Film Studies	9
76-318	Communicating in the Global Marketplace	9
76-385	Introduction to Discourse Analysis	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6

History		Units
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-205	20th Century Europe	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-258	French History: From the Revolution to De Gaulle	9
79-275	Introduction to Global Studies	9
79-350	Early Christianity	9
79-385	Out of Africa: The Making of the African Diaspora	9
79-386	Entrepreneurs in Africa, Past, Present and Future	9
79-396	Music and Society in 19th and 20th Century Europe and the U.S.	9

Modern Languages		Units
82-227	Germany & the European Union	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9

82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Music		Units
57-173	Survey of Western Music History	9
57-306	World Music	9
57-441	Analysis of 19th Century Music	9

Philosophy		Units
80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-281	Language and Thought	9
80-282	Phonetics and Phonology I	9
80-380	Philosophy of Language	9
80-381	Meaning in Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

Social and Decision Sciences		Units
88-419	International Negotiation	9

4. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad or internship is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 H&SS Senior Honors Thesis I/66-502 H&SS Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in French and a 3.25 QPA overall)

Sample Curriculum

Junior Year		Senior Year	
Fall	**Spring**	**Fall**	**Spring**
82-303 Introduction to French Culture	82-305 French in its Social Contexts	French & Francophone Studies (FFS) Elective From List A	FFS Elective From List A
82-304 The Francophone World	Interdisciplinary Elective From List B	FFS Elective From List A	FFS Elective From List A
Modern Languages core course or equivalent approved by advisor	Elective	FFS Elective From List A	82-580 Senior Seminar in Modern Languages
Elective	Elective	Elective	Elective
Elective	Elective	Elective	

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in German Studies (93 units)

Faculty Advisor

Dr. Stephen Brockmann, Professor of German Studies
(smb@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in German. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor: Dr. Gabriele Eichmanns Maier, eichgabi@andrew.cmu.edu)

Students may double count a maximum of one course taken for the German Studies major that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in German Studies (27 units)

Complete all three courses.*

		Units
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-323	Germany, Austria and Switzerland in the 20th Century	9
82-327	The Emergence of the German Speaking World	9

* A 400-level course may be substituted with the major advisor's approval.

2. Core Courses in Modern Languages (12 units)

Complete one 9-unit course* in Modern Languages, plus the senior seminar (3 units) in spring of the senior year.

		Units
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
82-580	Senior Seminar in Modern Languages	3

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in German Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

3. German Studies and Interdisciplinary Electives (54 units)

Complete five courses (45 units) from List A and one (9 units) from List B, or a minimum of three courses (27 units) from List A and one or two courses (9-18 units) from List B. The student may complete an additional 3 units of coursework in German to allow a List B elective to count as a List A elective, with permission of the major advisor and the course instructor.

List A. German Electives

		Units
82-420	The Crucible of Modernity:Vienna 1900	9
82-425/426	Topics in German Literature and Culture *	9

82-427	Nazi and Resistance Culture	9
82-428	History of German Film	9
82-505	Undergraduate Internship	Var.
82-521/522	Special Topics: German Studies *	Var.

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

From possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the German Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		Units
48-338	European Cities in the XIX Century: Planning, Architecture, Preservation	9
48-340	Modern Architecture and Theory 1900-1945	9
48-350	Postwar Modern Architecture and Theory	9

English		Units
76-239	Introduction to Film Studies	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6
76-483	Corpus Analysis in Rhetoric	9

History		Units
79-205	20th Century Europe	9
79-256	Sex, Guns, and Rock 'n Roll: Youth Rebellion in 1960s & 1970s Europe	6
79-257	Germany and the Second World War	9
79-349	United States and the Holocaust	6

Modern Languages		Units
82-227	Germany & the European Union	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-427	Nazi and Resistance Culture (when taken entirely in English)	9
82-428	History of German Film (when taken entirely in English)	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Music		Units
57-306	World Music	9

Philosophy		Units
80-136	Social Structure, Public Policy & Ethics	9
80-180	Nature of Language	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-256	Modern Moral Philosophy	9
80-275	Metaphysics	9
80-280	Linguistic Analysis	9
80-380	Philosophy of Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

4. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 H&SS Senior Honors Thesis I/66-502 H&SS Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in German and a 3.25 QPA overall)

Sample Curriculum

Junior Year		Senior Year	
Fall	**Spring**	**Fall**	**Spring**
82-320 Contemporary Society in Germany, Austria and Switzerland	82-323 Germany, Austria and Switzerland in the 20th Century	German Studies Elective From List A	German Studies Elective From List A
82-327 The Emergence of the German Speaking World	Interdisciplinary Elective From List B	German Studies Elective From List A	German Studies Elective From List A or Interdesciplinary Elective From List B
Modern Languages core course or equivalent approved by advisor	Elective	German Studies Elective From List A or Interdisciplinary Elective From List B	82-580 Senior Seminar in Modern Languages
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in Hispanic Studies (93 units)

Faculty Advisor

Dr. Therese Tardio, Associate Teaching Professor of Hispanic Studies (tardio@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in Spanish. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor: Dr. Therese Tardio, tardio@andrew.cmu.edu)

Students may double count a maximum of one course taken for the Hispanic Studies major that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in Hispanic Studies (27 units)

Complete two courses.

		Units
82-342	Spain: Language and Culture	9
82-343	Latin America Language and Culture	9
82-344	U.S. Latinos: Language and Culture	9

Complete required course.

		Units
82-345	Introduction to Hispanic Literary & Cultural Studies	9

2. Core Courses in Modern Languages (12 units)

Complete one 9-unit course* in Modern Languages, plus the senior seminar (3 units) in spring of the senior year.

		Units
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
82-580	Senior Seminar in Modern Languages	3

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or the acquisition of language and culture from the listings in Hispanic Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

3. Hispanic Studies and Interdisciplinary Electives (54 units)

Complete six courses (54 units) from or five courses (45 units) from List A and one (9 units) from List B.

List A. Hispanic Studies Electives

		Units
82-441	Studies in Peninsular Literature and Culture *	9
82-443	Spanish Reading and Translation Workshop	9
82-444	The Structure of Spanish	9
82-451	Studies in Latin American Literature and Culture *	9
82-455/456	Topics in Hispanic Studies *	9
82-506	Hispanic Studies Internship	Var.
82-541/542	Special Topics: Hispanic Studies *	Var.

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

From possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the Hispanic Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		Units
48-348	Architectural History of Mexico & Guatemala	9

English		Units
76-385	Introduction to Discourse Analysis	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6
76-484	Discourse Analysis	9

History		Units
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-224	Mayan America	9
79-235	Caribbean Cultures	9
79-237	Comparative Slavery	9
79-276	Beyond the Border	6
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-295	Archaeology of Technology	6

Institute for Policy and Strategy		Units
84-308	Political Economy of Latin America	9

Modern Languages		Units
82-245	New Directions in Hispanic Studies	9
82-247	The Hispanic World: History, Culture and Globalization	9
82-249	Hispanic Language & Cultures for the Professions	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Music		Units
57-306	World Music	9

Philosophy		Units
80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-285	Natural Language Syntax	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-380	Philosophy of Language	9
80-381	Meaning in Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

4. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 H&SS Senior Honors Thesis I/66-502 H&SS Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in Hispanic Studies and a 3.25 QPA overall)

Sample Curriculum

Junior Year		**Senior Year**	
Fall	**Spring**	**Fall**	**Spring**
82-342 Spain: Language and Culture	82-345 Introduction to Hispanic Literary & Cultural Studies	Hispanic Studies Elective From List A	Hispanic Studies Elective From List A
82-343 Latin America Language and Culture	Interdisciplinary ElectiveFrom List B	Hispanic Studies Elective From List A	Hispanic Studies Elective From List A
Modern Languages core course or equivalent approved by advisor	Elective	Hispanic Studies Elective From List A or Interdisciplinary Elective from List A or List B	82-580 Senior Seminar in Modern Languages
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language.

Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in Japanese Studies (102-105 units)

Faculty Advisors

Dr. Yasufumi Iwasaki, Associate Teaching Professor of Japanese Studies (yiwasaki@andrew.cmu.edu)
Dr. Keiko Koda, Professor of Japanese Studies and Second Language Acquisition (kkoda@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in the Japanese language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, Cambridge GCE Advanced level, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor - Dr. Yasufumi Iwasaki, yiwasaki@andrew.cmu.edu)

Students may double count a maximum of one course taken for the Japanese Studies major that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in Japanese Studies (36–39 units)

Complete all four courses.

		Units
82-272	Intermediate Japanese II *	12
82-273	Introduction to Japanese Language and Culture	9
82-371	Advanced Japanese I	9
82-372	Advanced Japanese II	9

*Students who place out of 82-272 Intermediate Japanese II must take 9 units chosen from List A electives.

2. Core Courses in Modern Languages (12 units)

Complete one 9-unit course* in Modern Languages, plus the senior seminar (3 units) in spring of the senior year.

		Units
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
82-580	Senior Seminar in Modern Languages	3

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or the acquisition of language and culture from the listings in Japanese Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

3. Japanese Studies and Interdisciplinary Electives (54 units)

Complete four courses (36 units) from List A and two (18 units) from List B. With permission of the major advisor, students are encouraged to complete at least one Japanese history course that qualifies for List A or List B at the University of Pittsburgh, one in Japan when they study abroad, or in a summer program at any other university.

List A. Japanese Electives

		Units
82-373	Structure of the Japanese Language	9
82-374	Technical Japanese	9
82-473/474	Topics in Japanese Studies *	9
82-505	Undergraduate Internship	Var.
82-571/572	Special Topics in Japanese Studies *	Var.

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the Japanese Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

English		Units
76-239	Introduction to Film Studies	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6

History		Units
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-275	Introduction to Global Studies	9

Modern Languages		Units
82-234	Topics in Chinese History	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-373	Structure of the Japanese Language	9
82-374	Technical Japanese	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Music		Units
57-306	World Music	9

Philosophy		Units
80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-380	Philosophy of Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

4. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 H&SS Senior Honors Thesis I/66-502 H&SS Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in Japanese Studies and a 3.25 QPA overall)

Sample Curriculum

This sample curriculum assumes that all prerequisites for 82-371 are fulfilled prior to the junior year.

Junior Year		Senior Year	
Fall	Spring	Fall	Spring
82-273 Introduction to Japanese Language and Culture	82-372 Advanced Japanese II	Japanese Studies Elective from List A	Japanese Studies Elective From List A
82-371 Advanced Japanese I	Modern Languages core course of equivalent approved by advisor	Japanese Studies Elective from List A	Interdisciplinary Elective From List B
Modern Languages core course of equivalent	Interdisciplinary Elective from List B	Elective	82-580 Senior Seminar in Modern Languages
Elective	Interdisciplinary Elective from List B	Elective	Elective
Elective	Elective	Elective	Elective
	Elective		

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in Russian Studies (105-108 units)

Faculty Advisor

Dr. Tatyana Gershkovich, *Assistant Professor of Russian*

The major in Russian Studies is jointly administered by the Departments of History and Modern Languages. Students are required to fulfill requirements in history and in language and culture.

Prerequisites

The major in Russian Studies is an interdepartmental, interdisciplinary major jointly administered by the Departments of History and Modern Languages. Students are asked to fulfill requirements in history and in language and culture. Additionally, students are strongly encouraged to study abroad in Russia or other parts of the Russian-speaking world. Not only does study abroad offer students a memorable and formative experience of cultural immersion, it also helps them advance to their highest possible levels of linguistic and cultural competence by the time they graduate.

Students may double count one course taken for the Russian Studies major that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Required Courses in Russian Language (48 units)

Modern Languages		
82-191	Elementary Russian I	12
82-192	Elementary Russian II	12
82-291	Intermediate Russian I	12
82-292	Intermediate Russian II	12

N.B. Students with native or near-native proficiency in Russian or with prior study at elementary or intermediate levels may begin language study at a higher level. Students with previous experience in Russian must consult with the major advisor about language placement prior to enrolling and to confirm the number of classes to complete the major.

2. Required Courses in Russian Culture (24 units)

Complete two courses. These courses are conducted in English. Russian Studies majors must complete the additional 3-units of work for each course.

Modern Languages		
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-294	Topics in Russian Language and Culture	9

3. Required Electives in History (18 units)

Complete two courses.		Units
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-341	The Cold War in Documents and Film	9

4. Required Elective (9-12 units)

Complete one course. Courses not listed below may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester. Courses marked by * are offered in English and Russian Studies majors must complete the additional 3-units of work for each course. All other courses are 9 units.

79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-322	Stalin and the Great Terror	9
79-341	The Cold War in Documents and Film	9
82-397	Radical, Heretics, Hackers: Russian Outlaws in History, Literature, and Film *	Var.
82-492	The Historical Imagination in Nineteenth-Century Russian Literature	Var.

5. Required Senior Thesis (9 units)

In their senior year, majors must complete a 20–25 page independent research or translation project making use of Russian sources. For this project, students may choose to work closely with a professor in History (79-XXX) or in Modern Languages (82-599). This in-depth research project offers students a unique opportunity to complete a piece of original scholarship in their areas of interest, and to develop an expertise with which to embark on future intellectual and professional pursuits. The number of credits for the thesis reflects the expectation that students will do significant work in Russian and use the project to advance their linguistic competence.

Recent theses topics have included:

- *Khrushchev, de-Stalinization, and the Twentieth Congress of the Communist Party*
- *Lunokhod and the Soviet Space Program*
- *Constructivism and New Sight: A Rhetorical Analysis of the Early Soviet Political Poster*
- *Alexander Rodchenko and the Development of Constructivism in Russian Art*
- *Boris Akunin and Contemporary Russian Fiction*

Dietrich College Honors Senior Thesis

Students who meet the eligibility requirements may extend their Russian Studies Thesis (9 units) into a Dietrich College Honors Thesis (18 units) with the approval of their advisor. Information on this program can be found at http://www.cmu.edu/dietrich/undergraduate/programs/shp/

Highly Recommended Opportunities for Majors

Study Abroad

Students are strongly encouraged to spend a semester or summer in Russia through an approved exchange program. Consult with your advisor and the Office of International Education (OIE) about possible options. Many exchange programs offer instruction at internationally recognized universities in Russian language, history, literature, and culture. They also offer travel to ancient sites and cities, visits to museums, palaces, exhibitions, and monuments, and the opportunity to live with a Russian host family. Scholarship opportunities are available.

Senior Seminar in Modern Languages

82-580 (3 units)

The senior seminar, offered in the senior spring semester, brings together majors from all of Modern Languages. In addition to offering students strategies for maintaining and advancing their language skills after they graduate, this course provides an occasion for students to reflect on their own language-learning experiences. Students are prompted to consider larger issues surrounding language learning and multiculturalism in the United States and globally.

Faculty Exchange Program

In 1993, the College of Humanities and Social Sciences at CMU initiated a faculty exchange program with the Russian State University of the Humanities (RGGU), one of the foremost universities in Russia, located in Moscow. Carnegie Mellon has hosted faculty members from RGGU specializing in history, language, and philosophy. These professors have joined our departments for a semester, offering unique courses on subjects not generally available to our students. Faculty members from Carnegie Mellon have visited Moscow, using the RGGU exchange to pursue archival research, attend conferences, and collaborate on common projects. The exchange offers students an opportunity to study language from native speakers, gain exposure to different perspectives on history and politics, and gather firsthand knowledge about recent developments in Russia. In addition, the exchange can provide important contacts for students interested in pursuing careers abroad.

Sample Curriculum

Junior Year		Senior Year	
Fall	**Spring**	**Fall**	**Spring**
82-291 Intermediate Russian I	82-292 Intermediate Russian II	82-399 Special Topics: Russian in Context	82-599 Russian Studies Thesis
Core Course in History 79-265 or 79-266	Required Elective in History	82-399 Special Topics: Russian in Context	Required Elective
Elective	Required Elective	Required Elective	82-580 Senior Seminar in Modern Languages
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

This is presented as a two-year (junior-senior) plan for completing the major requirements. Its purpose is to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

Modern Languages as an Additional Major

In addition to their primary major, a student may complete a major in Chinese Studies, French and Francophone Studies, German Studies, Hispanic Studies, Japanese Studies, and Russian Studies. Students outside of Dietrich College interested in an additional major in Modern Languages need to fulfill only the requirements for the Modern Languages major but not the Dietrich College General Education requirements.

Minors in the Department of Modern Languages

The Department of Modern Languages also offers minors in Arabic Studies, Chinese Studies, French and Francophone Studies, German Studies, Hispanic Studies, Japanese Studies, and Russian Studies. A minor in one of these language and culture areas requires core courses similar to the major and includes a variety of options for electives. Many students study abroad as part of their program. Students who minor in Modern Languages have found the program an enriching complement to their major areas of study and an asset to their work in government, entrepreneurship and business, law, technology and engineering firms, media, public health, health policy, and health professions, non-profit organizations, entertainment and creative arts, and education.

Curriculum

The minimum requirement for the minor in French and Francophone Studies, German Studies or Hispanic Studies is 54 units (not including any 100- or 200-level prerequisite work in the chosen language), as outlined below. The minimum requirement for the minor in Arabic Studies, Chinese Studies, Japanese Studies or Russian Studies is 54-60 units, depending on the student's language background.

Language-specific faculty advisors for these specializations are:

Arabic Studies - Dr. Khaled Al Masaeed, Assistant Professor of Arabic Studies **(Pittsburgh)** and Dr. Zeinab Ibrahim, Teaching Professor of Arabic Studies **(Qatar)**
Chinese Studies - Dr. Gang Liu, Assistant Teaching Professor of Chinese Studies, Dr. Sue-mei Wu, Teaching Professor of Chinese Studies, and Tianxue Yao, Lecturer of Chinese Studies
French & Francophone Studies - Dr. Bonnie Youngs, Teaching Professor of French & Francophone Studies
German Studies - Dr. Gabriele Eichmanns Maier, Associate Teaching Professor of German Studies
Hispanic Studies - Dr. Felipe Gómez, Associate Teaching Professor of Hispanic Studies
Japanese Studies - Dr. Yasufumi Iwasaki, Associate Teaching Professor of Japanese and Dr. Yoshihiro Yasuhara, Assistant Teaching Professor of Japanese Studies
Russian Studies - Dr. Tatyana Gershkovich, Assistant Professor of Russian Studies

The Minor in Arabic Studies (54-57 units)

Faculty Advisors

Dr. Khaled Al Masaeed, Assistant Professor of Arabic Studies (masaeed@andrew.cmu.edu) **(Pittsburgh)**
Dr. Zeinab Ibrahim, Teaching Professor of Arabic Studies (zeinab@qatar.cmu.edu) **(Qatar)**

Prerequisites

Pittsburgh Campus: Intermediate-level proficiency in the Arabic language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Khaled Al Masaeed (masaeed@andrew.cmu.edu).

Qatar Campus: Advanced-level proficiency in the Arabic language. CMU-Q students who need elementary and intermediate level courses should consult with the campus advisor for Arabic Studies before declaring the minor. Student progress may be accelerated or supplemented by study abroad. (Study abroad advisor for Qatar - Dr. Zeinab Ibrahim (zeinab@qatar.cmu.edu).

Students may double count a maximum of one course taken for the Arabic Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs.

Students with native or near-native proficiency in listening and speaking of the language prior to entering CMU should consult with the minor advisors for a different curriculum that may accelerate their completion of the requirement.

Course Requirements

1. Core Courses in Arabic Studies (27-30 units)

Complete three courses.*

82-212	Intermediate Arabic II	12
82-311	Advanced Arabic I	9
82-312	Advanced Arabic II	9

*Students who place out of 82-212 must take a total of 27 units in Core Courses

2. Arabic Studies and Interdisciplinary Electives (27 units)

Pittsburgh: Complete two courses (18 units) from List A and one course (9 units) from List B, or three courses (27 units) from List A.
Qatar: Complete four courses (36 units) from List A, and two courses (18 units) from List B, or five courses (45 units) from List A and one course (9 units) from List B, or six courses (54 units) course from List A.

List A. Electives

82-117	Arabic Conversation & Dialect I	6
82-118	Arabic Conversation & Dialect II	6
82-313	Topics in Modern Arabic Language, Literature and Culture (CMU-Q)	9
82-314	Literature of the Arabic-speaking World (CMU-Q)	9
82-411	Topics in Arabic Media *	Var.
82-412	Topics in Arabic Studies *	9

82-505	Undergraduate Internship	Var.
82-511	Special Topics in Arabic Studies *	9
82-512	Special Topics: Arabic Language & Culture *	9

*Students may repeat these courses with new topics with the instructor's permission.

List B. Interdisciplinary Electives

Architecture

48-240	Historical Survey of World Architecture and Urbanism I	9
48-315	Environment I: Climate & Energy in Architecture	9

Business Administration

70-321	Negotiation and Conflict Resolution	9
70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9

Engineering and Public Policy

19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-424	Energy and the Environment	9

English

76-318	Communicating in the Global Marketplace	9
76-472	Topics in Journalism: Storytelling in a Digital Age	9
76-386	Language & Culture	9
76-484	Discourse Analysis	9
76-491	Rhetorical Analysis	9

History

79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-233	The United States and the Middle East since 1945	9
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
79-307	Religion and Politics in the Middle East	9
79-336	Oil & Water: Middle East Perspectives	6
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-398	Documenting the 1967 Arab-Israeli War	9

Information Systems

67-329	Contemporary Themes in Global Systems	9

Institute for Politics and Strategy

84-275	Comparative Politics	9
84-310	International Political Economy	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-326	Theories of International Relations	9
84-362	Diplomacy and Statecraft	9
84-389	Terrorism and Insurgency	9

Linguistics

80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-282	Phonetics and Phonology I	9
80-381	Meaning in Language	9
80-383	Language in Use	9

Modern Languages

82-114	Arabic for Global Exchange Online	6
82-214	Topics in Modern Arabic Language, Literature, & Culture (CMU-Q)	9
82-215	Arab Culture Through Film & Literature	Var.
82-216	Literature of the Arabic-speaking World (CMU-Q)	9
82-280	Learning About Language Learning	9
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-300	Language & Society in the Arab World	9
82-313	Topics in Modern Arabic Language, Literature and Culture (CMU-Q)	9
82-314	Literature of the Arabic-speaking World (CMU-Q)	9
82-383	Second Language Acquisition: Theories and Research	9
82-411	Topics in Arabic Media	Var.
82-412	Topics in Arabic Studies	9
82-480	Social and Cognitive Aspects of Bilingualism	9
82-448	Topics in Arabic Language, Literature, & Culture (CMU-Q)	9
82-505	Undergraduate Internship	Var.

Philosophy

80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-281	Language and Thought	9
80-324	Philosophy of Economics	9
80-381	Meaning in Language	9
80-383	Language in Use	9

Psychology

85-219	Biological Foundations of Behavior	9
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

The Minor in Chinese Studies (57-60 units)

Faculty Advisors

Dr. Gang Liu, Assistant Teaching Professor of Chinese Studies (gangliu@andrew.cmu.edu)
Dr. Sue-mei Wu, Teaching Professor of Chinese Studies (suemei@andrew.cmu.edu)
Tianxue Yao, Lecturer of Chinese Studies (tyao@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in the Chinese language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Yueming Yu, yyu@andrew.cmu.edu).

Students may double count a maximum of one course taken for the Chinese Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs.

Students with native or near-native proficiency in listening and speaking of the language prior to entering CMU should consult with the minor advisors for a different curriculum that may accelerate their completion of the requirement.

Course Requirements

1. Core Courses in Chinese Studies (36–39 units)

Complete four courses.

82-232	Intermediate Chinese II (may be substituted by 82-235 Fables, Legends, and Stories from Ancient Chinese Civilization *	12
82-235	Fables, Legends and Stories from Ancient Chinese Civilization *	9
82-331	Advanced Chinese I	9
82-332	Advanced Chinese II	9
82-333	Introduction to Chinese Language and Culture **	Var.

*Students who place out of 82-232/82-235 must take a minimum of 9 additional units chosen from List A Electives.

**Students must take this course for 12 units with the additional work in Chinese to fulfill the requirement. Students who take this course for 9 units prior to declaring their minor must register for 3 units of independent study later in their studies.

2. Chinese Studies and Interdisciplinary Electives (18 units)

List A. Chinese Studies Electives

Complete two courses (18 units) from List A or one course (9 units) from List A and one (9 units) from List B.

82-334	Structure of Chinese	9
82-335	Chinese Culture Through Legends and Folktales	9
82-337	Mandarin Chinese for Oral Communication I	9
82-338	Mandarin Chinese for Oral Communication II	9
82-339	Business Language & Culture in China I	9
82-340	Business Language & Culture in China II	9
82-431	China and the West	9
82-432	Popular Culture in China	9
82-433	Topics in Contemporary Culture of China *	9
82-434	Studies in Chinese Traditions *	9
82-436	Introduction to Classical Chinese *	9
82-439	Modern China Through Literature *	Var.
82-440	Studies in Chinese Literature & Culture *	9
82-505	Undergraduate Internship	Var.
82-531/532	Special Topics in Chinese Studies *	Var.

*Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their minor advisor for the most up to date interdisciplinary electives appropriate for the Chinese Studies curriculum. Courses may be suggested to the minor advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		Units
48-351	Human Factors in Architecture	9
48-551	Ethics and Decision Making in Architecture	9

Art		Units
60-399	Critical Studies Independent Study	9

Business Administration		Units
70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-430	International Management	9

English		Units
76-318	Communicating in the Global Marketplace	9
76-339	Topics in Film and Media: Hollywood vs. the World	9
76-386	Language & Culture	9

History		Units
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-281	Introduction to Religion	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-341	The Cold War in Documents and Film	9

Modern Languages		Units
82-230	Topics in Cultural Comparison	9
82-234	Topics in Chinese History	9
82-238	Topics in Chinese Culture	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Philosophy		Units
80-180	Nature of Language	9
80-263	Approaching Chinese Philosophy: Basic Texts and Implications	9
80-276	Philosophy of Religion	9
80-280	Linguistic Analysis	9
80-380	Philosophy of Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

Social and Decision Sciences		Units
88-411	Rise of the Asian Economies	9

The Minor in French and Francophone Studies (54 units)

Faculty Advisor

Dr. Bonnie Youngs, Teaching Professor of French and Francophone Studies (byoungs@cmu.edu)

Prerequisites

Intermediate-level proficiency in French. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Michael West, mjwest@andrew.cmu.edu (eichgabi@andrew.cmu.edu))

Students may double count a maximum of one course taken for the French & Francophone Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in French and Francophone Studies (27 units)

Complete three courses.

82-303	Introduction to French Culture	9
82-304	The Francophone World	9
82-305	French in its Social Contexts	9

2. French and Francophone Studies and Interdisciplinary Electives (27 units)

Complete three courses (27 units) from List A, or two courses (18 units) from List A and one
(9 units) from List B.

List A. French Electives

		Units
82-415/416	Topics in French and Francophone Studies *	9
82-501/502	Special Topics in French & Francophone Studies *	Var.
82-505	Undergraduate Internship	Var.

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their minor advisor for the most up to date interdisciplinary electives appropriate for the French & Francophone Studies curriculum. Courses may be suggested to the minor advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		Units
48-338	European Cities in the XIX Century: Planning, Architecture, Preservation	9
48-340	Modern Architecture and Theory 1900-1945	9
48-341	Expression in Architecture	9
48-448	History of Sustainable Architecture	9

English		Units
76-239	Introduction to Film Studies	9
76-318	Communicating in the Global Marketplace	9

76-385	Introduction to Discourse Analysis	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6

History		Units
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-205	20th Century Europe	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-385	Out of Africa: The Making of the African Diaspora	9
79-258	French History: From the Revolution to De Gaulle	9
79-275	Introduction to Global Studies	9
79-350	Early Christianity	9
79-386	Entrepreneurs in Africa, Past, Present and Future	9
79-396	Music and Society in 19th and 20th Century Europe and the U.S.	9

Modern Languages		Units
82-227	Germany & the European Union	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Music		Units
57-173	Survey of Western Music History	9
57-306	World Music	9

Philosophy		Units
80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-281	Language and Thought	9
80-380	Philosophy of Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

Social and Decision Sciences		Units
88-419	International Negotiation	9

The Minor in German Studies (54 units)

Faculty Advisor

Dr. Gabriele Eichmanns Maier, Associate Teaching Professor of German Studies (eichgabi@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in German. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Gabriele Eichmanns Maier, eichgabi@andrew.cmu.edu)

Students may double count a maximum of one course taken for the German Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in German Studies (27 units)

Complete three courses.*

		Units
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-323	Germany, Austria and Switzerland in the 20th Century	9
82-327	The Emergence of the German Speaking World	9

* A 400-level course may be substituted with the minor advisor's approval.

2. German Studies & Interdisciplinary Electives (27 units)

Complete three courses (27 units) from List A or two courses (18 units) from List A and one (9 units) from List B.

List A. German Studies Electives

		Units
82-420	The Crucible of Modernity:Vienna 1900	9
82-425/426	Topics in German Literature and Culture *	9
82-427	Nazi and Resistance Culture	9
82-428	History of German Film	9
82-521/522	Special Topics: German Studies *	Var.

*Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their minor advisor for the most up to date interdisciplinary electives appropriate for the German Studies curriculum. Courses may be suggested to the minor advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		Units
48-338	European Cities in the XIX Century: Planning, Architecture, Preservation	9
48-340	Modern Architecture and Theory 1900-1945	9
48-350	Postwar Modern Architecture and Theory	9

English		Units
76-239	Introduction to Film Studies	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6
76-483	Corpus Analysis in Rhetoric	9

History		Units
79-205	20th Century Europe	9
79-257	Germany and the Second World War	9
79-349	United States and the Holocaust	6

Modern Languages		Units
82-227	Germany & the European Union	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-285	Podcasting: Language and Culture Through Storytelling	9
82-286	Understanding Cultural Complexities	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-427	Nazi and Resistance Culture (when taken entirely in English)	9
82-428	History of German Film (when taken entirely in English)	Var.
82-480	Social and Cognitive Aspects of Bilingualism	9

Music		Units
57-306	World Music	9

Philosophy		Units
80-136	Social Structure, Public Policy & Ethics	9
80-180	Nature of Language	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-256	Modern Moral Philosophy	9
80-275	Metaphysics	9

80-280	Linguistic Analysis	9
80-380	Philosophy of Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

54 units The Minor in Hispanic Studies

The Minor in Hispanic Studies (54 units)

Faculty Advisors

Dr. Felipe Gómez, Associate Teaching Professor of Hispanic Studies (fgomez@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in Spanish. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor – Dr. Therese Tardio, tardio@andrew.cmu.edu)

Students may double count a maximum of one course taken for the Hispanic Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in Hispanic Studies (27 units)

Complete two courses.

		Units
82-342	Spain: Language and Culture	9
82-343	Latin America Language and Culture	9
82-344	U.S. Latinos: Language and Culture	9

Complete the following course.

		Units
82-345	Introduction to Hispanic Literary & Cultural Studies	9

2. Hispanic Studies and Interdisciplinary Electives (27 units)

Complete three courses (27 units) from List A or two courses (18 units) from List A and one (9 units) from List B.

List A: Hispanic Studies Electives

		Units
82-441	Studies in Peninsular Literature and Culture *	9
82-443	Spanish Reading and Translation Workshop	9
82-444	The Structure of Spanish	9
82-451	Studies in Latin American Literature and Culture *	9
82-455/456	Topics in Hispanic Studies *	9
82-505	Undergraduate Internship	Var.
82-541/542	Special Topics: Hispanic Studies *	Var.

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their minor advisor for the most up to date interdisciplinary electives appropriate for the Hispanic Studies curriculum. Courses may be suggested to the minor advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		Units
48-348	Architectural History of Mexico & Guatemala	9

English		Units
76-385	Introduction to Discourse Analysis	9
76-484	Discourse Analysis	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6

History		Units
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-224	Mayan America	9
79-235	Caribbean Cultures	9
79-237	Comparative Slavery	9
79-276	Beyond the Border	6
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-295	Archaeology of Technology	6

Institute for Politics and Strategy		Units
84-308	Political Economy of Latin America	9

Modern Languages		Units
82-245	New Directions in Hispanic Studies	9
82-249	Hispanic Language & Cultures for the Professions	9
82-247	The Hispanic World: History, Culture and Globalization	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Music		Units
57-306	World Music	9

Philosophy		Units
80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-285	Natural Language Syntax	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-380	Philosophy of Language	9
80-381	Meaning in Language	9

Psychology		Units
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

The Minor in Japanese Studies (54–57 units)

Faculty Advisors

Dr. Yasufumi Iwasaki, Associate Teaching Professor of Japanese (yiwasaki@andrew.cmu.edu)
Dr. Yoshihiro Yasuhara, Associate Teaching Professor of Japanese Studies (yyashuar@andrew.cmu.edu)

Prerequisites

Intermediate-level of proficiency in the Japanese language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, Cambridge GCE Advanced level, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Yasufumi Iwasaki, yiwasaki@andrew.cmu.edu)

Students may double count a maximum of one course taken for the Japanese Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Core Courses in Japanese Studies (27–39 units*)

Complete four courses.

82-272	Intermediate Japanese II *	12
82-273	Introduction to Japanese Language and Culture	9
82-371	Advanced Japanese I	9
82-372	Advanced Japanese II	9

*Students who place out of 82-272 must take 9 units chosen from the List A electives.

2. Japanese Studies and Interdisciplinary Electives (18 units)

Complete two courses (18 units) from List A, or one course (9 units) from List A and one (9 units) from List B.

List A. Japanese Studies Electives

82-373	Structure of the Japanese Language	9
82-374	Technical Japanese	9
82-473/474	Topics in Japanese Studies *	9
82-505	Undergraduate Internship	Var.
82-571/572	Special Topics in Japanese Studies *	Var.

*Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their minor advisor for the most up to date interdisciplinary electives appropriate for the Japanese Studies curriculum. Courses may be suggested to the minor advisor for approval as a substitute. Note that not all courses are offered each semester.

English		
76-239	Introduction to Film Studies	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6

History		
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-275	Introduction to Global Studies	9

Modern Languages		
82-234	Topics in Chinese History	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-373	Structure of the Japanese Language	9
82-374	Technical Japanese	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9

Music		
57-306	World Music	9

Philosophy		
80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-380	Philosophy of Language	9

Psychology		
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

The Minor in Russian Studies (63 units)

Faculty Advisor

Dr. Tatyana Gershkovich, Assistant Professor of Russian Studies

The minor in Russian Studies is jointly administered by the Departments of History and Modern Languages. Students are required to fulfill requirements in history and in language and culture.

Prerequisites

Elementary-level proficiency in the Russian language. This is equivalent to the completion of two courses at the 100-level, or placement or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. Carnegie Mellon students who arrive with previous language study and/or who have high AP or CEEB scores will be able to begin taking courses toward the minor earlier in their undergraduate program. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors.

Students may double count a maximum of one course taken for the Russian Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs.

Course Requirements

1. Required Course in History (9 units)

Complete one course. *		Units
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9

* Both courses are recommended.

2. Required Electives in History (18 units)

In consultation with the minor advisor, students may choose a substitute.		Units
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-341	The Cold War in Documents and Film	9

3. Core Courses in Modern Languages (24 units)

Complete both courses.		Units
82-291	Intermediate Russian I	12
82-292	Intermediate Russian II	12

Should a student enter the Russian Studies program with demonstrated language proficiency at the intermediate or advanced level, higher level courses will be used to complete the required total of 18 units of core courses in Modern Languages. Advanced language options include 82-400 Russian Studies Topics, a repeatable course, as well as subject-oriented language supplements to existing courses taught in English in a variety of fields. The student can add a language supplement (3 units) to selected 9-unit electives, earning a total of 12 units for the language-supplemented course.

4. Interdisciplinary Electives (18 units)

Complete two courses. This list is compiled from possibilities such as but not limited to the following. Students should consult their minor advisor for the most up to date interdisciplinary electives appropriate for the Russian Studies curriculum. Courses may be suggested to the minor advisor for approval as a substitute. Note that not all courses are offered each semester.

History		Units
79-205	20th Century Europe	9
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-322	Stalin and the Great Terror	9
79-341	The Cold War in Documents and Film	9

Modern Languages		Units
82-283	Language Diversity & Cultural Identity	9
82-294	Topics in Russian Language and Culture *	Var.
82-296	A Century of Russian Film	9
82-396	The Faust Legend at Home and Abroad	Var.
82-397	Radical, Heretics, Hackers: Russian Outlaws in History, Literature, and Film	Var.
82-399	Special Topics: Russian in Context *	9
82-400	Russian Studies Topics (section A and/or B)	6
82-492	The Historical Imagination in Nineteenth-Century Russian Literature	Var.

* Students may repeat these course with new topics.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options. Students are encouraged to spend a semester or summer in Russia via an approved exchange program. Many exchange programs offer instruction in Russian language, history, literature, and culture, in internationally recognized universities. They also offer travel to ancient sites and cities, visits to museums, palaces, exhibitions, and monuments, and the opportunity to live with a Russian host family. Scholarship opportunities are available.

Faculty

KHALED AL MASAEED, Assistant Professor of Arabic Studies – Ph.D., The University of Arizona; Carnegie Mellon, 2016–

STEPHEN BROCKMANN, Professor of German with courtesy appointments in English and History – Ph.D., University of Wisconsin Madison; Carnegie Mellon, 1993–

CHARLENE CASTELLANO, Teaching Professor of Russian Emeritus – Ph.D., Cornell University; Carnegie Mellon, 1990–

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BARBARA FREED, Professor Emeritus of French & Francophone Studies and Second Language Acquisition – Ph.D., University of Pennsylvania; Carnegie Mellon, 1990–

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PAUL HOPPER, Paul Mellon Distinguished Professor Emeritus of the Humanities, Rhetoric and Linguistics with a courtesy appointment in Modern Languages – Ph.D., University of Texas; Carnegie Mellon, 1990–

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BRIAN MACWHINNEY, Professor of Psychology with a courtesy appointment in Modern Languages – Ph.D., University of California, Berkeley; Carnegie Mellon, 1981–

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SUSAN G. POLANSKY, Teaching Professor of Hispanic Studies and Head of Modern Languages – Ph.D., Boston College; Carnegie Mellon, 1986–

GIOVANNI PUPPO, Instructor of Italian – Ph.D., University of Rome; Carnegie Mellon, 1975–

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CANDACE SKIBBA, Assistant Teaching Professor of Hispanic Studies – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2006–

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JAN VAIRO, Senior Lecturer – M.A., University of Pittsburgh; Carnegie Mellon, 1992–

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MICHAEL J. WEST, Teaching Professor of French & Francophone Studies – PhD., University of California-Santa Barbara; Carnegie Mellon, 1989–

DANIELLE WETZEL, Teaching Professor and Director of First Year Writing with a courtesy appointment in Modern Languages – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2006–

SETH WIENER, Assistant Professor of Second Language Acquistion and Chinese – Ph.D., Ohio State University; Carnegie Mellon, 2015–

SUE-MEI WU, Teaching Professor of Chinese Studies – Ph.D., Ohio State University; Carnegie Mellon, 2000–

TIANXUE YAO, Senior Lecturer – M.A., Carnegie Mellon University, M.A., JiLin University; Carnegie Mellon, 1996–

YOSHIHIRO YASUHARA, AssociateTeaching Professor of Japanese Studies – Ph.D., Pennsylvania State University; Carnegie Mellon, 2010–

BONNIE L. YOUNGS, Teaching Professor of French & Francophone Studies and Director of Undergraduate Studies – Ph.D., University of Pennsylvania; Carnegie Mellon, 1993–

YUEMING YU, Teaching Professor of Chinese Studies – Ed.D., University of Pittsburgh; Carnegie Mellon, 1992–

Department of Modern Languages Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

82-101 Elementary French I
Fall and Spring: 12 units
This course is for students with no prior experience in French. Using a proficiency-oriented approach, students will develop contextually appropriate interpersonal communication skills in both written and spoken French, develop reading and listening skills through the use of various media, understand fundamental grammar, acquire vocabulary, and gain a basic understanding of French and francophone cultures through class activities. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in French must take the placement exam.

82-102 Elementary French II
Fall and Spring: 12 units
This course is designed for students who have taken first-semester French at Carnegie Mellon or learned its equivalent as determined by placement. Using a proficiency-oriented approach, students will expand contextually appropriate interpersonal communication skills in both written and spoken French, continue to develop reading and listening skills through the use of various media, review previously learned and practice new grammar and vocabulary, and gain a further understanding of French and francophone cultures through class activities. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in French must take the placement exam.
Prerequisites: 82-101 or 82-103

82-103 Elementary French I Online
Fall and Spring: 12 units
This course is designed for students with no prior experience with French and who need a more flexible approach to language learning than that offered in a standard classroom course. Beginning language learners will develop communicative competence in the four basic skills of listening, speaking, reading and writing. Basic vocabulary and sentence structures for use in essential daily-life situations, as well as cultural information, are taught through the course materials and assignments. Materials are web-based, with extensive use of Internet technologies for listening, reading, and communication. During regular semesters, this course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. A student with prior experience in French must take the placement exam.

82-104 Elementary French II Online
Fall and Spring: 12 units
This course is designed for students who need a more flexible approach to language learning than that offered in a standard classroom course. Students will learn more useful and complex expressions and sentence structures necessary for use in everyday life. Students will continue building their skills in listening, speaking, reading, and writing for everyday communication. Additionally, course materials and assignments are designed to improve students' understanding of French and francophone cultures and societies. Materials are web-based with extensive use of Internet technologies for listening, reading, and communication. During regular semesters, this course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. A student with prior experience in French must take the placement exam.
Prerequisites: 82-103 or 82-101

82-111 Elementary Arabic I
Fall: 12 units
This course introduces learners to Modern Standard Arabic (MSA) in its written and spoken forms to achieve communicative competence at the elementary level in all language skills (listening, speaking, reading, and writing). To this end the course follows a proficiency-oriented approach to language teaching. In addition to MSA, the course introduces students to one of the popular spoken dialects in the Arab world such as Egyptian, Levantine, or Moroccan (depending upon the instructor's background/expertise). Students will also study various cultural aspects of the Arab world through written, audio-visual and online-based materials. Students with prior knowledge of Arabic must take the placement exam.

82-112 Elementary Arabic II
Spring: 12 units
This course builds on Elementary Arabic I to continue introducing students to Modern Standard Arabic (MSA) to achieve communicative competence at the Novice-High/Intermediate-Low level in all language skills (listening, speaking, reading, and writing). To this end, the course follows a proficiency-oriented approach to language teaching. In addition to MSA, the course continues to introduce students to one of the popular spoken dialects in the Arab world such as Egyptian, Levantine, or Moroccan (depending upon the instructor's background/expertise). Students will continue to explore various cultural aspects of the Arab world through written, audio-visual and online materials.
Prerequisite: 82-111

82-114 Arabic for Global Exchange Online
Fall and Spring: 6 units
Arabic for Global Exchange is a course in Arabic language and culture that utilizes cognitive learning technologies and computer-assisted language instruction to enhance educational, governmental, and business exchanges that are increasingly vital to public policy and economic development in the global economy. This is a mini-course for individuals with no proficiency or extremely limited knowledge of Arabic language and culture who are about to begin study or work in an Arabic-speaking context. The course introduces learners to basic concepts and information to facilitate entry and engagement in an Arabic-speaking environment. The Arabic for Global Exchange project aims to meet a need for high quality, communication-oriented instructional materials to introduce basic cultural knowledge and survival language. Arabic for Global Exchange is a six-week, six-lesson, half-semester course (equivalent of six weeks of university-level instruction), or roughly sixty hours of student effort. Each of the six lessons in the course includes texts and activities to promote acquisition of cultural content in English as well as basic introductory exposure to the Arabic language.

82-115 Beginning Arabic for Oral Communication
Intermittent: 6 units
This course is meant for students who have either taken Arabic for Global Exchange or who seek an introductory course to the Arabic Language. It is designed to give learners an overview of Arabic, and introduce them to the letters, sounds, and symbols that make up the Arabic writing system. In addition to the sounds and letters of Arabic, the course also helps students to master basic vocabulary and important expressions for basic interaction with speakers of Arabic. Students will be provided with written, audio, and visual materials to prepare at home and should come to class ready to speak, read, and write using what they have studied outside class.

82-116 Arabic Cultural Issues Past & Present
Fall and Spring: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. This course is intended for students who wish to master speaking in Modern Standard Arabic (MSA). This is done through reading articles on customs and traditions of the Arabs and discussing them thoroughly in class using MSA. Since this is an elementary level course, it is to help students switch from their dialect to speaking MSA. Through the reading of complex articles and texts on customs and traditions of Arabs and discussing them thoroughly in class using Modern Standard Arabic (MSA), students will engage in academic conversations with the goals of a developing a deeper understanding of Arab cultures and a facility to use MSA at an academic level. An elementary level course, this course is designed for students who wish to improve their proficiency in speaking and reading MSA as an alternative to their dialect.

82-117 Arabic Conversation & Dialect I
Fall and Spring: 6 units
This course introduces students to a particular dialect of Arabic and to the culture of the region where the dialect is spoken. The dialect of the course will vary based on the instructor's background/expertise (for example, Levantine, Egyptian, Moroccan, etc.). This class adopts a proficiency-based approach and the content of the course will be organized around specific themes such as greetings, introductions, directions, family, food, etc. Students will be required to engage actively in speaking activities and complete a variety of related oral practice assignments outside of class. Because of the significant contribution of technology in facilitating and empowering language learning and language teaching, a substantial part of communication, activities, and assignments will be done via programs such as Aswaat Arabiyya, BYKI, Film clips, Skype, Youtube, etc. Please contact the department for specific information on the upcoming semester's course content.

82-118 Arabic Conversation & Dialect II
Fall and Spring: 6 units
This course continues students' exploration of the same regional dialect and culture taught in Arabic Conversation and Dialect I for that particular semester. The content of the course will be organized around specific themes that build on previously introduced topics (e.g., daily schedule, weddings, traveling, hobbies, etc.). Students will be required to engage actively in speaking activities and complete a variety of related oral practice assignments outside of class. Because of the significant contribution of technology in facilitating and empowering language learning and language teaching, a substantial part of communication, activities, and assignments will be done via programs such as Aswaat Arabiyya, BYKI, Film clips, Skype, Youtube, etc. Please contact the department for specific information on the upcoming semester's course content.
Prerequisite: 82-117 Min. grade C

82-119 Arabic Calligraphy Culture & Skills
Fall and Spring: 9 units
This course introduces its participants to historical and cultural contexts and various techniques used to produce Arabic calligraphy works. No previous knowledge of the Arabic script or language is necessary. At the end of the course, participants will demonstrate familiarity and comfort with key movements in the history and art of Arabic calligraphy, and read simple alphabet constructions or words in a variety of styles. Participants will apply proper techniques to producing calligraphy in two of the most commonly used styles, Naskh and Riq'ah, as well as experiment with some modern script styles. The class will use lecture discussions, audio-visual media, projects, guest speakers, and field trips as occasions arise.

82-121 Elementary German I
Fall and Spring: 12 units
This course is for students with no prior experience in German. Using a proficiency-oriented approach, students will develop contextually appropriate interpersonal communication skills in both written and spoken German, develop reading and listening skills through the use of various media, understand fundamental grammar, acquire vocabulary, and gain a basic understanding of German-speaking cultures through class activities. The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). A student with prior experience in German must take the placement exam.

82-122 Elementary German II
Fall and Spring: 12 units
This course is designed for students who have taken first-semester German at Carnegie Mellon or learned its equivalent as determined by placement. Using a proficiency-oriented approach, students will expand contextually appropriate interpersonal communication skills in both written and spoken German, continue to develop reading and listening skills through the use of various media, review previously learned and practice new grammar and vocabulary, and gain a further understanding of German cultures through class activities. The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). A student with prior experience in German must take the placement exam.
Prerequisites: 82-121 or 82-123

82-123 Directed Language Study: Elementary German I or II
Fall and Spring: 12 units
This course is a directed, instructor-supervised version of the courses 82-121 or 82-122. It is recommended for (1) students who are strongly motivated and have the time, self-discipline, and desire to work independently, (2) students whose schedule precludes enrollment in the regular elementary course, and/or (3) students who have had previous German study but are not prepared to take 82-122. This course develops the fundamental language skills as outlined in the descriptions of 82-121 and 82-122, and students complete the same work as for those courses. Written work is turned in for correction and tests covering each unit of material will be taken according to a schedule determined by the instructor. The instructor will be available during office hours or by appointment for individual consultations and testing. Students are permitted to take only one semester of 82-123. Prerequisite: There is no prerequisite for students enrolling for German Elementary I. For students enrolling in German Elementary II, the prerequisite is German Elementary I (82-121) or placement.

82-130 Navigating Chinese Culture: Intro to the Three Kingdoms
Intermittent: 9 units
This course introduces students to the basics of Chinese culture in order to assist them to better understand and appreciate traditional Chinese humanistic ideas, thoughts and value systems, with a focus on the Confucian point of view. Through the study of the classic novel, ?The Three Kingdoms?, the most valued virtues within Chinese culture and society - loyalty, filial piety, benevolence and righteousness ?are presented and discussed. Different aspects of the daily life culture will be introduced as well. Supplementary readings, video clips as well as video games will be used to provide students with a deeper insight, observation and motivation to explore more issues related to Chinese culture, history and philosophy. Assessment will be based on short essays, group projects and individual presentations. Some basic Chinese language instruction will be included to give students a taste of the Chinese language. After taking this course, students will - develop a basic understanding of the essence of Chinese culture - build an awareness of cultural differences between different countries - understand some basic characteristics of Chinese language This course is conducted in English; no prior knowledge of the Chinese culture is required.

82-131 Elementary Chinese I
Fall and Spring: 12 units
This course is for students with no prior experience in Chinese. Using a proficiency-oriented approach, students will develop contextually appropriate interpersonal communication skills in both written and spoken Chinese, develop reading and listening skills through various media, understand fundamental grammar, acquire vocabulary, and gain a basic understanding of Chinese cultures through class and extracurricular activities. Regular homework, quizzes, tests, and participation in class are mandatory (four in-class hours per week). Students will learn the phonetic transcriptions of Chinese (Pinyin) for speaking and listening as well as Chinese characters for reading and writing. The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Chinese must take the placement exam.

82-132 Elementary Chinese II
Fall and Spring: 12 units
This course is designed for students who have taken first-semester Chinese at Carnegie Mellon or its equivalent by placement. Students will continue developing contextually appropriate interpersonal communication skills in both written and spoken Chinese, developing reading and listening skills through various media, and working toward a deeper understanding of Chinese culture. Work for this course will include the introduction and use of more complicated sentence structures, grammar, and expressions. Students are also encouraged to communicate in longer sentences and write short paragraphs and essays in Chinese. Regular homework, quizzes, tests, and participation in class are mandatory (four in-class hours per week). Students will continue to learn the phonetic transcriptions of Chinese (Pinyin) for speaking and listening as well as Chinese characters for reading and writing. The elementary level is designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Chinese must take the placement exam.
Prerequisites: 82-131 or 82-133

82-133 Elementary Chinese Online I
Fall: 12 units
This course is designed for students who need a more flexible approach to language learning than that offered in a standard classroom course. It is designed to help beginners develop communicative competence in the four basic skills of listening, speaking, reading and writing the Chinese language. Basic vocabulary and sentence structures for use in essential daily-life situations, as well as cultural information, are taught through the course materials and assignments. Materials are web-based with extensive use of Internet technologies for listening, reading, and communication. This course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. Students in this class should be prepared to participate in such studies in the course of their classwork. A student with prior experience in Chinese must take the placement exam.

82-134 Elementary Chinese Online II
Spring: 12 units
This course is the continuation of 82-133, Elementary Chinese I Online. Students will continue learning more useful and complex expressions and sentence structures necessary for use in everyday life. Students will also continue building their skills in listening, speaking, reading, and writing for everyday communication, and their understanding of Chinese culture and society. This course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. A student with prior experience in Chinese must take the placement exam. Instructions for the placement exam are available in Baker Hall 160. Prerequisite: 82-131 or 82-133 or placement
Prerequisites: 82-131 or 82-133

82-135 Elementary Chinese for Heritage Students
Fall and Spring: 9 units
This course is designed for students who have some basic knowledge of spoken Chinese, but know little of how to read and write Chinese. While an integrated approach will be applied to the development of all the four language skills of listening, speaking, reading and writing simultaneously, the focus will be on the intensive study of Chinese characters through reading and writing practice. Based on their speaking and listening abilities, students will learn how to communicate in writing in everyday situations. The cultivation of cultural awareness will also be a focus of this course. At the end of this course, students will be well-equipped to continue their study of Chinese at the intermediate level. A student with prior experience in Chinese must take the placement exam. Prerequisites: Placement by test and Chinese group advisor

82-137 Chinese Calligraphy: Culture and Skills
Fall and Spring: 9 units
Chinese calligraphy is a crucial part of Chinese culture and world art. It is also a clear manifestation of Chinese philosophy that has influenced Chinese people for several thousand years. This introductory course on Chinese calligraphy provides students with basic knowledge of Chinese calligraphy and how it mirrors Chinese history, culture, and philosophy. It will also introduce the fundamental characteristics of the Chinese writing system, its cultural content, and principles of formation as well as the skills used in Chinese calligraphy. At the end of the course, students will have a good understanding of Chinese characters and their cultural and philosophical background but also be able to appreciate the art and beauty in Chinese calligraphy. Classes include lectures, movies, discussions, hands-on practice, and projects. Field trips and guest speakers may also be arranged if opportunities should arise.

82-141 Elementary Spanish I
Fall and Spring: 12 units
Elementary Spanish I is the first part of a two-semester course sequence for beginning students, emphasizing the development of communicative language and cultural competence. Students will work towards improving their writing, reading, listening and speaking abilities in Spanish, such that they become comfortable working with a variety of topics from Spanish-speaking cultural areas. Students will develop basic interactional and routine public communication patterns, frequently working in groups and pairs, and utilizing technologies that enhance learning opportunities and promote skill development. This course also provides extracurricular opportunities to interact with members of the Spanish-speaking community. Four hours of in-class instruction per week are required. A student with prior experience in Spanish must take the placement exam.

82-142 Elementary Spanish II
Fall and Spring: 12 units
Elementary Spanish II is the second part of a two-semester course sequence for beginning students, emphasizing the development of communicative language and cultural competence. Students will work towards improving their writing, reading, listening and speaking abilities in Spanish, such that they become comfortable working with a variety of topics from Spanish-speaking cultural areas. Students will develop basic interactional and routine public communication patterns, frequently working in groups and pairs, and utilizing technologies that enhance learning opportunities and promote skill development. This course also provides extracurricular opportunities to interact with members of the Spanish-speaking community. Four hours of in-class instruction per week are required. A student with prior experience in Spanish must take the placement exam.
Prerequisites: 82-143 or 82-141

82-143 Elementary Spanish I Online
Fall: 12 units
Elementary Spanish Online I is for beginning students, emphasizing the development of communicative language and cultural competence. Students will work towards improving their writing, reading, listening and speaking abilities in Spanish, such that they become comfortable working with a variety of topics from Spanish-speaking cultural areas. Students will develop basic interactional and routine public communication patterns. This course is designed for students with no previous knowledge of Spanish and who need a more flexible approach to language learning than that offered in a standard classroom course. All materials are Web-based, with extensive use of Internet technologies for research, writing, and communication. During regular semesters, this course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. Students who have taken Spanish before are required to take the placement exam.

82-144 Elementary Spanish II Online
Spring: 12 units
Elementary Spanish Online II is the second part of a two-course sequence, emphasizing the development of communicative language and cultural competence. Students will work towards improving their writing, reading, listening and speaking abilities in Spanish, such that they become comfortable working with a variety of topics from Spanish-speaking cultural areas. Students will develop basic interactional and routine public communication patterns. This course is designed for students who need a more flexible approach to language learning than that offered in a standard classroom course. All materials are Web-based, with extensive use of Internet technologies for research, writing, and communication. During regular semesters, this course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. A student with prior experience in Spanish must take the placement exam. Instructions for the placement exam are available in Baker Hall 160. Prerequisite: 82-141 or 82-143 or placement
Prerequisites: 82-141 or 82-143

82-161 Elementary Italian I
Fall: 12 units
This course is for students with no prior experience in Italian. Using a proficiency-oriented approach, students will develop contextually appropriate interpersonal communication skills in both written and spoken Italian, develop reading and listening skills through the use of various media, understand fundamental grammar, acquire vocabulary, and gain a basic understanding of Italian culture through class activities. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Italian must take the placement exam.

82-162 Elementary Italian II
Spring: 12 units
This course is designed for students who have taken first-semester Italian at Carnegie Mellon or learned its equivalent as determined by placement. Using a proficiency-oriented approach, students will expand contextually appropriate interpersonal communication skills in both written and spoken Italian, continue to develop reading and listening skills through the use of various media, review previously learned and practice new grammar and vocabulary, and gain a further understanding of Italian culture through class activities. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Italian must contact the Department of Modern Languages for placement.
Prerequisites: 82-163 or 82-161

82-163 Directed Language Study: Elementary Italian I or II
Fall and Spring: 12 units
A self-paced version of first or second semester Elementary Italian, this course is for highly motivated students capable of working independently. The coursework includes weekly classes, aural practice using online materials, periodic assessments, and individual meetings with the instructor. Students are permitted to take only one semester of 82-163. A student with prior experience in Italian must take the placement exam.

82-171 Elementary Japanese I
Fall and Spring: 12 units
This course is the first part of a two-semester course sequence (82-171, 82-172) for students with no prior experience in Japanese. It emphasizes the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Japanese society. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Japanese must take the placement exam.

82-172 Elementary Japanese II
Fall and Spring: 12 units
This course is a sequel to Elementary Japanese I (82-171) and continues to further the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Japanese society. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Japanese must take the placement exam.
Prerequisites: 82-171 or 82-174

82-173 Introduction to Japanese I
Fall and Spring: 9 units
This course is the first part of a two-semester sequence (82-173, 82-174) for students with no background in Japanese. Since it covers the first half of 82-171 in one semester, it is suitable for those students who need sufficient practice time both in and outside of class to begin their study of Japanese. It emphasizes the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Japanese society. Regular homework, quizzes, tests, presentations, and class participation are mandatory (three in-class hours per week plus six hours of required homework). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Students who intend to minor or major Japanese should consult with their Japanese minor or major advisor before deciding on 82-171 or 82-173.

82-174 Introduction to Japanese II
Fall and Spring: 9 units
This course is a sequel to Introduction to Japanese I (82-173) for students with no background in Japanese. Since the course covers the second half of the 82-171 in one semester, it is suitable for those students who need lots of practice time both in and outside class. It continues to further the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Japanese society. The elementary level is also designed to help students learn to reflect upon and draw upon strategies used by good language learners in their second language study. Regular homework, quizzes, tests, presentations, and class participation are mandatory (three in-class hours per week plus six hours of required homework The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Upon completion of this course, students can take 82-172.
Prerequisite: 82-173

82-176 Intensive Japanese Language & Culture: Elementary Level
Intermittent
No course description provided.

82-191 Elementary Russian I
Fall: 12 units
This course is for students who have never studied Russian. It begins the Russian language sequence and is offered in the fall semester only. The course takes a communicative approach to teaching basic skills in listening, speaking, reading and writing. Language is presented in communicative contexts illustrating cultural aspects of daily Russian life. The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Daily homework and participation in class are mandatory (four in-class hours per week), as is weekly consultation and conversation practice with a course assistant. A student with prior experience in Russian must take the placement exam. **If you would like to take this course, but the current time slot does not work with your schedule please contact the instructor as soon as possible and we may be able to accommodate you**

82-192 Elementary Russian II
Spring: 12 units
Elementary Russian II is the second semester of a yearlong beginning Russian sequence. Students who complete this yearlong sequence will acquire the basics of Russian grammar and develop an active vocabulary of approximately 1,000 words. They will learn how to tell simple stories on familiar topics, ask questions, and express their opinions. They will be able to grasp the main ideas of short newspaper articles and understand the gist of straightforward Russian speech. Throughout the course, students will encounter oral, visual, and written content and engage in the interpretive, interpersonal, and presentational modes of communication. A student with prior experience in Russian must take the placement exam.
Prerequisite: 82-191

82-198 Research Training: Modern Languages
Fall and Spring
These courses are designed to give eligible and interested students some hands-on research experience working on a faculty project or in a lab in ways that might stimulate and nurture the students' interest in doing more research. They are open to students who are Dietrich College, SHS, or BHA majors, double majors, and minors who will be second semester freshmen or sophomores during the semester they take the course. Prerequisites: At least a 3.0 cumulative QPA or approval by petition and permission of instructor A sample course contract can be found here: http://www.cmu.edu/dietrich/docs/undergraduate/RTC-Contract.pdf S18: Section A: Section B:Encoding Hispanic Comics This project involves research of Spanish-language comics. The course will teach Comic Book Markup Language (CBML, a TEI-based XML vocabulary) for encoding and analyzing the structural, textual, visual, and bibliographic complexity of digitized comic books and related documents. Student researchers will assist in: a) editing, marking up, and structuring digitized Spanish-language comics; b) reading and subjecting these texts to interpretation, making inferences, and embarking in theoretical explorations of issues according to given criteria. Long-term results of this project entail possible inclusion of encoded materials in the Latin American Comics Archive, collaboration with national and international students and researchers, and perhaps a published work (for which student participants would be acknowledged as contributors). Interested students: Send an email to Professor Gomez and include information about your interests in this project. Open to one or two students with at least intermediate level reading skills in Spanish. Section C:

Course Website: http://www.cmu.edu/dietrich/docs/undergraduate/RTC-Contract.pdf

82-201 Intermediate French I
Fall and Spring: 9 units
At the intermediate level, students will continue to improve listening, speaking, reading and writing skills with the goal of becoming more proficient in daily and extended communication needs. In addition to an ongoing review of basic grammar, a greater variety of grammar, expressions and complicated sentence structures will be taught so that students can carry on more sophisticated conversations on various topics. In-class activities and homework using authentic texts related to the broad spectrum of French and francophone cultures will be used to integrate language learning with content and culture. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory. A student with prior experience in French must take the placement exam.
Prerequisites: 82-104 or 82-102

82-202 Intermediate French II
Fall and Spring: 9 units
At the intermediate level, students will continue to improve listening, speaking, reading and writing skills with the goal of becoming more proficient in daily and extended communication needs. In addition to an ongoing review of basic grammar, a greater variety of grammar, expressions and complicated sentence structures will be taught so that students can carry on more sophisticated conversations on various topics. In-class activities and homework using authentic texts related to the broad spectrum of French and francophone cultures will be used to integrate language learning with content and culture. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory. A student with prior experience in French must take the placement exam.
Prerequisite: 82-201

82-208 Topics in European Studies
Intermittent: 9 units
F17: European Society and Culture Between and After the Two Great Wars of the 20th Century. How did World War I and World War II change European society and culture? Defining the meaning of Europe or European is complicated, since it refers to both a geographical location and a shared history and cultural identity. Based on an interdisciplinary approach to the multiple regions and countries located on a single continent, the course will equip students with the skills, methods, and concepts essential for a better understanding of European culture, society and thought. It will focus particularly on such tragic events as World War I and World War II, and the rise and fall of Nazi and Communist regimes and ideologies. Students will learn how to present material effectively, to analyze texts critically and to construct coherent arguments.

82-211 Intermediate Arabic I
Fall: 12 units
This course builds on Elementary Arabic II to continue building students' communicative competence at the Intermediate Low-Mid level in Modern Standard Arabic in all four language skills (listening, reading, speaking, and writing) following a proficiency-oriented teaching approach. The course also continues to 1) integrate a spoken dialect to enrich students' background in oral communication; and 2) educate students about to various aspects of Arab culture through written and audio-visual materials.
Prerequisite: 82-112

82-212 Intermediate Arabic II
Spring: 12 units
This course follows Intermediate Arabic I. It continues to build students' communicative competence at the Intermediate Mid-High level in Modern Standard Arabic in all four skills (listening, reading, speaking, and writing) following a proficiency-oriented teaching approach. The course also continues to 1) integrate a spoken dialect to enrich students background in oral communication; and 2) educate students about to various aspects of Arab culture through written and audio-visual materials.
Prerequisite: 82-211

82-214 Topics in Modern Arabic Language, Literature, & Culture
Fall and Spring: 9 units
An integrated approach to the study of the Arabic language, literature and culture by means of literary and cultural readings.This course explores definitions of culture and analyzes the dynamic role of language in culture and culture in language, with an aim to foster cross-cultural awareness and self-realization while developing proficiency in Arabic. This course is designed to strengthen listening, speaking, reading and writing, within the context of an evolving Arabic culture.

82-215 Arab Culture Through Film & Literature
Fall and Spring: 9 units
This course introduces students to the Arab World through a lens that challenges stereotypes, fosters a better understanding of the social reality of Arab societies, and appreciates the diverse identities. The objective is to increase cross-cultural understanding and equip students with the skills needed to thrive in the 21st century and become global citizens. Students will build cultural literacy and relationships through virtual meetings with Arab students in Saudi Arabia, Egypt, Qatar, and Morocco, in addition to watching a variety of critically-acclaimed films and reading two novels. Topics covered are the diversity of the Arab World, homo/sexuality, gender roles, social values, the effect of modernization on changes, and revolution music and art that emerged since the Arab uprisings of 2011.

82-216 Literature of the Arabic-speaking World
Fall and Spring: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. This repeatable introductory course explores the Arab world through a thematic or conceptual focus. In spring 2016, the theme will be "Cultural Issues in the West and the Arab World". Coursework will include reading short stories and novels to understand the cultural context that gave rise to specific literary works. Students will also continue to develop their abilities to express their ideas both in speaking and in writing, as well as their listening skills in Modern Standard Arabic.

82-217 Multilingualism and Multiculturalism in the Arab World
Fall and Spring: 9 units
This course brings linguistic and cultural diversity in the Arab world to the forefront through exposing students to the key social issues in the study of multilingualism. To this end, the course will explore and analyze some of the deeply held language ideologies in Arab and international contexts. Topics to be covered in the course include (but are not limited to) multilingualism within and across languages (e.g., multidialectal practices, code-switching between languages, language variation and change), societal and individual multilingualism (e.g. language and identity), multilingualism in institutional sites (e.g. schools, the work place), language policy and planning, and language rights. The course is taught in a seminar, discussion-based format and students will construct projects to explore course topics in a hands-on manner. The course is taught in English and students who wish to take the course as a Modern Languages major or minor elective will need to complete their final project on a topic relevant to the language they study.

82-221 Intermediate German I
Fall and Spring: 9 units
The goal of Intermediate German I is to further develop students linguistic and cultural knowledge, allowing them to feel more comfortable as a user of German. By the end of the semester, students should be able to: use and understand German in everyday situations; communicate effectively in general areas and in individual areas of interest; understand general cultural perspectives in contemporary Germany; and read and understand authentic materials from German-speaking countries. Activities will help develop the four skills and of cultural knowledge. This course focuses on intercultural concepts and will help students see what things Germans view differently from other nations and what things might be similar. Topics will include issues such as travel, politics, immigration, and music. A student with prior experience in German must take the placement exam.
Prerequisites: 82-122 or 82-123

82-222 Intermediate German II
Fall and Spring: 9 units
In this class, students will expand and develop their speaking, listening, reading, and writing skills, as well as their cultural knowledge of German-speaking countries. This course focuses on intercultural concepts and will help students see what things Germans view differently from other nations and what things might be similar. Topics will include issues such as views on German history, prospects for Germany's future, art and artists, and the German film industry. By the end of the course, students should be able to make themselves understood in German and understand German-speakers with experience dealing with foreigners. A student with prior experience in German must take the placement exam. Instructions for the placement exam are available in Baker Hall 160. Prerequisite: 82-221 or placement
Prerequisite: 82-221

82-227 Germany & the European Union
Spring: 9 units
This course offers an overview of contemporary Germany, its problems and its promise, with a particular focus on German politics, the German economy, and Germany's role in the European Union and in the world system. Primary topics include: 1) Germany on the World Stage; 2) Germany and the Past; 3) the German political system; 4) the German economic system; 5) the European Union, its challenges, and Germany's role in it; 6) Germany, the EU, and multiculturalism and ethnic and cultural pluralism, including the role played in Germany and Europe by ethnic, religious, and cultural minorities. Each of these topics will take about 2-3 weeks of the course. Students in the course will be required 1) to complete all required course readings (the equivalent of about three books in English, although in most cases we will be reading chapters from books rather than entire books, plus about five separate articles in English), 2) to take five short fifteen-minute quizzes on the some of the various themes of the course, 3) to do a book review of a book of their choosing dealing with contemporary Germany and/or the European Union and to make a presentation about that book in class, 4) to write three short (four page) papers on the themes of the course, and 5) to participate in two debates about A) Germany's response to the past; and B) Whether or not Germany and the EU should be more open to ethnic, cultural, and religious minorities.

82-230 Topics in Cultural Comparison
Intermittent: 9 units
Courses offered under this repeatable title will transcend the focus on one area or nation or language by engaging in cultural comparison. This course makes full use of the variety of faculty specializations in the department and Dietrich College to broaden students' perspectives and help them gain an understanding of the divergences and convergences of world cultures. This course and all source materials will be in English. Past titles have included The Great Divergence Debate in Chinese Economic History. SPRING 2017:

82-231 Intermediate Chinese I
Fall and Spring: 12 units
This course is the continuation of Elementary Chinese II (82-132). At the intermediate level, students will continue to improve the basic skills of listening, speaking, reading and writing with the goal of becoming more proficient in daily communication needs. In addition to an ongoing review of basic grammar, a greater variety of expressions and complicated sentence structures will be taught so that students can carry on more sophisticated daily conversations on various topics related to every day life. While equal emphasis will still be on both Pinyin and characters, students will be encouraged to use more and more Chinese characters with the help of Pinyin for communication. In-class and extracurricular activities related to the broad spectrum of Chinese culture will be organized to facilitate language learning using knowledge of the cultural background of the language. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory (four in-class hours per week). A student with prior experience in Chinese must take the placement exam.
Prerequisites: 82-134 or 82-132 or 82-135

82-232 Intermediate Chinese II
Fall and Spring: 12 units
This is the second semester of Intermediate Chinese. Its primary goals are to expand students' vocabulary and knowledge of grammar of the Chinese language by learning more new words, expressions, and sentence patterns needed for everyday communication and by consolidating their knowledge through oral and written practice in and out of class. In this course, students will participate in classroom discussions in Mandarin Chinese on various topics concerning everyday life and write short paragraphs on those topics using Chinese characters. Different aspects of Chinese culture will also be introduced during the whole semester through multimedia, lectures, and discussions. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). A student with prior experience in Chinese must take the placement exam.
Prerequisite: 82-231

82-234 Topics in Chinese History
Intermittent: 9 units
In fewer than three decades, the People's Republic of China has transformed itself from an underdeveloped and reclusive state to become the world's next probable superpower. Divided roughly into three sections, this course examines: 1) the miraculous economic development that made China's rise possible; 2) the political system that allowed the Chinese Communist Party to rule over that rise; 3) China's rising global stature and its implications for the rest of the world. In combination these sections allow us to understand how China's rise happened and what it means for the future of the entire globe. Issues addressed include: economic development, inequality, cyber-security and internet censorship, Intellectual Property Protection, China's influence in Africa, China's military capability, and the Beijing Consensus. The goal of this course is to prepare students for a world where China is increasingly important, but also to ask how China got to where it is today, and where it is going as chances are highly likely that students in most any area of study will be influenced by China's future. This course and all source materials will be in English. No knowledge of Chinese is required.

82-235 Fables, Legends and Stories from Ancient Chinese Civilization
Spring: 9 units
This course is designed for intermediate level students who would like to focus on improving their reading and writing skills in Mandarin Chinese. One major course goal is to teach students to read in Chinese with fluency and proficiency within a format of rich cultural content by expanding their vocabulary and building up their knowledge of socio-cultural influences on Chinese language use. Readings will include traditional fables, mini-stories, and articles on the lifestyle and social changes in ancient and modern China. Discussion will be one major class activity, however students will also be expected to develop long-term retention and control of the knowledge acquired through reading and writing assignments.
Prerequisites: 82-231 or 82-135

82-236 Intensive Chinese Language & Culture: Intermediate Level
Spring
No course description provided.

82-238 Topics in Chinese Culture
Intermittent: 9 units
Courses offered under this repeatable title will focus on aspects of modern and contemporary Chinese culture, including, for example, literature, the arts, theater and music, and gender studies. Through the critical analysis of original sources in translation, film, as well as outstanding works of scholarship, students will gain a deeper understanding of important developments in modern and contemporary China and will learn how to locate and evaluate sources of knowledge about China for future study. This course and all source materials will be in English. No knowledge of Chinese is required. Past titles have included Gender & Sexuality in China: Tradition and Transformation. F18: Gender & Sexuality in China: Tradition and Transformation Over the past 100 years, Chinese women and men have seen tremendous changes in their social and private lives as China underwent wars, revolutions, market reform and opening up. The study of gender and sexuality provides a unique opportunity to explore how Chinese social/ private life has been transformed through economic development and social revolution in China. The course begins with a background discussion of Chinese traditions in the field of gender and sexuality, and covers the period from the beginning of the 20th century to the present. It aims to help student explore the answers to questions on the cultural expectations behind the idea of "man", "woman" and "sex" and the role the government p has played in regulating intimacy/sex/gender in different historical periods of China. Discussions will also be conducted on the changes in Chinese people's gender/sexuality experiences in contemporary to help students develop a deeper understanding of the sexual revolution in China, and changing conceptions of gender/sexuality identity under Confucianism, Western Imperialism, socialism and globalization. Course materials include articles, books, as well as films.

82-241 Intermediate Spanish I
Fall and Spring: 9 units
Intermediate Spanish I is the first part of a two-semester course sequence (82-241, 82-242) designed to familiarize students with the cultures and perspectives of the Spanish-speaking world. Students will develop self-expression across a range of culturally significant topics, improving their speaking, listening, reading, and writing skills while working with longer passages of language in context through reading, writing and listening/viewing (e.g. tv series, movies, short novels, plays) and frequently working in groups and pairs, and utilizing technologies that enhance learning opportunities and promote skill development. The course provides extracurricular opportunities to interact with members of the Spanish-speaking community.
Prerequisites: 82-142 or 82-144

82-242 Intermediate Spanish II
Fall and Spring: 9 units
Intermediate Spanish II is the second part of a two-semester course sequence (82-241, 82-242) designed to familiarize students with the cultures and perspectives of the Spanish-speaking world. Students will develop self-expression across a range of culturally significant topics, improving their speaking, listening, reading, and writing skills while working with longer passages of language in context through reading, writing and listening/viewing (e.g. tv series, movies, short novels, plays) and frequently working in groups and pairs, and utilizing technologies that enhance learning opportunities and promote skill development. The course provides extracurricular opportunities to interact with members of the Spanish-speaking community.
Prerequisites: 82-243 or 82-241

82-245 New Directions in Hispanic Studies
Intermittent: 9 units
FALL 2019: Death, Dope, Drag and Doctors in 20th and 21st Century Spanish Film "Even today, I've no idea what the truth is, or what I did with it." ¿ Luis Buñuel, My Last Sigh Spanish film is known for its quirkiness, irreverence and, as referenced by the inimitable Luis Buñuel, contemplation of truth. This course will enter into that discourse by analyzing films from 20th and 21st century Spain. While no prior knowledge of Spanish language, culture nor history are required, interest in cultural exploration and critical thinking are necessary. Film analysis will form part of the crux of the course, as we will examine cinematography, sound, script, and music. Some questions that might arise may include - How does the film portray emotion? How does the film reflect cultural nuance? The class will be student-centered, and thus highly interactive. It is also a goal of this course to stimulate analytical thinking, and to promote the close readings of texts directed by argumentation and well-structured insights. "

82-247 The Hispanic World: History, Culture and Globalization
Intermittent: 9 units
This course examines the histories, cultures, and current socio-political and economic concerns of the Hispanic world including Spain, Latin America, and transnational Hispanic communities around the world. The course provides a historical foundation in order to understand the impact of various historical events on the Hispanic world today such as the Arab conquest, the colonization of Latin America, independence movements, revolutions, dictatorships, democratization, and globalization. We will examine current concerns of the Hispanic world such as democratization processes, trade, economic crisis, and migration that have shaped its languages, cultures, politics, and economies. These topics will be explored through readings, films, music, classroom visits, field trips, and exploration of the Spanish language. The course is intended to lead to a greater knowledge and an increased appreciation of the cultural and historical roots, past and current life-styles, and languages of the peoples of the Hispanic world. (The language of instruction is English.)

82-248 Topics in Social Change
Fall and Spring: 9 units
FALL 2019: Arts, Media and Social Change: The Arts in Revolution ¿ Cuba and Nicaragua. This course will examine the Cuban and Nicaraguan Revolutions and their relationships to artistic production in a larger socio-political context, considering the complex dynamic of both fomenting creative expression, while also (on occasion) stifling its content. 2019 marks 60 years since the Cuban Revolution, touted as the victory of a tiny island over US imperialism, and 40 years since the triumph of the Sandinistas in Nicaragua - both cases garnering broad international attention due to their importance in Cold War political agendas and the subsequent interplay of US-Soviet relationships in the US' "backyard". While quite different, the Cuban and Nicaraguan Revolutions shared an inherent understanding of the value of capturing the public imaginary and support through the use of the arts to promote their messages and as such, invested significant resources in the promotion of creative production. This course will interrogate the relationships between political and artistic movements, examining for example the formation of ICAIC (Instituto Cubano del Arte e Industria Cinematográficos) in Cuba and the mural movement in Nicaragua. Once these political movements had triumphed, how did artists negotiate the institutionalization of revolution? How did the role of prominent cultural workers like Tomas Gutierrez Alea (Cuba) and Ernesto Cardenal (Nicaragua) evolve as these revolutions aged? We will also question the dynamic between artists whose works express discontent and the State - what was/is the space for dissent? How do artists of newer generations create space for different types of expression that diverge from what early revolutionary moments considered to be transformative? Decades later with deeply entrenched governments, what now is the relationship between the arts and socio-political change?

82-249 Hispanic Language & Cultures for the Professions
Fall and Spring: 9 units
FALL 2019: This course focuses on building proficiency in Spanish-language communicative skills and cultural awareness for business contexts in the very diverse Spanish-speaking world, one with over 437 million speakers worldwide. Students will be introduced to a variety of contexts in the Spanish-speaking world of global business and finance through multimodal materials, e.g., newspapers, film, advertisements, and other relevant texts. By examining different scenarios such as job interviews, international trade, and workplace environments, students will build knowledge of vocabulary and develop a real-world understanding of appropriate linguistic, cultural, and discipline-specific practices.
Prerequisite: 82-241

82-253 Korean Culture Through Film
Intermittent: 9 units
South Korean cinema became one of the most vibrant local film industries at the end of the last century, attracting great attention from both the public and scholars, not only at home but abroad as well. Intriguingly, its renaissance involves a strong tendency to revisit and reassess a variety of historical traumas from the last century, which makes it an important venue for discussing the evolution of modern Korean society and culture. This course thus explores works of acclaimed filmmakers such as Im Kown-taek, Park Kwang-su, Jang Sun-woo, Hong Sang-soo, Lee Chang-dong, Park Chan-wook, Bong Joon-ho, Kim Ji-woon, etc. to enrich our understanding of social and cultural formations in South Korea over the last century. In examining the voices from the Korean peninsula whose history had remained obscured until recently, this course also aspires to contribute fresh perspectives to broader geopolitical settings such as East Asian and Pacific Rim discourses.
Prerequisite: None

82-254 World of Korea, Then and Now
Intermittent: 9 units
Over the past two decades or so, South Korea has grown to become a major player, not only in East Asia, but also in world politics, economy, and culture. While Korean society thus certainly deserves enough attention as a venue for discussing the changes occurring across the world, its history and culture still remains less known than it should be to the outside world including the U.S. This course thus aims to offer an opportunity to explore the evolution of Korean society and culture over the course of its modern history. By enriching the knowledge of Korean history, it also hopes to help the student gain fresh perspectives on broader contexts such as East Asia and the Pacific Rim. This course covers a broad range of time periods: the colonial era to the present. Yet designed to inspire critical approach rather than just offer sketchy overviews, it is structured around key sociocultural issues such as colonial legacies, the cold war paranoia, dictatorship, democratization, national culture, gender politics, diaspora, globalization, hallyu (k-pop/k-drama), etc. To better serve its objectives, this course also utilizes diverse forms of texts: historical studies, critical essays, literary works, films, TV dramas, and music videos. Prerequisite: None

82-261 Intermediate Italian I
Fall: 9 units
This course begins a two-semester course sequence (82-261, 82-262) for intermediate-level students. At the intermediate level, students will continue to improve listening, speaking, reading and writing skills with the goal of becoming more proficient in daily and extended communication needs. In addition to an ongoing review of basic grammar, a greater variety of grammar, expressions and complicated sentence structures will be taught so that students can carry on more sophisticated conversations on various topics. In-class activities and homework using authentic texts related to the broad spectrum of Italian culture will be used to integrate language learning with content and culture. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory. A student with prior experience in Italian must take the placement exam.
Prerequisites: 82-162 or 82-163

82-262 Intermediate Italian II
Spring: 9 units
At the intermediate level, students will continue to improve listening, speaking, reading and writing skills with the goal of becoming more proficient in daily and extended communication needs. In addition to an ongoing review of basic grammar, a greater variety of grammar, expressions and complicated sentence structures will be taught so that students can carry on more sophisticated conversations on various topics. In-class activities and homework using authentic texts related to the broad spectrum of Italian culture will be used to integrate language learning with content and culture. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory. A student with prior experience in Italian must take the placement exam. Instructions for the placement exam are available in Baker Hall 160. Prerequisite: 82-261 or placement
Prerequisite: 82-261

82-263 Intensive Italian Language & Culture: Intermediate Level
Intermittent: 9 units
No course description provided.

82-267 Topics in Italian Language & Culture
Intermittent: 9 units
FALL 2019 Beyond the Mafia and Michelangelo: Italy Unmasked Eclipsed by the consumer obsessions of tourists and the most well-known figures of Italian history, the uniqueness of Italy, offering distinct cultures in the north, central, and south, is rarely understood by outsiders. In this course, students will discover an Italy rich with cultural variants, radically diverse histories, customs, cults, and superstitions, in addition to physical expressions of culture in cooking and clothing, art and architecture. Students will identify and critically analyze diversity within the peninsula and its islands, and expand their awareness and understanding of the role of culture in behavior. Film, documentaries, and readings from epistolary and literary sources will help reveal a more profound Italy, for example, the science of Dulbecco (the Human Genome), the architecture of Trulli conical houses, the religious importance of Pitigliano ('Little Jerusalem'), and the immigration problems of San Marino. Coursework will include class participation, readings, film viewings, and writing. Final projects will be based on interviews and oral histories with the Italo-American community in Bloomfield (Pittsburgh), leading to critical comparisons of that population with Italians in Italy. This course is offered in English.

82-271 Intermediate Japanese I
Fall and Spring: 12 units
This course is the first part of a two-semester course sequence (82-271, 82-272). At the intermediate level, students will continue to improve the basic skills of listening, speaking, reading and writing skills with the goal of becoming more proficient in daily communication needs, and takes an integrated approach to the study of Japanese language and culture, consisting of grammar review, reading, and intensive practice in written and spoken Japanese. Course materials include authentic audiovisual and written texts in addition to the assigned textbooks. Also integrated are cultural explorations through direct interactions with native speakers. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory (four in-class hours per week). A student with prior experience in Japanese must take the placement exam.
Prerequisite: 82-172

82-272 Intermediate Japanese II
Spring: 12 units
This course is a sequel to Intermediate Japanese I (82-27182-171). At the intermediate level, students will continue to improve the basic skills of listening, speaking, reading and writing skills with the goal of becoming more proficient in daily communication needs, and takes an integrated approach to the study of Japanese language and culture, consisting of grammar review, reading, and intensive practice in written and spoken Japanese. Course materials include authentic audiovisual and written texts in addition to the assigned textbooks. Also integrated are cultural explorations through direct interactions with native speakers. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory (four in-class hours per week). A student with prior experience in Japanese must take the placement exam. Prerequisite: 82-271 or placement
Prerequisite: 82-271

82-273 Introduction to Japanese Language and Culture
Fall and Spring: 9 units
This course is an introduction to modern Japanese. Given the close link between the Japanese language and culture, the examination of the distinctive characteristics of the Japanese language and its sociocultural context provides important insights into contemporary Japan. This course is taught in English and is intended both for individuals who want to gain a better understanding of modern Japanese society, as well as for students of the Japanese language.

82-276 Intensive Japanese Language & Culture: Intermediate Level
Intermittent
No course description provided.

82-278 Japanese Film and Literature: The Art of Storytelling
Intermittent: 9 units
This course explores how the art of storytelling is in tandem with the vicissitudes of the human condition as illustrated in Japan's variety of fictions, non-fictions, and films in the twentieth and twenty-first centuries. Analyses of each storytelling not only reveal the cultural dynamics behind Japanese modernity, but also invite students to find new insights into Japanese culture and their ways of perceiving our globalized world. What kind of cultural exchanges took place between modern Japan and the West? How are Japan's traditional values transformed in the face of modern technicalization and industrialization, compared to the modernization of other countries? And, in turn, what kind of impact has modern Japanese culture had on today's world? Tackling these questions among others, the course also extends to such issues as the legacy of traditional Japanese culture, the modern Emperor system, World War II experiences, emerging voices of minorities, and popular culture (e.g., anime and subculture). This course is taught in English.

82-279 Anime - Visual Interplay between Japan and the World
All Semesters: 9 units
In contemporary Japanese culture, anime plays a vital role, unfolding a wide range of stories with its distinct modes of visual representation and complementing to other forms of culture (e.g., literature, film, and art). This course explores Japanese anime¿s appeal to the international viewers today, centering around cultural analyses of anime such as the Studio Ghibli production and Cyberpunk. Equally important are to locate the origin of Japanese animation, which is also investigated through the prewar and postwar works of animation in conjunction with related forms such as manga, or comic strips (e.g., Osamu Tezuka¿s works that was initially inspired by Disney) and to discuss the potential of anime as an art form.

82-280 Learning About Language Learning
Fall: 9 units
This seminar focuses on the role of diverse affective, cognitive and social factors in second language learning. All participating students are required to be studying an additional language while taking this seminar. Each class is devoted to discussion of assigned readings as well as to completion of various measures, inventories or questionnaires that assess diverse predictors of second language learning. These data are collected throughout the term, and then analyzed and related to predictions based upon previous research that have been discussed in class. Each student also identifies a "good" or a "poor" second language learner to interview and then report back to the class on the learners' characteristics. Prerequisite: None
Corequisite: Study of a foreign language

82-281 Tutoring for Community Outreach
Intermittent
6-9 units This course enables students to participate in a community outreach program in the Pittsburgh Public Schools with either elementary school, middle school, or high school students, and, depending on the site, foster their studies of Chinese, French, German, Japanese, Spanish or ESL. The elementary school experience will involve regular visits, mentoring, and tutoring at school sites in the East End of Pittsburgh. The middle school experience provides opportunity for tutoring in Japanese, French, or Spanish at Barack Obama Academy of International Studies. The high school or middle school experience invites advanced students, majors, or minors in Chinese, French, German, Japanese, or Spanish to work with language students and teachers at local schools. During the early weeks of the semester, students will meet to arrange their community outreach activities and prepare for their experience. Depending on the number of units to be earned, students will spend a certain number of hours per week engaged in some of the following activities: attending and participating in the individual and group meetings, working in the schools four to six hours per week, reading and preparing for their volunteer activities, keeping a journal of their experiences and responses to course readings, writing a paper or completing a project at the end of the term that reflects experiences. The weekly on-campus class meeting will run 50 minutes. The remaining 30 minutes will be devoted to individual consultations related to school-site activities. The final course grade will be based on the student's participation at the school site and fulfillment of the plan set at the beginning of the semester, participation in weekly on-campus discussions, weekly journal submissions, and final synthesis project.

82-282 Community Service Learning
Intermittent
In this course students of Modern Languages will work in the Pittsburgh community to promote learning of cultures and languages. This work may be done to complement course work in modern languages on campus and involve an experience in one of a variety of community settings, such as a heritage language school, hospital translation center, or neighborhood center. Grade will be based on the student's participation at the outreach site and fulfillment of the plan set at the beginning of the semester.
Prerequisite: Permission of instructor

82-283 Language Diversity & Cultural Identity
Fall and Spring: 9 units
Culture, language, and identity are intimately tied together. Individuals, families, communities, and nations identify themselves in relation to the language or languages they speak. Local, national, and international governmental organizations make choices about the language or languages they recognize and use for political and economic affairs. The United Nations even recognizes language as integral to maintaining the cultural heritage of communities and peoples around the world, and the freedom to choose ones language of expression as a universal human right. In this course, we will explore a variety of questions, advantages, and challenges related to language diversity and cultural identity across the globe. Our main focus will be on contexts of multilingualism that is, contexts in which two or more languages may be used. Adopting a comparative case study approach, we will explore the following themes: (i) The historical underpinnings of language diversity and its consequences for cultural identity today (e.g., migration, colonization, conquest); (ii) How language diversity and cultural identity shapes, and is shaped by, local, regional, national, and international politics; (iii) The relationship between language diversity and language use and visibility in public spaces (i.e., the linguistic landscape); (iv) Relations between linguistic communities (e.g., majority and minority language users) and the sense of belonging to a culture. The course is taught in English. Students who wish to take the course as a Modern Languages major or minor elective will need to complete their final project on a topic relevant to the language they study.

82-284 Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit
Fall and Spring: 9 units
Pittsburgh is known for its multicultural landscape and communities. Through this course, students will explore the cultures, identities, languages, and groups that have historically shaped, and are still shaping Pittsburgh. Students will develop digital documentation of the city¿s communities, for example using video, photography, audio podcast augmented AR and immersive VR. Through active learning, students will employ approaches such as testimony, psycho-geography, use map-making and topographical tools, and explore data visualization and 3D imaging. Students will craft their work in a new multimedia space for engagement with global languages and cultures housed in the newly opened Tepper Quad, and at the end of the semester, their work will be on exhibit for the campus community and the wider public. This course will develop your research and fieldwork skills, media creation skills and multicultural literacy. The only pre-requisites are an adventurous spirit and an open approach to creativity. Limited to 12 students.

82-285 Podcasting: Language and Culture Through Storytelling
Fall: 9 units
Do you love stories? Stories told on the radio have always had significant power. For example, the 1938 War of the Worlds broadcast by Orson Welles was so effective that it panicked the entire United States. Today, podcasts such as Serial, This American Life, and The Moth have the same power to tell stories and provide audiences with rich, intimate and immersive audio experiences while often supporting diversity and giving voice to minorities and those under-represented in mainstream media. Owing its rising popularity to the ease and accessibility of production and distribution, there has never been a better time to create and tell stories in audio. In this course students will take on the role of podcast producers, learning while creating a series of podcasts that explore linguistic and cultural landscapes with the goals of educating and entertaining. Possible audio resources include field interviews with native speakers in their own language, allowing student producers to document informants' personal histories and aspects of their life related to culture, multilingualism, or political, social or environmental issues. Students will blend studio recordings with interviews and/or suitable "found" recordings, music, and sound. Coursework will include skill development on audio recording and podcasting, production management, creative thinking, materials sourcing, and giving and receiving constructive feedback from classmates and varied audiences on team and individual projects. The course will be offered in English.

82-286 Understanding Cultural Complexities
Fall and Spring: 9 units
Section A: Haiti: Challenge & Hope: CANCELLED Section B: Service Learning or Poverty Tourism? Exploring Pedagogy & Privilege in Int'l Contexts: We will examine the phenomenon of short-term trips to the developing world, as thousands of people each year travel from the United States to Asia, Africa and Latin America with the goal of "helping" people. Recently, this has been one of the fastest-growing populations of students who go abroad. From church groups, to medical organizations, to student groups, these initiatives propose to build houses, provide medical care, plant trees, and teach children. There is no shortage of projects. What do these short-term engagements do, and who is served? We will explore the ethical questions that arise around the themes of "service" and "engagement", with particular focus on initiatives in Latin America. We will consider to what extent these projects respond appropriately to the cultural contexts. What is the responsibility of participants to ensure the best experience for the communities they visit? Can these initiatives have the impact they propose? Students who have participated or will participate in short-term service trips are encouraged to enroll. Opportunity will be given to study the organizations and locations related to their trips.

82-288 Introduction to Haitian Studies
Intermittent: 9 units
TBA

82-291 Intermediate Russian I
Fall: 12 units
This course is designed for students who have taken two semesters of Russian at Carnegie Mellon or the equivalent. It is offered in the fall only. This course furthers communicative proficiency through intensive practice in written and spoken Russian. Complex grammatical structures and stylistic variations are mastered and extensive vocabulary is acquired. Through reading materials, fictional and non-fictional, acquaintance is made with the basic components of Russian cultural literacy as well as the distinctive cultural aspects of daily Russian life. Attention is directed toward the dynamic interaction of language and culture in order to foster cross-cultural awareness. Attendance is required at three-hourly class meetings per week, as is weekly consultation and conversation practice with a peer language assistant. **"If you would like to take this course, but the current time slot does not work with your schedule please contact the instructor as soon as possible and we may be able to accommodate you**
Prerequisite: 82-192

82-292 Intermediate Russian II
Spring: 12 units
In this second semester of the yearlong intermediate Russian course students will review the basics of Russian grammar, develop listening comprehension, and expand their vocabularies. They will learn to relate simple narratives on familiar topics, express their opinions, ask questions, and speak about hypothetical situations. Students will be able to grasp the main ideas and certain nuances of texts presented in print and visual media as well as conduct straightforward conversations with native speakers. Students will also begin to build their skills in interpreting Russian poetry, literary prose, and film. A student with prior experience in Russian must take the placement exam.
Prerequisite: 82-291

82-293 Russian Cinema: From the Bolshevik Revolution to Putin's Russia
Intermittent: 9 units
"Last night I was in the kingdom of shadows," said the writer Maxim Gorky in 1896 after seeing a film for the first time. "How terrifying to be there!" Early film inspired fear and fascination in its Russian audiences, and before long became a medium of bold aesthetic and philosophical experimentation. This seminar-style course surveys the development of Russian and Soviet film, paying equal attention to the formal evolution of the medium and the circumstances¿historical, cultural, institutional¿that shaped it. We will examine Sergei Eisenstein's and Dziga Vertov's experiments with montage in light of the events of the Bolshevik Revolution and the directors' engagement with Marxism; Georgi Alexandrov's and the Vasiliev brothers' Socialist Realist production against the backdrop of Stalinist censorship; Andrei Tarkovsky's and Kira Muratova's Thaw-era films within the broader context of New Wave Cinema; and the works of contemporary directors, including Aleksei Balabanov, Alexander Sokurov, and Andrey Zvyagintsev, in connection with the shifting social and political landscape of post-Soviet Russia. Besides introducing students to the Russian and Soviet cinematic tradition, this course will hone their skills in close visual analysis. No prior knowledge of Russian language or culture is required. The course is conducted in English, but students will have the option to do work in Russian for three extra course units.

82-294 Topics in Russian Language and Culture
Intermittent: 9 units
SPRING 2019: Topics in Russian Language and Culture: 20th Century Russian Masterpieces. The October Revolution of 1917 had profound effects not only for Russian society, but also for literature and culture. Even before the Revolution, Vladimir Lenin stressed the importance of literature on the hearts and minds of people. After the Revolution, the new Soviet state demanded writers to become, in Stalin's words, engineers of human souls, and proclaimed socialist realism as the only permissible method of creative work in literature. This course focuses on masterpieces of Russian prose and poetry of the 20th century. Readings will include the proletarian writings of Maxim Gorky, the symbolism of Alexander Blok, the futurism and modernism of Vladimir Mayakovsky, as well as works by many other authors. We will discuss such important issues for Russian cultural history as the role of the intelligentsia in the Russian Revolution; the content and method of Russian decadence; symbolism and modernism; and the experience of imprisonment, liberation, and exile that became so important for many writers and poets.

82-296 A Century of Russian Film
Intermittent: 9 units
FALL 2014 This course presents a selection of the dominant works, directors and genres that have defined Russian film-making from its birth to the present. About twenty sub-titled films are viewed and discussed within the context of artistic trends and political events shaping the Russian film industry. Films are screened in class on Mondays. While the primary aim is to acquaint you with Russian film in its cultural context, a secondary purpose is to focus your attention on the aesthetics of film form. This will increase your pleasure in viewing any film, Russian or otherwise. Discussion will be organized around topics such as these: intellectual climate and key issues in national life at the time of a film?s making; a film?s major and minor themes; historical/national/political/social/artistic issues a film raises; how a film affects its viewers? thinking about these themes and issues. The instructor's own experience as a film director will provide further insight into various aspects of film-making and getting a deeper pleasure from viewing film. No knowledge of Russian is required.

82-299 Alternative Break Project (General)
Intermittent
This course provides ML language students and non-ML students enrolled in an Alternative Break student trip project the opportunity to earn credit by engaging in "connected" modes of knowing, by identifying and analyzing a problem, and developing plans for short-term and sustainable solutions, reflecting, and creating and disseminating an informational and interpretive website and print materials about their experience. Students will also bring to bear or gain experience in non-academic skills/talents/interests in areas like photography, image editing, video production, writing, design, website development, sound recording, and art, etc., by doing community service under the auspices of Carnegie Mellon University's Alternative Break program. Students will earn three (3) units for full participation and fulfillment of course requirements. With the approval of the faculty facilitator, an additional three (3) units may be earned by completing an additional assignment. Prerequisite: Permission of instructor

82-300 Language & Society in the Arab World
Fall and Spring: 9 units
Course content varies. Last offered topic: Negotiating Arab Identities & Gender Roles in Film & Literature. This course focuses on the processes of self-definition by Arab men and women in conflict zones in the Middle East and North Africa with relation to national and religious identities, social stratification, sexuality/homosexuality, and gender roles. Students will learn about the social, economic, and political contexts of the films and literary works representing the Maghreb, Egypt, Palestine, Lebanon, Syria, Iraq, the Gulf countries, and Yemen. This course fosters a better understanding of Arab societies and the hybrid identities that negotiate their presence and space within. Students will have the opportunity to engage in a video-conference dialogue with students in the American University in Cairo, Egypt, attend an Arab film during CMU's International Film Festival, and interview native speakers of different Arab countries to further their learning of Arab culture.

82-303 Introduction to French Culture
Fall and Spring: 9 units
Through deep cultural analysis of France and the French, students attempt to discover the French "mentality" or what it means to be French. By studying French history, institutions, regions, literature, and current events, students understand how a cultural identity is developed throughout a country's history. Comparisons between current events and France's cultural and social development from the Renaissance forward explain in part the French mentality and how and why France and the French react to the world as they do. The coursework will develop students skills in writing, reading, speaking, and listening, and improve their control of grammar through class discussions, presentations, and essays. Prerequisite: 82-202 or placement
Prerequisites: 82-204 or 82-202

82-304 The Francophone World
Fall and Spring: 9 units
This course introduces the students of French to several of the francophone regional cultures outside of France, including North and sub-Saharan Africa, Belgium, Switzerland, Quebec, Louisiana, and the French Antilles. The culture commonly associated with the French language is the primarily Christian and Cartesian European tradition. Through this course, students will learn about the socio-political and cultural realities of the Francophone sphere. The course will also explore the multiple synthetic cultural realities which have arisen through the colonial and post-colonial processes of contact between European and non-European cultures, and which are now expressed through the medium of the French language. Students will expand their interpersonal and presentational communication skills in both written and spoken French, improve reading and listening skills through various media so as to analyze content objectively, use appropriate vocabulary and grammar to express critical judgments, synthesize ideas from different source materials, and continue perfecting cultural analysis skills. Assignments will include using accepted academic conventions for research documentation and exposition. Social debates and current events will add a valuable perspective to our study.
Prerequisite: 82-303

82-305 French in its Social Contexts
Fall and Spring: 9 units
S18: This course is designed to introduce students to how the French is used by its speakers to create meaning in a wide variety of contexts, which in terms are influenced by various variables (e.g., the political and historical circumstances within which French has developed and continues to change, social and geographic variables). To explore these issues, we will create interactive multimedia experiences aimed at being deployed on an interactive video wall and/or in augmented reality settings. This course includes a trip to France over Spring Break. If you have experience in French as well as design, film and photography, or computer-science, this is a course for you! Prerequisites: 82-303 and 82-304 or permission of the instructor,
Prerequisites: 82-303 and 82-304

82-311 Advanced Arabic I
Fall: 9 units
This course promotes multiple literacies in an integrated approach to Arabic language and culture studies and builds students' ability to function at the Intermediate High/Advanced Low level in a variety of topics. It also embraces the diglossic nature of Arabic by explicitly integrating the teaching of Arabic regional spoken varieties alongside Modern Standard Arabic. Moreover, the course incorporates Computer and other Technology Assisted Language Learning pedagogies to support student learning inside and outside the classroom. The course is aligned with ACTFL's updated Arabic guidelines that perceive the Arabic language as a continuum in which both the regional spoken varieties and Modern Standard Arabic constitute a whole in terms of usage.
Prerequisite: 82-212

82-312 Advanced Arabic II
Spring: 9 units
The course is the continuation of Advanced Arabic I. It continues promoting multiple literacies in an integrated approach to Arabic language and culture studies and builds students' ability to function at the advanced level in a variety of topics. It also embraces the diglossic nature of Arabic by explicitly integrating the teaching of Arabic regional spoken varieties alongside Modern Standard Arabic. Moreover, the course incorporates technology-assisted language learning pedagogies to enhance student learning inside and outside the classroom. The course also implements ACTFL's Arabic guidelines that recognize Arabic as a continuum in which both the regional spoken varieties and Modern Standard Arabic constitute a whole in terms of language use.
Prerequisite: 82-311

82-313 Topics in Modern Arabic Language, Literature and Culture
Fall: 9 units
This course explores definitions of culture and analyzes the dynamic role of language in culture, and culture in language, with an aim to foster cross-cultural awareness and self-realization while developing proficiency in Arabic. Using an integrated approach to the study of the Arabic language, literature, and culture through close readings of current media sources (press, news, magazines, as appropriate), and literary and cultural readings. Additionally, this course is designed to strengthen listening, speaking, reading and writing, within the context of an evolving Arabic culture.

82-314 Literature of the Arabic-speaking World
Intermittent: 9 units
This repeatable introductory course explores the Arab world through a thematic or conceptual focus. In spring 2018, the theme will be 'Diversity in The Arab Culture'. Coursework will include reading short stories and novels to understand the cultural context that gave rise to specific literary works. Students will also continue to develop their abilities to express their ideas both in speaking and in writing, as well as their listening skills in Modern Standard Arabic. There is no prerequisite for this course but it is expected that your language proficiency in the Arabic language is good. **This is a content course in the Arabic language and not an Arabic language course.**

82-320 Contemporary Society in Germany, Austria and Switzerland
Fall: 9 units
This course offers an introduction to contemporary German culture since 1989. Switzerland and Austria will be frequently included in class discussions but the main focus will be on Germany. In the wake of reunification, constructions of German cultural identity have undergone radical changes. Through encounters with articles, literary texts, popular music, and film students will explore these transformations and examine German culture and (both individual and collective) "identities" after reunification. The class sessions will be organized around several thematic segments, including East/West relations during and after reunification, German media, multiculturalism and minorities, and, finally, a segment on how to navigate the business world in German-speaking countries. The course will be conducted entirely in German and is designed to deepen students' understanding and awareness of issues in contemporary German culture.
Prerequisite: 82-222

82-323 Germany, Austria and Switzerland in the 20th Century
Spring: 9 units
This course advances proficiency in communicative and grammatical skills in the German language and knowledge of German-speaking cultures through the study of important events, trends, and people of the twentieth century in Germany, Austria, and Switzerland. Examples will be drawn from literature, newspapers, television, film and other sources. Students will be expected to complete assignments that demonstrate the ability to express critical judgments in both written and oral form, documented through readings and personal research. The course includes a review of the most troublesome points of German grammar.
Prerequisite: 82-222

82-327 The Emergence of the German Speaking World
Intermittent: 9 units
The Italian literary theorist Franco Moretti has written that "Germany is a sort of Magic Stage, where the symbolic antagonisms of European culture achieve a metaphysical intractability, and clash irreconcilably. It is the center and catalyst of the integrated historical system we call Europe." This course is a general introduction to German culture, German history, and German society, with a focus on Germany's role as center and catalyst of the European system. The course is conducted entirely in German. Its goal is to provide students with a basic level of cultural literacy about the German-speaking world. In the course, we will study major trends from the earliest days of German civilization through the middle ages but with primary emphasis on the 18th, 19th and 20th centuries and with a special focus on problems of national, political and cultural identity. Students coming out of the course should have a broad understanding of the various tensions and problems that have characterized German culture and society for the last two centuries. In addition to broadening students' cultural knowledge about the German-speaking world, this course will continue to emphasize the improvement of students' ability to speak, read, write, and listen to German.
Prerequisites: 82-323 or 82-320 or 82-324

82-331 Advanced Chinese I
Fall and Spring: 9 units
This course is designed for students who have reached the intermediate level of proficiency in the use of Chinese language to develop their language competency in all four skills to a more advanced level. Students will expand explicit knowledge of socio-cultural influences on Chinese language use, and be able to apply the knowledge to conduct culturally appropriate spoken and written communication across various social domains and genres. Topics to be covered in this class will be closely related to some current social issues in China, such as population, youth, love & marriage, and popular culture. Students will also develop a repertoire of strategies and resources to assist their learning so that they will be gradually become autonomous learners who are able to conduct independent learning of the Chinese language, culture, history, and society. Classroom discussions and essay writing will be the major forms of work throughout the semester. Research projects on Chinese culture and society are also a requirement so that students will be able to gain a deeper understanding of the cultural background of the language. With Pinyin for support, students will learn both the traditional and simplified forms of Chinese characters.
Prerequisites: 82-232 or 82-235

82-332 Advanced Chinese II
Fall and Spring: 9 units
A continuation of Advanced Chinese I, this course is designed to improve students' proficiency to function with Chinese in situations beyond their everyday life. Students will continue to learn more complex language phenomena in order to use exposition, explanation, description, and argumentation in Chinese. More sophisticated language phenomena will be introduced to students together with their social and cultural background through texts and multimedia related to various social issues in China today, for example, traffic, education, employment, healthy living, and other human relations as well as economic situations. Classroom discussion and research project presentations will be the major forms of oral practice, and writing practice will mainly focus on essays and group research project papers.
Prerequisite: 82-331

82-333 Introduction to Chinese Language and Culture
Fall and Spring
This course will introduce students to important developments in China's culture and language since the end of the nineteenth century focusing on the interactions between Chinese and Western cultural traditions and the historical, social, and political contexts in which these interactions evolved. The following questions will motivate discussion: What is Chinese culture in the modern world? What is "modern" and what "traditional" Chinese culture? How does high culture interact with folk culture and popular culture? How have education and language policies shaped Chinese cultural identities over the last century? What does it mean to be Chinese in a diaspora context? Secondary readings, primary documents, and video material chosen for analysis will provide students with important insights into the diverse factors that have been shaping contemporary Chinese culture. This course is conducted in English with no requirement of prior knowledge of Chinese language for students who take it for 9 units. Students who take this course towards fulfillment of requirements for the Chinese major or minor must register for 12 units requiring completion of three (3) units of study in Chinese Studies. Prerequisites: To register for 12 units, there is a prerequisite of either 82-232 or 82-235 or placement. There is no prerequisite for students taking the course for 9 units.

82-334 Structure of Chinese
Fall and Spring: 9 units
This is an upper-level Chinese course for students who have completed the requirements for intermediate Chinese with the goal of enabling students to build up a more comprehensive and systematic understanding of the structure of Chinese so as to lay a solid foundation for the further development of their advanced level language proficiency. This course will cover major complicated structural phenomena in Modern Chinese through the study of specially selected sample texts. Special emphasis will be given to high frequent errors and weaknesses on particularly problematic elements and sentence structures that are common among non-native Chinese speakers. After this course, students can expect to have the ability to use Chinese more accurately and naturally in both speaking and writing on sophisticated topics in life. Prerequisite: 82-232 or 82-235 or placement
Prerequisites: 82-235 or 82-232

82-335 Chinese Culture Through Legends and Folktales
Intermittent: 9 units
This is an upper-level Chinese Reading course for students who have reached intermediate level proficiency in Chinese. It is designed to train students to read extensively in Chinese with fluency and proficiency within a context of rich cultural content. Materials used in this class are selected from traditional fables, mini-stories, and articles from newspapers and magazines on the lifestyle and social changes in modern China. While discussion will be one of the major class activities, students are strongly encouraged to profit from opportunities to build their vocabulary and improve their sense of the Chinese language through reading and writing assignments throughout the semester. Prerequisite: 82-232 or 82-235 or placement
Prerequisite: 82-232

82-337 Mandarin Chinese for Oral Communication I
Fall: 9 units
This course is designed for students who have reached intermediate level in reading and writing Chinese, but have little knowledge of Mandarin Chinese pronunciation, as well as those who aim to further improve their speaking in Chinese. Students will be introduced to Pinyin, the phonetic system of Mandarin Chinese, and work to refine and perfect their speaking skills through special attention to different styles, colloquialisms, and dialectal variations of contemporary spoken Mandarin. Course materials will include authentic Chinese TV programs, documentaries, films, recorded materials, and contemporary literary and non-literary texts. Students will be required to participate in intensive speaking activities, such as interviewing native speakers of Chinese, oral presentations, discussions, debates, and special projects. At the end of the course, students are expected to carry on oral communication with native Mandarin speakers in a clearly participatory fashion on topics related to various social issues in Modern China.
Prerequisite: 82-232

82-338 Mandarin Chinese for Oral Communication II
Spring: 9 units
This is an upper-level course focused on the improvement of students' oral communicative competence and self-expression in Chinese. This course is designed for students who have reached intermediate level in reading and writing Chinese, and who would like to promote their oral communicative competence and knowledge of Chinese culture. It is a seminar-type class that relies on active participation from the students. Students will practice various conversational tasks, such as giving presentations, participating in discussions and debates, interviewing, describing, and interpreting. Topics will include current events and cultural trends in the U.S. and China, analysis of Chinese culture and comparisons with other cultures, contemporary Chinese television shows and movies, and other modern issues.
Prerequisites: 82-232 or 82-235

82-339 Business Language & Culture in China I
Fall: 9 units
Designed for students who have had at least two years of Chinese language training, this course enables students to enhance their language proficiency for professional environments and develop an in-depth understanding of the current business culture in China. Substantial authentic materials from newspapers, magazines, TV shows and online sources will be introduced in class to help students interact smoothly with the Chinese business world. Students will also be encouraged to foster creative and independent thinking, which is crucial for survival in today's business world, through a variety of classroom activities such as group discussion/debate, professional interviews, business projects and presentations, and oral/written business reports. Professional language skills (both speaking and writing) as well as social and business etiquette will be introduced and reinforced throughout the course. Sample topics include: China's reform and "opening up", China's market, "Made in China", marketing in China, Chinese business cards and connections, Chinese etiquette at business banquets, consumer psychology in China.
Prerequisites: 82-232 or 82-235

82-340 Business Language & Culture in China II
Spring: 9 units
The goal of this course is to help students improve their language proficiency in professional environments and develop an in-depth understanding of the current business culture in China. Authentic materials from newspapers, magazines, TV shows, and online sources will be introduced in class to help students interact smoothly with the Chinese business world. Students will be encouraged to foster creative and independent thinking skills, which are crucial for survival in today's business world, through a variety of classroom activities such as group discussion/debate, professional interviews, business projects and presentations, and oral/written business reports. Professional language skills (both speaking and writing) as well as social and business etiquette will be introduced and reinforced throughout the course. Sample topics include: appreciation of the Chinese currency RMB, the Chinese perspective of privacy, euphemism in Chinese culture, China's gift-giving culture, how to properly promote yourself in China, the Chinese perspective of wealth management, the Chinese management style. Prerequisite: 82-232 or 82-235 or placement
Prerequisites: 82-331 or 82-339

82-342 Spain: Language and Culture
Fall and Spring: 9 units
This course is part of the post-intermediate, 300-level program that forms the introduction to the major or minor in Hispanic Studies. Students may begin with any one of the three courses at this level or they may be taken concurrently. Spain: Language and Culture focuses on the cultures of Spain, the autonomous regions and the creation of a national identity as a reaction to the multiple ethnicities that have inhabited the peninsula since ancient times. The course advances proficiency in grammatical accuracy, the ability to communicate one's ideas in Spanish, and cultural proficiency. The focus of in-class activities is on written and non-written sources such as history, literature, film, art, and elements of popular culture; the building of reading and writing skills will be complemented by continued oral practice in the form of small and large group discussions and class presentations. Treatment of reading selections is designed to increase students general familiarity with a variety of genres, devices, and discourse types and to build a foundation for the department's more advanced courses in literature, history and culture. The course will be taught in Spanish.
Prerequisites: 82-244 or 82-242

82-343 Latin America Language and Culture
Fall and Spring: 9 units
This course is part of the post-intermediate, 300-level program that forms the introduction to the major or minor in Hispanic Studies. Students may begin with any one of the three courses at this level or they may be taken concurrently. This course will explore Latin American culture and language, focusing on issues of cultural identity. Tracing the historical thread of the construction of Latin American cultural identity we will distinguish 6 periods organized around crisis when the topic of Who we are? becomes a central debate (Larrain 1996). These periods include: the conquest and colonization, the independence and constitution of nation-states, the inter war period and the depression, the 1970s and the military dictatorships and the present globalization stage. These phases in the development of a Latin American cultural identity represent the existence of certain dominant discourses and controversies that are important in understanding Latin American culture (Larrain 1996). The idea is to explore how Latin America imagines itself and constructs a narrative about its origins and development. There are three main questions we will be exploring throughout the course: Where does the discussion about Latin America emerge from?; How does Latin America think of itself?; What does Latin America want to be?. These questions will be explored historically through readings of philosophical and political texts that deal with Latin American identity as well as with literary texts, films and music that represent practices that enact this/ese identity/ies. The course will be taught in Spanish.
Prerequisites: 82-242 or 82-244

82-344 U.S. Latinos: Language and Culture
Fall and Spring: 9 units
This course is part of the post-intermediate, 300-level program that forms the introduction to the major or minor in Hispanic Studies. Students may begin with any one of the three courses at this level or they may be taken concurrently. This course provides an introduction to and analysis of the cultures and histories of U.S. Latinos. The course will trace the historical trajectories of these groups, both those dating back centuries, such as Mexican-Americans and certain Caribbean populations, and those with more recent, quickly growing populations, such as Salvadoran and Honduran immigrants, in an effort to understand how their identities are forged and transformed over time, considering both internal and external perspectives. Our exploration of U.S. Latino history and cultures will compare and contrast the experiences of people from the above-described categories and analyze the dynamic tension amongst them, with other minority groups, and with the mainstream US society. We will examine a wide variety of materials, including texts, film, art, music etc. in order to gain a better understanding of Latino populations in the United States. Ultimately, we seek to question and to understand the complexities of Latinidad in the 21st century U.S. The course will be taught in Spanish.
Prerequisites: 82-242 or 82-244

82-345 Introduction to Hispanic Literary & Cultural Studies
Fall and Spring: 9 units
This advanced-level course is required for the Hispanic Studies major or minor, and should be taken prior to the 400-level courses. The course is transatlantic, incorporating the study of the cultures of Latinos in the US, Latin American and Spain. Topics vary from semester to semester, aiming to provide a thorough understanding of Latin American, Spanish and U.S. cultures in connection to issues such as race, gender, socio-economic class. Students will improve their language use (reading, speaking, writing, and listening). SPRING 2019: The Case of the Hispanic Detective: The development of a specific and idiosyncratic detective genre in Spain and Latin America is considered one of the most important cultural phenomena in the Hispanic World since the second half of the 20th century. This course is a thematic introduction to the cultural production of the transatlantic, Hispanic world (Spain and the Americas) through the lens of the Hispanic detective genre as presented in texts, film, music, and other arts. We will be using detective fiction as a tool to increase linguistic and cultural proficiency, while also addressing a selection of theoretical readings in order to gain knowledge about the development of the genre, often comparing it to the Anglo- and Francophone models. More importantly, we will use these texts as a means to inquire about the crucial roles played by language and discourse, politics, religion, and economic factors in the constant shaping and reshaping of the histories and cultures of the Hispanic world; likewise, these texts will be used to explore relevant and current issues such as socioeconomic, racial, and gender inequalities, immigration and exile, etc. Materials will include classic literary texts by Borges, Ocampo, Taibo II, Piglia, and Vázquez Montalbán, among others, alongside notable and more recent examples of the genre in various formats.
Prerequisites: 82-342 and 82-343

82-355 Tpcs in Hispanic Std: Beyond the Film Screen: The Hispanic World Through Film
Intermittent: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. The purpose of this course is to explore Hispanic culture and history through contemporary films in Spanish. Undoubtedly, films are a rich source of meaningful cultural information that can provide the audience with an understanding of a countrys culture (history, politics, social problems, etc.) through their discussion and analysis. Movies not only represent reality, but they do it from a particular position. The images produced in films are charged with political interests that reproduce or challenge established beliefs and views. Films offer different representations of reality as well as different ways of relating to it (Achugar, 2008). We will view and analyze a selected group of films portraying four main issues in Hispanic history and society: memory and oblivion, immigration and exile, marginalized identities throughout history, and the Hispanic world in globalization. An understanding of the socio-political context that these films aim to portray through in-depth reading, analysis, discussion, and investigation will provide a thorough understanding of the complexities of various historic events, and opportunities and challenges faced by the Hispanic world. Throughout the semester, we will practice the four language skills (listening, speaking, reading, and writing) as we continue to build on vocabulary and review grammar points based on the films viewed, the texts read, and the topics discussed. The course is conducted in Spanish and has a prerequisite of 82-242 or equivalent.
Prerequisite: 82-242

82-361 Italian Language and Culture I
Fall: 9 units
This is a course in Italian culture and language with a streamlined review of grammar. The course deals with the social, political, economic, demographic, and cultural issues of contemporary Italy. At the same time links are drawn between past and present, evidencing the importance of tradition and history in Italian society.
Prerequisite: 82-262

82-362 Italian Language and Culture II
Spring: 9 units
This is a course in Italian culture and language with a streamlined review of grammar. The course deals with the social, political, economic, demographic, and cultural issues of contemporary Italy. At the same time links are drawn between past and present, evidencing the importance of tradition and history in Italian society. A student with prior experience in Italian must take the Italian placement exam. SPRING 2018: This course traces the development of Italian film from the 1900's silent films to the 21st Century. We will follow a trajectory beginning with the epic tradition of Pastrones Cabiria (1914) and Carmine Gallone's Scipio Africans of the Fascist Regime, and continue with study of the Telefoni Bianchi (Art Deco) films of the 30s, neorealism of post-war Italy, the commedia all italiana (Italian style comedy (1950-1970), the humor of Paolo Virzì, the intellectual and artistic concerns of Nanni Moretti, and conclude with Sorrentino's, Il Divo. Students will continue to build their skills in listening, speaking, reading and writing Italian while developing their appreciation of the impact of Italian Film as a cultural and artistic force. The assignments and learning activities which accompany each film provide opportunities for discussion, research, reflection and conversation. The course places emphasis on the historical and cultural situations presented in the films, to help students broaden their background on the history, customs, and geographical representations of Italy. The class will be conducted in Italian.
Prerequisite: 82-262

82-363 Intensive Italian Language & Culture: Advanced Level
Intermittent
No course description provided.

82-371 Advanced Japanese I
Fall: 9 units
This course emphasizes the acquisition of advanced level of communicative language proficiency by immersing students in authentic cultural explorations. The curriculum includes authentic reading texts, multimedia, interviews with native speakers, and viewing and summarizing Japanese films that depict current Japanese society and cultural trends. The course also provides an individualized learning environment throughout the term in improving students' language skills and cultural proficiency. Students may pick a topic of personal interest for their term project thesis. A student with prior experience in Japanese must take the placement exam.
Prerequisite: 82-272

82-372 Advanced Japanese II
Spring: 9 units
This course continues to further improve the acquisition of advanced level communicative language proficiency by immersing students in authentic cultural explorations. The curriculum includes authentic reading texts, multimedia, interviews with native speakers, and viewing and summarizing Japanese films that depict current Japanese society and cultural trends. The course also provides an individualized learning environment throughout the term in improving students' language skills and cultural proficiency. Students may pick a topic of personal interest for their term project thesis. A student with prior experience in Japanese must take the placement exam.
Prerequisite: 82-371

82-373 Structure of the Japanese Language
Fall: 9 units
This course examines the basic Japanese grammar covered in elementary and intermediate Japanese courses by comparison with English and aids students in systematizing their knowledge of Japanese and in deepening their understanding of Japanese culture (i.e., cultural ways of thinking underlying Japanese verbal behaviors). After a brief discussion of the overall typological differences between the two languages and an initial training to analyze them cross-linguistically, it deals with specific areas of grammar that exhibit pervasive structural and semantic differences and serve as exercises for cross-linguistic analysis. On the basis of the discussions and exercises in class, students gather and analyze relevant Japanese data for their project, which facilitates their understanding of the grammar points and cultural ways of thinking in question, and develops their analytical skills. This course is taught in Japanese. A student with prior experience in Japanese must take the placement exam.
Prerequisite: 82-272

82-374 Technical Japanese
Spring: 9 units
This course seeks to (1) introduce students to technical Japanese or Japanese language used in the field of science and technology, (2) acquaint them with current issues in Japan involving science and technology, and (3) deepen their understanding of the science and technology culture of Japan. It draws on various sources of information such as books, newspapers, video clips, and TV news to familiarize students with current issues in Japan related to science and technology. Through understanding those issues, the course enables them to acquire necessary knowledge of technical Japanese and Japanese cultural perspectives on science and technology. It also requires them to work on an individual project to form and express their own thoughts and opinions on a science and technology issue of personal interest. This course is taught in Japanese. A student with prior experience in Japanese must take the placement exam.
Prerequisite: 82-272

82-376 Intensive Japanese Language & Culture: Advanced Level
Intermittent
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82-380 Independent Study in Second Language Acquisition
Spring
An opportunity for students who wish to pursue independent supervised study in second language acquisition (SLA). In conjunction with a faculty member, students will arrange a program of study to explore aspects of SLA. Prerequisite: Permission of the Instructor.

82-383 Second Language Acquisition: Theories and Research
Fall: 9 units
This course provides an introduction to research and theories in Second Language Acquisition (SLA). Processes that underlie the learning and use of second languages are examined from four perspectives: 1) as linguistic knowledge, 2) as a cognitive skill, 3) as a personality-meditated process, and 4) a socio-culturally mediated process. Factors examined include: age-related differences, the influence of the first language, the role played by innate (universal) principles, the role of memory processes, attitudes, motivation, personality and cognitive styles, and formal versus naturalistic learning contexts. Issues that arise from the course readings are investigated through practical experience in applying theoretical knowledge to small-scale empirical research projects. Students are also provided with opportunities to consider the relevance of these issues to their own language learning experiences.
Prerequisite: 82-280

82-385 Language Across the University
Fall and Spring
Language credit may be attached to any course, independent study, or project unit for which a student receives content-area academic credit. The program is available at the discretion of the responsible content-area faculty, who should be sufficiently skilled in the chosen language to be able to evaluate the technical content of a student's work. The student, content-area faculty and language faculty negotiate a plan for the semester's work, designed to consume approximately three hours per week for three units of academic credit. The course may be repeated on multiple occasions.
Prerequisites: Intermediate level language proficiency or above and permission of a content-area faculty member and the Department of Modern Languages

82-388 Understanding Second Language Fluency
Fall: 9 units
This course examines differences and similarities in the way literacy is learned and used in diverse languages and cultures. In the first step of examining the cognitive and social consequences of literacy, students will analyze the major characteristics of spoken and written communications. Following that analysis, students will compare literacy practices in a variety of cultural contexts and explore how literacy utilization alters its collective impacts on the users. Finally, through systematic comparisons of literacy education, students will identify the social, cognitive, linguistic factors directly affecting literacy development in different cultural contexts.

82-391 Advanced Russian I - Modern Russia
Intermittent: 9 units
This course seeks to enhance listening-comprehension skills while perfecting the linguistic and stylistic practices of advanced students. Intensive study is made of varied literary, journalistic and colloquial texts in audio-visual and print media. Focus is on rapid vocabulary expansion as well as correction of high frequency syntax errors that persist beyond the intermediate level. Practice with online resources, additional to three class hours per week, is mandatory for the evolution of aural/oral fluency. Written compositions and translations, assigned for homework, are required for the development of grammatical accuracy and stylistic appropriateness. All class discussions are conducted in Russian. Prerequisite or approved equivalent
Prerequisites: 82-292 or 82-399

82-392 Advanced Russian II: Great Short Works
Intermittent: 9 units
A mad copy clerk declares himself the King of Spain. A nightmarish visit to a local museum somehow spirits a Russian refugee back to the Soviet Union. A bespectacled Jewish reporter brutally kills a goose to earn the respect of his Cossack platoon. Although Russian literature is famous for its long 19th-century novels, the absurdities of Russian society were explored no less profoundly in short stories by Gogol, Chekhov, Nabokov, Babel, and many others. This seminar examines the Russian short story as a form particularly suited to revealing the barbarism, hilarity, and ecstasy of human experience. The course aims to advance Russian language learning by expanding students' vocabulary, reinforcing grammatical knowledge, and developing their capacity to speak and write on abstract topics. The readings will be available in English, though students will be encouraged to read the works in Russian. In addition to discussing the texts in Russian, students will complete short weekly homework assignments.
Prerequisite: 82-391

82-394 Russian for Heritage Speakers: Babushkas, Russia & Beyond
All Semesters: 9 units
This course is designed to address the linguistic and cultural learning needs of heritage speakers of Russian, those who grew up hearing and speaking Russian at home but who have had little or no formal study of Russian language, culture, or history. Although heritage speakers of Russian often achieve advanced or near-native listening comprehension skills, they require further training in reading, writing, and speaking. Heritage speakers may also be unfamiliar with important aspects of Russian culturekey events in Russian and Soviet history, well-known cultural phenomena, literary works, films, and so onand have gaps in their knowledge of social norms. Russian for Heritage Speakers aims to fill these gaps through a combination of grammar instruction and student-led close analysis of texts and audiovisual material. The course is organized around five thematic units that allow students to learn about Russian culture while engaging in interpretive, interpersonal, and presentational modes of communication: "Foundations: Truth & Legends," "Revolutions: Political, Cultural, Social," "Student Life: ' ,'" "Russia in the World," and "Individual and Community."
Pre-requisite: Permission of the Instructor.

82-396 The Faust Legend at Home and Abroad
Intermittent
This course introduces students to the basic outlines of the Faust story, and examines its nineteenth- through twenty first-century manifestations in a variety of European, Russian and American novels, plays, films and operas. On the assumption that cultures reveal something distinctive about themselves by the particular way in which they adapt the legend, this course aims to discover how and why these Faustian works of art respond and contribute to the social, political and historical context in which they are produced. On what is the persistent appeal of the Faust legend based? To what needs does it speak? How does the history of its own, continual reemergence affect the meanings it communicates? Prerequisites: None for 9 units; an additional 3 units, requiring permission of the instructor, can be earned for work done in Russian.

82-397 Radical, Heretics, Hackers: Russian Outlaws in History, Literature, and Film
Intermittent
The Russian hacker looms large in the global imagination. He's the cyber outlaw who we imagine can take down the powerful with the click of a finger, sometimes serving as an agent of the Russian government, at other times threatening the state itself. This course will examine the mythology and reality of the Russian hacker by tracing its prehistory, from anarchists in Imperial Russia, to Bolshevik revolutionaries, to dissident artists of the Soviet Union, and finally to contemporary heretics such as Pussy Riot and Edward Snowden. The course will culminate in a student-led symposium on the sociocultural role of the Russian hacker. This course follows a seminar format. Students will be required to critically analyze literature, film, and historical documents. They will work on written exercises that prepare them to write a research paper to be presented at the symposium. This is a 9-unit course. For those proficient in Russian, however, a total of 12 units can be earned by conducting some portion of the work in Russian and meeting outside of class for some additional hours. Details are to be worked out in advance, in consultation with the instructor.

82-399 Special Topics: Russian in Context
Fall and Spring: 9 units
This course is designed for students who have completed four semesters of Russian at Carnegie Mellon or for those who have equivalent Russian skills as demonstrated via placement exam. The course focuses on further development of the linguistic and stylistic practices of advanced students based on cultural analysis of Russian literature. Focus is on rapid vocabulary expansion as well as correction of high frequency syntax errors that persist beyond the intermediate level. Written compositions and translations, assigned for homework, are required for the development of grammatical accuracy and stylistic appropriateness. All class discussions are conducted in Russian. A student with prior experience in Russian must take the placement exam.

82-400 Russian Studies Topics
Fall and Summer: 6 units
(A1)Literary Culture of the 19th Century Russia (6 Units) The purpose of the course is to give students an introduction to the cultural environment of the Imperial Russia through the works of major 19th century Russian writers. We will read and analyze some masterpieces of Russian fiction, including works of Pushkin, Lermontov, Gogol, Turgenev, Dostoevsky, Tolstoy, and Chekhov. Emphasis will be made on how these brilliant classics reflected turbulent history of the 19th century Russia. (A2) Literary Culture of the 20th Century Russia (6 Units) This mini-course focuses on Russian prose and poetry of the early 20th century. Readings will include the "proletarian" writings of Maxim Gorky, "symbolism" of Alexander Blok, "futurism" and "modernism" of Vladimir Mayakovsky as well as works of some other authors. We will discuss such important issues for 20th century Russian Cultural History as the role of intelligentsia in the Russian Revolution, the content and method of Russian decadence, symbolism, and modernism, as well as imprisonment, liberation, and exile that became so important for many writers and poets.

82-411 Topics in Arabic Media
Fall and Spring
Given the development and spread of new and multi-literacies around us today, the course focuses on reading and analyzing Arabic media sources to engage in discussions about current topics in our modern world. Topics of interest include (but are not limited to): Culture, politics, economy, environment, education, and linguistic diversity. While reading and writing will be mainly in Modern Standard Arabic, class discussions will be of a multidialectal and multilingual nature to encourage questioning, analyzing, and conceptualizing topics in various contexts.

82-412 Topics in Arabic Studies
Spring: 9 units
This course is designed for students who have completed Advanced Arabic. Students will study written, audio, and video material taken from well-known Arabic-language media outlets such as Al-Jazeera, BBC Arabic, al-Arabiyya, etc. Linguistically, this course focuses on Modern Standard Arabic (MSA) because the media is one of the main domains in which MSA is significantly utilized in our modern age. Students will utilize reading, writing, and speaking skills to engage actively in class activities such as group discussions, debates, interviews, short presentations, etc. Students will prepare and present a final project in Arabic to share with the class. **The course can be repeated but after consent of instructor.**

82-413 Readings in Islamic History
Fall and Spring: 9 units
This course focuses on Islamic history and enables students to read authentic historical texts in Arabic written three to five centuries ago and to understand the cultural context that gave rise to these texts. Students also will continue to develop their ability to express their ideas both in speaking and in writing and to develop their listening skills in Modern Standard Arabic.

82-415 Topics in French and Francophone Studies
Fall: 9 units
This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. FALL 2019: La France au Moyen Orient
Prerequisites: 82-303 Min. grade C and 82-304 Min. grade C and 82-305 Min. grade C

82-416 Topics in French and Francophone Studies
Spring: 9 units
This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. Spring 2019: Growing up Black or Asian in Contemporary France: Frenchness redefined through the Arts This course will examine the impact of the Post-World War II migrations on 21st-century France's definitions of national identity. Our study will particularly focus on the cultural productions of a new generation of French painters, filmmakers, writers and influencers with roots in sub-Saharan Africa, the Caribbean and Asia. We will investigate the ways in which these works, rooted in hybridity and the celebration of non-French ethnic heritage, interrogate the French republican tradition of a "singular and indivisible" identity. Readings will include Grace Ly's Une Enfance Modèle, Aya Cissoko's N'ba and Julie Hamaïde's Koï. The course will also examine the filmic representations of hybrid identity in works such as Ça reste entre nous (Irène Nam/Grace Ly), YA'R (Brams Koudié) and Mariannes Noires (Niang/Nielsen). Throughout the semester, students will have the opportunity to meet some of the artists and writers whose works we will analyze in class. A the end of the semester, Afro-French visual artist Alexis Peskine will accompany the students in the creation of their final project for the course. Good reading skills in French and a good ability to express oneself both orally and in writing are essential."
Prerequisites: 82-303 and 82-304

82-420 The Crucible of Modernity:Vienna 1900
Intermittent: 9 units
Vienna 1900 was many things: the political center of the Austro-Hungarian Empire; the center of German-language music and theater; the birthplace of Zionism and of psychoanalysis; the home of cafe culture and the waltz; the city of baroque urban palaces and squalid backyard tenements; and the showcase for historicism. And while the story of Vienna's cultural and political turmoil is interesting, it probably would not command our attention today were it not for its role as the birthplace of Modernism. The class explores Vienna before the collapse of the Austro- Hungarian Empire in 1918. We will be looking at a huge and at times confusing canvas, which by necessity includes almost every aspect of culture. From history and politics we will move on through art, architecture, psychoanalysis, literature, music, and philosophy. We will be looking at art nouveau buildings and furniture, reading literature, viewing films, and listening to recordings. Using an enhanced historical map of the city as a digital interface and an interactive learning tool, we will add a crucial visual component to the course and research the connections between urban and architectural space and the intellectual activity that took place in it. You will work in teams with students from other disciplines. You will research networks of intellectual and artistic activities and create 3D models of the spaces, from public squares to cafe interiors, in which these intellectual activities took place. You will create and expand a growing collection of records, photos, archival materials, as well as artwork, music and other media in an effort to reconstruct the dialogue among the arts and the cultural debate of this key moment in the passage to Modernism. No previous knowledge of 3D modeling software is required, software instruction and tutoring will be provided. The language of instruction is English with a German credit option

82-425 Topics in German Literature and Culture
Fall: 9 units
This repeatable course explores the culture of the German-speaking nations through a thematic or conceptual focus. Students critically analyze authentic documents, for example, historical, biographical, and literary texts, as well as film and works of the visual arts while improving and expanding their language skills. FALL 2019: 82-425 Thirty Years Later: The Collapse of East Germany and the Fall of the Berlin Wall This course, conducted entirely in German, observes the thirtieth anniversary of the collapse of the German Democratic Republic (GDR) in the autumn of 1989 and the fall of the Berlin Wall on November 9, 1989. These events in 1989 were followed by German reunification in October of 1990. The revolution in East Germany, the collapse of the GDR, the fall of the Berlin Wall, and German reunification fundamentally transformed Germany, Europe, and the world. The course will take a close look at the events of 1989 and 1990. Course materials will include documentary and fiction films, plays, essays, novels, and articles. A central part of the course will be interviews conducted by the class as a whole and by individual students with eyewitnesses to the events of 1989-1990. These interviews will be recorded and archived, and students will be required to complete a final project that summarizes what they have learned about these momentous events and their significance. Required work includes active participation in class, preparation of all readings, watching all assigned films, taking two tests, completing an eyewitness interview, completing a final project, and leading one class session, together with a partner, in the final weeks of the semester.
Prerequisites: 82-320 or 82-323 or 82-426 or 82-327

82-426 Topics in German Literature and Culture
Spring: 9 units
This repeatable course explores the culture of the German-speaking nations through a thematic or conceptual focus. Students critically analyze authentic documents, for example, historical, biographical, and literary texts, as well as film and works of the visual arts while improving and expanding their language skills. SPRING 2019: "It was the best of times; it was the worst of times." What Charles Dickens said about the French Revolution also applies to Germany between the wars. Germany had taken the first tentative steps toward democracy in its thousand year history, beginning a journey that was soon to end in one of the most repressive political regimes the world has ever seen. But amid the confusion and uncertainty of the Weimar Republic, German literature, film, art, science, philosophy, music, and architecture flourished like never before since the Age of Goethe—only to see many of the nation's intellectuals emigrate to democratic countries after the rise of Nazism. Come and explore Albert Einstein, Sigmund Freud, Max Planck, Bertolt Brecht, Rainer Maria Rilke, Hermann Hesse, Walter Gropius, Albert Speer, Joseph Goebbels, Wassily Kandinsky, Paul Klee, Max Beckmann, Käthe Kollwitz, Otto Dix, George Grosz, Edith Stein, Kurt Weill, Lotte Lenya, Marlene Dietrich, Emil Jannings, and others.
Prerequisites: 82-324 or 82-325 or 82-323

82-427 Nazi and Resistance Culture
Spring: 9 units
SPRING 2019: "It was the best of times; it was the worst of times." What Charles Dickens said about the French Revolution also applies to Germany between the wars. Germany had taken the first tentative steps toward democracy in its thousand year history, beginning a journey that was soon to end in one of the most repressive political regimes the world has ever seen. But amid the confusion and uncertainty of the Weimar Republic, German literature, film, art, science, philosophy, music, and architecture flourished like never before since the Age of Goethe—only to see many of the nation's intellectuals emigrate to democratic countries after the rise of Nazism. Come and explore Albert Einstein, Sigmund Freud, Max Planck, Bertolt Brecht, Rainer Maria Rilke, Hermann Hesse, Walter Gropius, Albert Speer, Joseph Goebbels, Wassily Kandinsky, Paul Klee, Max Beckmann, Käthe Kollwitz, Otto Dix, George Grosz, Edith Stein, Kurt Weill, Lotte Lenya, Marlene Dietrich, Emil Jannings, and others.
Prerequisite: 82-327

82-428 History of German Film
Intermittent: 9 units
This course is a chronological introduction to one of the world's greatest cinema traditions: German cinema. It moves from the silent cinema of the 1910s to the Weimar Republic, when German cinema represented Hollywood's greatest challenger in the international cinema world. It then addresses the cinema of Hitler's so-called "Third Reich," when German cinema dominated European movie theaters, and moves on to the cinema of divided Germany from 1949-1989, when cinema in the socialist east and cinema in the capitalist west developed in very different ways. In the final week of the semester, the course will address German cinema in the post-unification period, which has experienced a revival in popularity and interest. The two historical foci of the semester will be the Weimar Republic, the classic era of German cinema, and the era of the so-called "New German Cinema" of the 1970s and 1980s, when major German directors developed radical new approaches to cinema and critiques of Hollywood. Among the great directors focused on in the course of the semester will be Friedrich Wilhelm Murnau, Fritz Lang, Leni Riefenstahl, Wolfgang Staudte, Werner Herzog, Wim Wenders, and Rainer Werner Fassbinder. No knowledge of the German language is required for this course. Most of the films will be in German with English subtitles. The course will be cross-listed in the departments of Modern Languages, English, and History. Students will be required to attend class, including all film screenings, to actively participate in discussion, to write a term paper on a topic related to German cinema history, and to take two midterm examinations.

82-429 German Reading and Translation Workshop: German in Today's World
Intermittent: 9 units
This course will address issues of translation, mostly from German into English, but to a lesser extent also from English into German. It will focus primarily on texts coming from the spheres of current events, politics, economics, and the cultural sphere, but students will also be encouraged to explore and locate texts based on their own interests and concerns. In order to facilitate well-honed translation, it will be necessary to address points of advanced grammar where the structures of the German and English languages feature not only similarities but also differences. The course will thus also constitute a review of issues in German grammar that English speakers may sometimes find particularly challenging. The language of instruction will be primarily German, and students should be comfortable speaking and listening to German. Students will be required to complete a several translation projects, to locate a number of texts from the contemporary German-speaking world that interest them, and to take a midterm and final examination that will focus on translation, issues of advanced grammar, and cultural content.
Prerequisite: 82-324

82-431 China and the West
Intermittent: 9 units
FALL 2012 This course takes a look at the multifaceted relationship between China and the Western world from Marco Polo's time to the present. The focus will be on how people in China and the West imagined each other in different times of history and in what ways some historical events and figures, as well as concepts and cultural practices are interpreted differently from Chinese and Western perspectives. Students are expected to reach a deeper understanding of the complexities of cultural interactions and their implications for the diverse world in which we now live. The students will read a rich collection of scholarly writings, and the class will be conducted primarily in discussion format. The class is conducted in English and Chinese. Students will complete readings in both English and Chinese. Assessment will be based on participation in the discussion, student presentations, and written assignments (including research papers, book reviews, and translations). Prerequisits: 82-332, or instructor's approval.

82-432 Popular Culture in China
Intermittent: 9 units
This class is a general introduction to various aspects of popular culture in twentieth century and contemporary China. Students will gain a critical understanding of common people's perspectives and experiences with China's revolutionary past and its contemporary global economy through fiction, film, music, newspaper and magazine articles, internet discussion forums, and other forms of visual and written materials. The class is conducted in Chinese, supplemented by occasional scholarly writings in English. Prerequisite: 82-332 or placement
Prerequisite: 82-332

82-433 Topics in Contemporary Culture of China
Fall: 9 units
This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. Prerequisite: 82-332
Prerequisite: 82-332

82-434 Studies in Chinese Traditions
Intermittent: 9 units
Traditional Chinese Thought and Literature through Comic Books Starting from the 1980's, Tsai Chih Chung (a master cartoonist in Taiwan) created a series of comic books illustrating canonical works in traditional Chinese philosophy and literature. The series soon became a great hit both in Taiwan and China, and has since been translated into different languages around the world. While its popularity continues to grow among its readers, its wide circulation also raises questions among scholars and critics of traditional Chinese literature and culture. In this course, students will be asked to read Tsai Chih Chung's comic books and their animated adaptations, the English translations of the Chinese canonical texts of philosophy and literature, and the secondary sources that provide historical and analytical introductions to the texts. While enjoying Tsai's innovative and delightful comic interpretation, students will work in Chinese to consider serious philosophical questions along with the early Chinese thinkers, to learn to savor the aesthetic beauty of traditional Chinese literature, and to prepare to share their ideas and discovery with the rest of the class.
Prerequisite: 82-332

82-436 Introduction to Classical Chinese
Intermittent: 9 units
This course is designed for students who have reached the advanced level of Modern Chinese and would like to promote their knowledge and skills in reading Classical Chinese, a language shaped in the latter half of the first millennium B. C. which still persists as a living medium of expression today. The course aims to introduce students to the basic syntactic patterns of Classical Chinese and the most frequently used Classical Chinese vocabulary. In the course, readings will be representative selections from ancient Chinese texts, chosen for their historical value, beauty, and influence on later writers. With this knowledge and training, students will be sufficiently equipped to read the Chinese Classics and will gain a deeper understanding of the history of Chinese civilization, culture and language. Moreover, knowledge of Classical Chinese will help students read and understand sophisticated modern Chinese texts, which make frequent use of Classical allusions and constructs. Prerequisite: 82-332 or 82-337 or 82-338
Prerequisites: 82-332 or 82-337 or 82-338

82-439 Modern China Through Literature
Intermittent
This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills.

82-440 Studies in Chinese Literature & Culture
Fall: 9 units
This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. SPRING 2019:This is an introductory course on Chinese folk performance traditions. It aims to help students obtain a general understanding of the various Chinese folk performance forms including puppetry, opera, oral storytelling traditions, and temple festival performances. It will also explore the culture of folk performance, dramatic literature and performing arts, their relationship with Chinese local culture and societies, and their national and global impact. Class activities will include lectures, guest speakers, and discussion, as well as presentation of multimedia examples of folk performances. At the end of the course, students are expected to have a better understanding of the nature and scope of the Chinese folk performance traditions and gain some fundamental training that will enable them to carry on related field work and research.
Prerequisite: 82-332

82-441 Studies in Peninsular Literature and Culture
Intermittent: 9 units
This repeatable course explores the cultures of Spain through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. SPRING 2017 This course explores contemporary peninsular texts of corporeal representation - medicalized, personalized, objectified and empowered. In this course, we will explore the Spanish body through the lens of medical humanities and disability studies. The former includes texts created in medical environments and from medical experiences, written by doctors, patients and members of the community. Spain has a rich history of doctor/authors that can provide some level of insight into the narrative of the Spanish medical community. Disability studies, on the other hand, views the body in a non-medical context. Instead of proposing the abnormal body as a medical phenomenon to be studied in a petri dish, these expression of (corpo)reality trace ideas of normalcy as societal constructs. The theme of disability in Spain comes in to play with the wealth of organizations dedicated to disability rights (while also mired in controversy). The texts will come in the form of advocacy pamphlets, novels written by doctors, fictional (and non) depictions of the medical field, illness, etc., painting and sculpture, and films. This course will prompt us to pay attention to the objectification and abjectification of these bodies and consider that through this awareness must also come understanding the body as a text - not an object - but a text that warrants intricate observation. We will analyze these texts in an effort to understanding the constructions of normalcy. In the end, our analysis will be used to create our own texts.
Prerequisite: 82-345

82-443 Spanish Reading and Translation Workshop
Intermittent: 9 units
This course is of interest to advanced Spanish majors and minors as well as other native or heritage speaker non-specialists seeking to develop translation skills from English-Spanish and Spanish-English. It provides students with an introduction to basic concepts, theories, and techniques of translation, and helps them develop a systematic approach to resolving language transference problems. Students will deepen their understanding of Spanish and English as they consider how best to translate structures, words, text, and discourse styles unique to each respective language while simultaneously acquiring a valuable and highly marketable skill. This course is conducted in Spanish. *Prerequisites: 82-345 or permission of instructor.
Prerequisites: 82-342 or 82-343 or 82-344 or 82-345

82-444 The Structure of Spanish
Intermittent: 9 units
This course will provide students with a theoretical framework and analytic tools to investigate how Spanish speakers represent, construct, and transform their social worlds. In particular, the focus is on language as a social practice through which power relations are maintained or challenged. Using a variety of spoken and written texts, the course seeks to analyze to explore the discourse-semantic and lexico-grammatical features that Spanish users deploy to make meanings and negotiate understandings. This analysis will later be interpreted from an interdisciplinary perspective drawing on social theory and history. FALL 2017: This course is an advanced introduction-in Spanish-to contemporary "print," digital and visual media from North, Central & South America, and the Caribbean, and how "information" and "opinion" produce, disseminate, and communicate specific messages. We will review and analyze the rhetorical and visual toolse.g., style, tone, perspective, purpose, exaggeration, distortion, symbolism, labels, irony, and allusionsthese texts deploy to determine their role in meaning making for readers and viewers. A primary goal for this course is for students to develop and sharpen the skills necessary to determine reliability in information sources, and hone their ability to write and talk about this.
Prerequisite: 82-345

82-445 U.S. Latino Literature
Intermittent: 9 units
This course proposes to problematize socio-political and historico-cultural issues concerning U.S. Latinos and Hispanic immigrants in the United States. This will involve the analysis and application of assimilation, transculturation and bilingualism theory, and rhetorical/translational problematics of the material under examination. Also of interest will be an ongoing class discussion of Latinos/Hispanics in history, the media, entertainment, politics, and education. Students will consider the question of the "borders," geographical, political and societal, that may or do exist between U.S. mainstream society, Latinos and Hispanic immigrants, and strategies employed by hyphenated-Americans for overcoming, subverting or undermining this situation. Materials for the course will include literature, film, essays, and music by and about Latinos and Hispanics in the United States. FALL 2016: Mapping Dreams and Nightmares: Transfronteriza Aesthetics on the US-Mexico Border This course will focus on the US-Mexico border, with particular emphasis on visual representations of the border from both the US and Mexico, and on the unique, vibrant fronteriza cultures that result in the space betwixt and between. The course will emphasize key moments and events in the history of the border, including for example the Mexican Revolution, the creation of the border patrol in the 1920s, the Bracero program, Operation Wetback, the Chicano movement, Operation Gatekeeper, and will consider how visual and textual representations have responded to and been conditioned by the political and economic relationship between the US and Mexico, particularly in the wake of neoliberal policies. We will draw on a wide variety of materials, including film, video, visual arts, performance, border theory, and literary and journalistic texts.
Prerequisite: 82-345

82-448 Topics in Arabic Language, Literature, & Culture
Intermittent: 9 units
This repeatable course explores the Arab world through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. Prerequisite: 82-312
Prerequisite: 82-312

82-450 Advanced Research in Hispanic Language & Culture
Fall and Spring: 9 units
This course permits in-depth, 400-level study in the following courses: 82-342 Spain: Language and Culture, 82-343 Latin America: Language and Culture, and 82-344 U.S. Latinos: Language and Culture. Students will meet with the regularly scheduled 300-level class, read additional texts, and produce research assignments as agreed upon by the instructor and student. The focus is on a deeper understanding and individualized research of the course topics. Prerequisite: Permission of instructor

82-451 Studies in Latin American Literature and Culture
Intermittent: 9 units
This repeatable course explores the cultures of Latin America through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. FALL 2019: Venezuela y Colombia: War, Peace, Migration and Exile Venezuela and Colombia converge around many elements, from a common colonial past to shared geographical regions and cultural customs. However, their societies, politics, and cultural production often have followed divergent paths, leading to a current juncture characterized by both fraternity and adversity. Many of these differences stem from societal and cultural transformations developed during the twentieth century. Over the past few decades, for instance, Colombians have gone from emigrating to Venezuela in search of a peaceful and prosperous future, to hosting thousands of Venezuelan refugees fleeing current economic and political conditions. This course will compare the varied ways in which literary and non-literary sources have represented the transformations, challenges, and hopes stemming from situations of violence, war, peace, migration or exile in these two neighboring countries from the 1800 to the present.Students will use these sources to identify significant historical and cultural trends and agents of change, and ultimately to develop an informed perspective on the current cultural and political landscape of the two countries. Student performance in the course will be assessed using various types of written assignments (online posts, online discussion boards, final paper), in-class discussion, and an oral presentation. The course will be taught in Spanish.
Prerequisite: 82-345

82-455 Topics in Hispanic Studies
Fall: 9 units
This repeatable course explores Spanish-speaking cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. FALL 2018:(Post)Apocalyptic visions are metaphors for the human condition and may often be an expression of political turmoil or social and cultural fears. Their evolution and meaning can be explored and traced to a current complex lexicon pointing to science, technology, globalism, and humankind as catalysts for the end of the world. How are discussions about the end of the world framed in Latin America? What is the relationship between the monstrous & popular fear? What parts of humanity remain when death is rampant and social structures have broken down? How can these visions address social and environmental changes, and the possible future human outcomes of these changes? In pursuit of answers to these questions, the course will be an exploration of written and visual narratives used to contain and explain threats pertaining to Latin America and/or created from within its diffuse borders, with an emphasis on texts produced after the second half of the 20th century. We will examine how different kinds of Spanish-language Latin American mediafrom literature to film, from the Internet to news coverage, from art to comic bookshave looked to the past, seen into the present, and envisioned the future in framing discussions and representations of (post)apocalyptic events and of threats in the post-human world. Contemporary reviews and short historical, critical, and theoretical readings will serve to supplement and provide context for primary texts. The class will be taught entirely in Spanish. *Prerequisites: 82-345 or permission of instructor.
Prerequisite: 82-345

82-456 Topics in Hispanic Studies
Spring: 9 units
This repeatable course explores Spanish-speaking cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. SPRING 2017: Southern Cone Dictatorships in the Movies (1984-2016) This course explores the Southern Cone dictatorships during the period of the Cold War through their representation in films. The military-civilian dictatorships of the 1970s in Argentina, Chile and Uruguay were a period of State terrorism. This violent period resulted in thousands of disappeared people, political prisoners and exiles. These experiences have had a lasting impact in the new democracies. There is still a debate over how to address violations of human rights and how to make sense of the past, so that these events don't happen again. There has been a rich production of movies focusing on this historical period that serves as a document of how the struggles over how to come to terms with a traumatic past have been dealt with by different countries. These films also provide a glimpse of how popular culture serves as a vehicle to construct a social memory of recent history. Through films new generations that did not experience these traumatic events learns about what happened and what it means for particular social actors. We will analyze films from Argentina, Chile and Uruguay in order to better understand how these countries have dealt with a contested past. The course will provide students with historical background, theoretical frameworks and analytic tools to approach these cultural productions as documents and discourses about the recent dictatorships.
Prerequisite: 82-345

82-473 Topics in Japanese Studies
Fall: 9 units
This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, cultural, social, historical, biographical, filmic, artistic, literary, musical, linguistic, and theoretical perspectives, while improving and expanding their language skills. FALL 2018: Youth Culture Japanese society is currently confronted with a massive array of social and cultural anomalies among its youth. In the culture, which values and emphasizes conformity, the phenomenon is utterly unprecedented. Accordingly, in this course, we will first explore the defining features of these anomalies by examining how Japanese youth are portrayed in modern day fictions and films. We will then scrutinize the extent to which these portrayals actually reflect real lives of young Japanese by analyzing newspaper articles and essays commenting on the social issues surrounding them. Finally, we will take a close look at the dramatic social changes, over the past three decades, to trace their long-term impacts as a significant factor contributing to the emergence of the new culture, particularly with respect to the changing youth behaviors. F17:The Evolution of Japan's Urban Culture This course analyzes various aspects of Japan's urban culture, the evolution of which has centered around Tokyo, focusing on such topics as the Taisho modernism during 1912-1926, the post-WWII Americanization of Japanese culture and society, the culture surrounding the Bubble Economy during 1980-1995, and the popular culture that has continued to thrive on a global scale, through fictions, non-fictions, films, and multimedia. Taught in Japanese.
Prerequisite: 82-372

82-474 Topics in Japanese Studies
Spring: 9 units
This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, cultural, social, historical, biographical, filmic, artistic, literary, musical, linguistic, and theoretical perspectives, while improving and expanding their language skills. SPRING 2019: Japanese Language and Culture from a Pragmatics Perspective This course deals with topics such as enryo-sasshi, indirectness and politeness in Japanese culture and communication from a pragmatics perspective and provides cultural and linguistic analysis training by using pragmatic concepts. Pragmatics is a sub-field of linguistics that deals with language use in social communication. This course introduces students to basic concepts of pragmatics, including context and co-text, speech acts, conversational implicature, indirectness, and politeness theory, with the aim of understanding them in Japanese language. A variety of Japanese texts and media sources are brought to the class for students to analyze how pragmatics is in place in everyday social interaction and to help them consider cultural background and norms behind the social acts. The course invites active and critical participation in the exploration of Japanese language and culture through pragmatics, as well as other closely related issues including intercultural communication, sociolinguistic variation, and linguistic ideology.
Prerequisites: 82-372 or 82-373

82-480 Social and Cognitive Aspects of Bilingualism
Intermittent: 9 units
This course introduces students to the nature and extent of bilingualism in individuals and diverse communities in the US and abroad, with an emphasis on the social, historical and political forces that shape the language varieties and abilities of bilinguals. There is also a brief exploration of the psycholinguistic features that characterize bilingual individuals. It also addresses the challenges and opportunities that bilingualism posses for multilingual societies and individuals. Students will develop their knowledge and critical analysis skills of bilingualism through readings, group discussions, field projects and a research paper. Prerequisite: 82-180 or 82-280 or 82-382 or 82-384 or permission of instructor
Prerequisites: 82-180 or 82-280 or 82-382 or 82-384

82-483 Topics in Modern Languages
Intermittent
This course introduces students to research methodology as it applies to language learning and language teaching through an examination of different approaches currently used in Second Language Acquisition (SLA) research ranging from experimental studies to case studies. The goal is to develop an ability to critically evaluate, design and implement sound SLA research. Prerequisite: None

82-489 Service Learning in the Community
Intermittent
This is a community-based research (CBR) course for advanced students who wish to bridge service and action research. The course provides an experiential component that allows students to use their second language and culture skills while acquiring or honing their research skills. CBR helps bridge the gap between university and community life to facilitate the development of life-long learning habits and humanistic citizenship. ML students and faculty will jointly design and execute ways in which to 'give back' to the community being studied, which will be chosen based upon the language, culture and/or history of a specific community. Students in this course may participate in historical, ethnographic and cultural research; ethnographic fieldwork; problem solving activities around a particular issue the community is facing; discover how to best identify a particular linguistic/cultural community and document, interpret, preserve and disseminate its history and culture. Class activities may include group, pair and independent reading and research; group and pair travel; group, pair and one-on-one interaction with community members; public presentations; photography, filming, scanning; webpage and document design; and different kinds of writing. Prerequisite: Completion of all 300-level coursework, or an approved equivalent, or permission of instructor

82-492 The Historical Imagination in Nineteenth-Century Russian Literature
Intermittent
Pushkin, Gogol, Lermontov, Turgenev, Dostoevsky and Tolstoy all ruminated upon their nation's historical destiny. This course aims to describe the role played by imagination in these authors' efforts to wreak from Russia's past a vision of her future. Emphasis is placed upon the figurative operations of language that allow narrative to function as a guidepost to a collective mission and a map of the individual's location within the projected historical scheme. Lecture and discussion formats are combined at each class meeting. Written papers, oral presentations, and participation in discussions are required. Prerequisites: None for 9 units; an additional 3 units, requiring permission of the instructor, can be earned for work done in Russian.

82-495 Topics in Applied Second Language Acquisition
Intermittent: 9 units
SPRING 2016: Section A:Teaching Chinese as a Foreign Language This course aims to expose students to current professional practices and common situations related to teaching Chinese as a Foreign Language (CFL). It will provide an overview of CFL research, teaching and learning with demonstrations of CFL pedagogical issues, applications and solutions. It is intended to help students become familiar with specific CFL issues concerning the special characteristics of the Chinese language, including tones, a character-based writing system, and special Chinese grammatical structures. Students will be able to apply course material to their CFL teaching and research, and feel more comfortable and adaptable in their CFL professional careers. Section B: Issues in TESOL In this course, students will receive a broad overview of current topics that will introduce them to the pedagogic and sociocultural issues that Teachers of English to Speakers of Other Languages (TESOL) instructors encounter in classrooms today, in a variety of contexts. Students will be required to familiarize themselves with and be prepared to address issues in TESOL classrooms. These issues include but are not limited to methodology, teacher education, the role of culture and intercultural communication, and specific challenges in diverse settings, such as modifying course content to focus on academic language. The course will be conducted as a seminar with students completing readings outside class time and discussing the topics and perspectives during class time. Students will engage in reflection through class discussions and electronic discussion forums. The main assignments for the course will be case histories of diverse populations of students who are found in TESOL classrooms, and a final research paper. Students will gain in-depth knowledge of the state of the art in TESOL today.

82-499 Alternative Break Projec (Language Specific)
Intermittent
This course provides advanced ML language students and non-ML students enrolled in an Alternative Break student trip project the opportunity to earn credit by engaging in "connected" modes of knowing, by identifying and analyzing a problem, and developing plans for short-term and sustainable solutions, reflecting, and creating and disseminating an informational and interpretive website and print materials about their experience. Students will also bring to bear or gain experience in non-academic skills/talents/ interests in areas like photography, image editing, video production, writing, design, website development, sound recording, and art, etc., by doing community service under the auspices of Carnegie Mellon University's Alternative Break program. Students will earn three (3) units for full participation and fulfillment of course requirements. With the approval of the faculty facilitator, an additional three (3) units may be earned by completing an additional assignment.

82-501 Special Topics in French & Francophone Studies
Fall
Restricted to language majors who wish to go beyond the regular course offerings in French and Francophone Studies involving group or individual study in a subject area approved by the instructor.

82-502 Special Topics in French & Francophone Studies
Spring
Restricted to language majors who wish to go beyond the regular course offerings in French and Francophone Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-505 Undergraduate Internship
Intermittent
Approved upper-class language majors may receive credit in connection with work experience related to language learning and language use outside of the classroom setting. As a rule, this experience takes the form of work involving language use or research related to language study at off-campus sites or in the Department. Work or research must be done using the language of study. For off-campus internships, there must be an on-site supervisor appointed to collaborate with the faculty advisor in the final evaluation of the student's work and progress. The student will be responsible for three written reports evaluating the non-classroom experience with the language of study and several other criteria. Students must obtain prior approval for proposed work. Prerequisites: Permission of target faculty member and the Modern Languages internship advisor

82-506 Hispanic Studies Internship
Fall and Spring
Pre-approved, advanced Hispanic Studies majors may receive credit in connection with volunteer or paid work experience (usually in Pittsburgh) in which they primarily or significantly use their target language outside the traditional classroom setting. As a rule, this experience takes the form of work involving language use or research at off-campus sites or in the Department. Work or research must be done using the language of study. For off-campus internships, there must be an on-site supervisor available to collaborate with the faculty advisor in the ongoing and final evaluation of the student's work and progress. Students will be required to write and submit reflexive projects, as determined by the faculty advisor, that evaluate the non-classroom experience in the context of the language- and cultural-learning experience and several other criteria that show how the internship connects back to the student's academic or professional education. Prerequisite: Students must be advanced Hispanic Studies majors and obtain prior permission for the proposed work from a Hispanic Studies advisor and/or the Modern Languages internship advisor.

82-511 Special Topics in Arabic Studies
Fall: 9 units
This repeatable course explores the Arabic language and culture through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills.

82-512 Special Topics: Arabic Language & Culture
Spring
This repeatable course explores the Arabic language and culture through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. Prerequisite: 82-411 or placement.

82-521 Special Topics: German Studies
Fall
Restricted to language majors who wish to go beyond the regular course offerings in German Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-522 Special Topics: German Studies
Spring
Restricted to language majors who wish to go beyond the regular course offerings in German Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course
Prerequisites: 82-427 or 82-428 or 82-438 or 82-437 or 82-436 or 82-435 or 82-431 or 82-429 or 82-430

82-531 Special Topics in Chinese Studies
Fall
Restricted to language majors who wish to go beyond the regular course offerings in Chinese Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of instructor and a 400-level course
Prerequisites: 82-436 Min. grade C or 82-434 Min. grade C or 82-433 Min. grade C or 82-440 Min. grade C

82-532 Special Topics in Chinese Studies
Spring
Restricted to language majors who wish to go beyond the regular course offerings in Chinese Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of instructor and a 400-level course

82-533 Cultural Topics in Chinese Studies
Fall: 9 units
F18: Visions of China: Modern Chinese Society and Culture through Documentary Films and New Media People who study China often cherish a secret desire to discover the "real China," which they believe could have been revealed through close examination its different forms of representations, such as history, arts, literature, news reports, or films. While the existence of this so-called "reality" and its ultimate discovery are still very much in question, there are indeed some forms, in which China is presented or represented in a much less embellished, dramatized, stereotyped, albeit no less complex and intriguing way. By way of watching, analyzing and discussing a variety of documentary films and TV shows made with a documentary touch, this course encourages students to develop in-depth knowledge of modern Chinese society and culture in the closest proximity to its bare "reality." The course will use a thematic approach to cover different social and cultural issues that China is facing nowadays, including the harmony/conflicts between human and nature, the social/economic gap between city and countryside, the rise of the second generation of the nouveau riche, a humanitarian tale from the AIDS village, the life of foreigners in Chinese society, and so on. Secondary readings in English and Chinese about these social and cultural issues will be provided. All classroom discussions and course projects will be given or conducted in Chinese and/or English. Students are expected to have excellent Chinese listening and speaking skills and very good writing and reading skills, in order to fully grasp the content of this course.To promote intercultural communications, the course welcomes and invites participation of native Chinese speakers and cross-cultural peer learning.
Prerequisites: 82-433 Min. grade C and 82-434 Min. grade C

82-541 Special Topics: Hispanic Studies
Fall
Restricted to language majors who wish to go beyond the regular course offerings in Hispanic Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-542 Special Topics in Hispanic Studies
Spring
Restricted to language majors who wish to go beyond the regular course offerings in Hispanic Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-561 Special Topics: Italian Studies
Fall
Restricted to language majors who wish to go beyond the regular course offerings in Italian Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-562 Special Topics: Italian Studies
Spring
Restricted to language majors who wish to go beyond the regular course offerings in Italian Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-571 Special Topics in Japanese Studies
Fall
Restricted to language majors who wish to go beyond the regular course offerings in Japanese Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-572 Special Topics in Japanese Studies
Spring
Restricted to language majors who wish to go beyond the regular course offerings in Japanese Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-580 Senior Seminar in Modern Languages
Spring: 3 units
This mini-seminar for majors in Modern Languages focuses on general issues in second language learning. It provides an integrative and culminating experience for students as they complete their studies. The course includes consideration of language learning and language maintenance, the role of second languages in American life, issues of linguistic and cultural diversity in the United States today and discussions of multiculturalism throughout the world. The goal of the seminar is for students to reflect upon their language learning experience and to discuss the role that a second language plays in their own lives and in American society today. Corequisite: Open only to Modern Languages majors

82-585 Topics in Second Language Acquisition
Intermittent: 9 units
This repeatable course promotes inquiry into issues related to second language acquisition, for example, use of technology in language learning, language variation, code-switching, pragmatics, sociocultural theory. Students will engage in research and project work and employ qualitative and/or quantitative research methodology and analytical and/or empirical methods to illuminate and understand the acquisition, use, and maintenance of second languages. Prerequisite: Permission of instructor SPRING 2016 Section B: East Asian Psycholinguistics Our understanding of cognitive processes and mechanisms underlying language has primarily come from studies of European languages. However, languages such as Chinese, Japanese and Korean offer profound implications for the acquisition, representation, and processing of language, due to their differences from most European languages. Topics include first and second language acquisition, spoken word recognition, reading, language disorders, and the relationships between language, culture, and cognition. This course serves to prepare students for more advanced studies of East Asian languages, experimental linguistics, and linguistic theory.

82-591 Modern Languages Honors Thesis
Fall: 9 units
Modern Languages majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of an individual faculty member. Students and faculty select the research topics. Prerequisites: Senior standing; a 3.5 QPA in one's language major; a 3.25 QPA overall; permission of the Department Head and approved entry into the College's Honors Program

82-592 Modern Languages Honors Thesis
Spring: 9 units
Modern Languages majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of an individual faculty member. Students and faculty select the research topics. Prerequisites: Senior standing; a 3.5 QPA in one's language major; a 3.25 QPA overall; permission of the Department Head and approved entry into the College's Honors Program

82-599 Russian Studies Thesis
Intermittent
The Russian Studies thesis, as described for the Russian Studies major, is required of all Russian Studies majors and consists of researching and writing a thesis employing both Russian-language and English-language sources, and generally completed during the senior year. Work is done individually under the guidance of a Russian Studies advisor.

Department of Philosophy

David Danks, Department Head

Location: Baker Hall 161
www.cmu.edu/dietrich/philosophy

The Department of Philosophy was founded in 1985 and reflects the tradition of philosophy as a central discipline in the humanities. The department has achieved an international reputation through the acclaimed research of its members and its innovative educational programs, not only in traditional topics such as ethics, philosophy of mind, logic, and theory of knowledge, but in such contemporary and applied areas as automated theorem proving, machine learning, the foundations of statistics, causal discovery, forward learning theory, game and decision theory, conflict resolution, and business ethics.

Philosophy thrives through contact with other disciplines. Interdisciplinary work, a traditional strength of the Carnegie Mellon community, is vital to the department and is reflected in the courses we offer, many of which incorporate substantive material from a range of other disciplines. Some courses are actually team-taught with professors from other departments and schools around the university.

Our programs are designed to develop our students' analytical sophistication and their practical and theoretical skills in specializations outside the department (see the sample curricula below). The department welcomes and, indeed, encourages minors and additional majors from other disciplines who are interested in reflecting on the foundation of their own subjects. The department offers two different undergraduate major programs, and jointly sponsors two interdepartmental majors: Ethics, History, and Public Policy (with the Department of History), and Linguistics (with English, Modern Languages, and Psychology):

- the B.A. or B.S. in Ethics, History, and Public Policy (interdisciplinary major with Department of History)
- the B.S. in Logic and Computation
- the B.A. in Philosophy
- the B.A. in Linguistics (interdisciplinary major with Departments of English, Modern Languages, and Psychology)

The major in Logic and Computation is perhaps the most non-traditional of the department's majors. It offers students a firm background in computer science, together with a solid grounding in logic, philosophy, and mathematics. This reflects the department's commitment to the use of formal, analytic methods in addressing philosophical issues. A flexible system of electives allows students to focus their efforts in any of a wide range of disciplines, from engineering to the fine arts. As a capstone to the program, students engage in original research in their senior year, and write a thesis under the direction of an advisor.

The department also sponsors four minor programs:

- the minor in Ethics
- the minor in Linguistics
- the minor in Logic and Computation
- the minor in Philosophy

Finally, the department offers two master's programs directly extending the departmental majors. Both programs are coordinated with and build on the undergraduate programs, so that majors can complete the requirements for the master's degree in one additional year:

- the M.S. in Logic and Computation
- the M.A. in Philosophy

Students who choose the appropriate specialized track in the Logic and Computation major (namely, sample 2 of the Curricula listed below) can be admitted to the M.S. program in Language and Information Technology offered by the School of Computer Science. To complete the discussion of departmental programs, it should be mentioned that the department sponsors as part of the Program in Pure and Applied Logic (offered jointly with the Departments of Computer Science and Mathematics) a Ph.D. in Logic, Computation, and Methodology.

The Major in Ethics, History, and Public Policy

Alex John London, *Director*
Location: Baker Hall 150A
ajlondon@andrew.cmu.edu
www.cmu.edu/dietrich/ehpp

The B.A./B.S. in Ethics, History, and Public Policy is an interdepartmental major offered jointly by the Departments of History and Philosophy. It prepares students for leadership positions by providing them with a rigorous, interdisciplinary humanistic and social-scientific education. It also serves as an excellent springboard for graduate study in a wide variety of disciplines such as law, public policy, ethics, and advocacy. The program focuses equally on the historical understanding of how modern-day problems have evolved, and the importance of developing clear criteria for ethical decision-making. The capstone project course provides students with the opportunity to engage with real-world public policy challenges using the methods, theories, and knowledge that they have gained through the major. Offered jointly by the departments of History and Philosophy, the B.A./B.S. in EHPP encourages specialization, internship experiences, and research in a wide range of policy areas.

Curriculum

Students graduating with a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science Degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 9 units in Economics, 36 units in History, 36 units in Philosophy, 27 units of elective courses, and a 12-unit senior capstone course. This program may also be taken as an additional (e.g., second) major. All courses toward the major must be taken for a letter grade, and 79-300 must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundations of Public Policy 9 units

Choose one 9-unit course from the list below.

73-102	Principles of Microeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-110	Foundations of Political Economy	9

II. History Core 36 units

Choose one 9-unit course from each category below:

Policy History (9 units)

79-300	Guns in American History: Culture, Violence, and Politics	9

U.S. History (9 units)

79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-249	20th & 21st Century U.S. History	9
79-320	Women, Politics, and Protest	9

Non-U.S. History (9 units)

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9

79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-237	Comparative Slavery	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-307	Religion and Politics in the Middle East	9

History Elective (9 units)

Take at least 9 additional units in the History Department with course number 79-200 or above. The following courses may not count: 79-400, 79-420, 79-449, 79-491, 79-505, 79-506.

III. Philosophy Core — 36 units

Choose one 9-unit course from each category below. No more than 9 units at the 100 level may be counted toward the Philosophy Core.

Ethics (9 units)

80-130	Introduction to Ethics	9
80-330	Ethical Theory	9

Political Philosophy (9 units)

80-135	Introduction to Political Philosophy	9
80-335	Social and Political Philosophy	9

Foundations of Social Science (9 units)

80-221	Philosophy of Social Science	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9

Applied Philosophy (9 units)

80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

IV. Senior Capstone Project Course — 12 units

79-449	EHPP Project Course [cross-listed]	12
80-449	EHPP Project Course	12

The Ethics, History and Public Policy Project Course is required for the Ethics, History and Public Policy major and is taken in the fall semester of the senior year. In this capstone course, Ethics, History and Public Policy majors carry out a collaborative research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis. The students develop an original research report based on both archival and contemporary policy analysis and they present their results to a client organization in the community.

V. Elective Courses — 27 units

Choose any three courses (at least 27 units) from any category or categories shown below. Substitution of elective courses that cohere with a student's interest or concentration may be allowed after consultation with and approval from the Director.

Engineering and Public Policy (some courses have prerequisites; see EPP catalog listing)

19-424	Energy and the Environment	9

Business

70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-332	Business, Society and Ethics	9
70-364	Business Law	9
70-365	International Trade and International Law	9
70-430	International Management	9

Economics (some courses have prerequisities; see Economics catalog listing)

73-352	Public Economics	9
73-359	Benefit-Cost Analysis	9
73-365	Firms, Market Structures, and Strategy	9
73-372	International Money and Finance	9
73-408	Law and Economics	9
73-476	American Economic History	9

English

76-492	Rhetoric of Public Policy	9

History

Courses from the EHPP History Core (above) may be taken as electives only if they are not being used to fulfill the core requirement. Double counting is not permitted.

79-206	Crime and Punishment in Early Modern Europe	9
79-228	The Civil Rights Movement and the World	9
79-233	The United States and the Middle East since 1945	9
79-234	Technology and Society	9
79-242	African American History: Reconstruction to the Present	9
79-247	African Americans, Imprisonment, and the Carceral State	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-298	Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal	6
79-299	From Newton to the Nuclear Bomb: History of Science, 1750-1950	9
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-305	Moneyball Nation: Data in American Life	9
79-310	Modern U. S. Business History: 1870 to the Present	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-320	Women, Politics, and Protest	9
79-322	Stalin and the Great Terror	9
79-325	U.S. Gay and Lesbian History	6
79-330	Medicine and Society	9
79-331	Body Politics: Women and Health in America	9
79-336	Oil & Water: Middle East Perspectives	6
79-338	History of Education in America	9
79-339	Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)	6
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6
79-342	Introduction to Science and Technology Studies	9
79-343	Education, Democracy, and Civil Rights	9
79-349	United States and the Holocaust	6
79-370	Disasters in American History (2):Epidemics & Fires	6
79-371	African American Urban History	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-397	Environmental Crises and the City	6

Philosophy

Courses from the EHPP Philosophy Core (above) may be taken as electives only if they are not being used to fulfill the core requirement. Double counting is not permitted.

80-256	Modern Moral Philosophy	9

80-305	Choices, Decisions, and Games	9
80-405	Game Theory	9

Institute for Politics and Strategy

84-310	International Political Economy	9
84-380	Grand Strategy in the United States	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6

Social and Decision Sciences

88-223	Decision Analysis	12
88-281	Topics in Law: 1st Amendment	9
88-444	Public Policy and Regulation	9

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

21-257	Models and Methods for Optimization	9
36-202	Statistics & Data Science Methods	9
or 36-208	Regression Analysis	
or 70-208	Regression Analysis	
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
70-257	Optimization for Business	9
80-305	Choices, Decisions, and Games	9
80-405	Game Theory	9
84-265	Political Science Research Methods	9
88-251	Empirical Research Methods	9
88-221	Analytical Foundations of Public Policy	9
88-223	Decision Analysis	12
88-300	Programming and Data Analysis for Social Scientists	9

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy, Professor Alex John London, ajlondon@andrew.cmu.edu.

Ethics, History, and Public Policy Sample Curriculum

Junior Year		Senior Year	
Fall	**Spring**	**Fall**	**Spring**
Core requirement in Economics	Core requirement in History or Philosophy	Capstone Course	EHPP Elective Course
Core requirement in History or Philosophy	Core requirement in History or Philosophy	EHPP Elective Course	Second Course (open)
Core requirement in History or Philosophy	Core requirement in History or Philosophy	EHPP Elective Course	Third Course (open)
Core requirement in History or Philosophy	Core requirement in History or Philosophy	Fourth Course (open)	Fourth Course (open)
Core requirement in History or Philosophy	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be. Students may enter the EHPP major, and begin major course requirements, as early as the start of the sophomore year, or even in the first year. Students should consult their advisor when planning their program.

The Major in Linguistics

Tom Werner, *Director*
Location: Baker Hall 155F
twerner@andrew.cmu.edu
www.cmu.edu/dietrich/linguistics

Linguistics is the study of human language, and it encompasses a broad spectrum of research questions, approaches and methodologies. Some linguists are concerned with the cognitive aspects of language learning, production and comprehension; some are concerned with language as a social and cultural phenomenon; others engage in the analysis of linguistic form and meaning, some from a functional and others from a formal perspective. There are also computational approaches to linguistics with both applied and theoretical goals.

The major in Linguistics reflects the multidisciplinary character of the field and of the Linguistics faculty here at Carnegie Mellon, offering a program which provides students with the fundamental tools of linguistic analysis while maintaining a focus on the human context in which language is learned and used. The major is available as either a primary major or an additional major. It is an ideal choice for students with a general interest in their own or other languages, and combines well thematically with studies in any of the departments represented in the major.

Curriculum

The Linguistics primary major requires a total of 12 courses plus a senior thesis. The Linguistics additional major requires at total of 13 courses. This includes 2 semesters of language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor.

Linguistics Core (36 units)

Complete the following requirements.

80-180	Nature of Language	9
80-282	Phonetics and Phonology I	9
80-280	Linguistic Analysis	9
or 80-285	Natural Language Syntax	
80-381	Meaning in Language	9
or 80-383	Language in Use	

Extended Core (27 units)

Choose three courses (27 units) from Extended Core and/or additional courses from Linguistics Core.

80-283	It Matters How You Say It	9
80-284	Invented Languages	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: Transcription and Analysis	9
80-382	Phonetics and Phonology II	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9

Electives

Primary majors choose **three** additional electives (27 or more units). Additional majors choose **four** additional electives (36 or more units). *Primary majors see thesis requirement below.*

These can be **additional courses from the Core or Extended Core courses listed above**, **the electives list below**, or any other course which is approved by the Director as a linguistics elective. Listed below are the additional electives taught on a regular basis. **Additional appropriate courses** are offered irregularly or on a one-off basis. The Director will provide students with a list of possible electives each semester, and will assist students in selecting electives which are consistent with their goals and interests.

Philosophy

80-380	Philosophy of Language	9
80-484	Language and Thought	9

English		
76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-385	Introduction to Discourse Analysis	9
76-386	Language & Culture	9
76-389	Rhetorical Grammar	9

Modern Languages		
82-283	Language Diversity & Cultural Identity	9
82-305	French in its Social Contexts	9
82-373	Structure of the Japanese Language	9
82-383	Second Language Acquisition: Theories and Research	9
82-585	Topics in Second Language Acquisition	9

Psychology		
85-354	Infant Language Development	9
85-421	Language and Thought	9

Language Technologies Institute		
11-411	Natural Language Processing	12
11-423	ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.	12
11-492	Speech Processing	12
11-661	Language and Statistics	12
11-722	Grammar Formalisms	12

Language Requirement

Students must successfully complete two semesters of consecutive language courses. (Note that students may not 'test out' of this requirement. However, language courses taken at other institutions or as part of a study abroad program will typically substitute for a semester of language study.)

Senior Thesis [primary majors only]

Primary majors must complete a senior thesis (a workload equivalent to a 12-unit course) during their senior year. Topics must be approved by an advisor, who will work with the student and guide the thesis project. Students are responsible for identifying their topic and securing their thesis advisor. Students should work with the director of the major to begin the process of identifying their thesis topic and advisor during the fall of their senior year at the latest. Students will be required to submit a written proposal of their thesis project, signed by their thesis faculty advisor, before the end of the second week of classes in which the thesis is being completed.

Note

- All 11-xxx courses have significant Computer Science prerequisites. Interested students should check with the course instructor before registering.

The Major in Logic and Computation

Joel Smith, *Director*
Location: Baker Hall 161C
joelms@cmu.edu
www.cmu.edu/dietrich/philosophy/undergraduate/logic-and-computation

The Logic and Computation curriculum takes advantage of the preparation provided by the Dietrich College General Education Program in mathematics, philosophy, psychology, and statistics. It is flexible in that it permits students to focus on any of a number of areas including (but not limited to):

- computer science;
- language and information technology;
- artificial intelligence and cognitive science;
- logic and the foundations of mathematics;
- methodology and philosophy of science.

Students in the program take a common core of courses in logic, methodology, and computer science, together with an associated seminar in their senior year. The individual focus is achieved by selecting a sequence of four advanced and closely related courses. It is in this area of focus (or specialization) that students write their senior thesis under the supervision of a faculty member. A number of sample curricula are presented below.

The resulting education in logic, analytic philosophy, mathematics, statistics, and computer science enables students to pursue professional careers or graduate study. The analytic and communication skills developed in the major support a wide range of career choices, including those among the fields of technology, business, and law. Fields of graduate study for which students are well prepared include, for example, computer science, cognitive science, philosophy, logic, and linguistics.

Students who are interested in pursuing this major, or who are pursuing it already, should take note of the Cognitive Science major in the Department of Psychology. That major is so closely related that it is not difficult to pursue it as an additional major, and it provides an intellectually exciting complement.

Curriculum

Logic and Computation is a B.S. degree. In their freshman and sophomore years, students are expected to take three courses that provide preparation in computer science, mathematics, and statistics: 15-112 Fundamentals of Programming and Computer Science, 21-127 Concepts of Mathematics, 36-201 Statistical Reasoning and Practice (or 36-200 Reasoning with Data). 80-211 Logic and Mathematical Inquiry is part of the major's Core Requirements, but should be taken no later than the spring of the sophomore year. This also applies to the computer science sequence 15-122 and 15-150.

NOTE: Students should complete the prerequisites before their junior year. It is strongly recommended that students take 80-211 Logic and Mathematical Inquiry no later than the spring of their sophomore year and, if possible, also 15-122 and 15-150. However, with suitable planning and advice from the program director, it is possible to complete the program in two years, beginning in the junior year.

The course requirements for the major consist of seven core courses (including the Senior Thesis) and four electives. The core courses provide comprehensive background in logic, computability, and analytic philosophy. 80-310 Formal Logic and 80-150 Nature of Reason must be taken no later than the fall of the junior year. Four advanced electives are chosen in the area of focus, and should support independent research towards fulfilling the senior thesis requirement. In their senior year, students engage in original research under the supervision of a faculty advisor in 80-595 Senior Thesis (a workload equivalent of 12 units). Students are responsible for identifying a thesis topic and securing a faculty advisor prior to the start of the semester in which they plan to complete the thesis. Students should work with the program director during their junior year to begin the process of identifying their topic and potential advisors.

All courses, if taken at CMU, must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major with another major or minor.

Prerequisites		29 units
15-112	Fundamentals of Programming and Computer Science	12
21-127	Concepts of Mathematics	10
36-200	Reasoning with Data	9

Logic and Computation Core		69–71 units
80-150	Nature of Reason	9
80-211	Logic and Mathematical Inquiry	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
80-595	Senior Thesis	Var.

Logic and Computation Electives 36 units

Bearing in mind prerequisites, Logic and Computation majors must complete four advanced courses in areas that use logical and computational tools, such as philosophy, computer science, linguistics, mathematical logic, psychology, or statistics. The sequence of courses, mostly at the 300-level, must be selected in consultation with the program director.

Sample Curricula

Here are five samples of Logic and Computation curricula (beyond the core courses), each reflecting a different emphasis.

Sample 1.
A student interested in Computer Science might take the following courses:

80-315	Modal Logic	9
80-413	Category Theory	9
15-312	Foundations of Programming Languages	12
15-317	Constructive Logic	9

Sample 2.
A student interested in Language and Information Technology might take the following courses:

80-280	Linguistic Analysis	9
80-281	Language and Thought	9
80-381	Meaning in Language	9
80-383	Language in Use	9
80-580	Seminar on the Philosophy of Language	9

Sample 3.
A student interested in Artificial Intelligence and Cognitive Science might take the following courses:

80-314	Causal Discovery, Statistics, and Machine Learning	9
80-315	Modal Logic	9
80-411	Proof Theory	9
85-412	Cognitive Modeling	9

Sample 4.
A student interested in Logic and the Foundations of Mathematics might consider the following courses:

80-254	Analytic Philosophy	9
80-312	Mathematical Revolutions	9
80-411	Proof Theory	9
80-413	Category Theory	9

Sample 5.
A student interested in Methodology might consider the following courses:

80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-321	Causation, Law, and Social Policy	9
36-309	Experimental Design for Behavioral & Social Sciences	9

Logic and Computation Degree Requirements (minimum)	**360 units**

Logic and Computation as a Second Major

The Logic and Computation major is also suitable as a second major for students in Dietrich College or for students in other colleges within the university. Non-Dietrich students interested in an additional major in Logic and Computation need to take only those courses in the Dietrich College General Education Program that are prerequisites to courses required in the major; all other Dietrich College General Education requirements are waived for these students. Depending on the student's background, the requirements of the second major in Logic and Computation can be fulfilled with as few as five additional courses. The Philosophy Department does not limit the number of courses that can be counted for other majors and minors around the university.

The M.S. Program in Logic and Computation

The Department of Philosophy also offers a graduate M.S. degree in Logic and Computation, which culminates with the writing of a master's thesis. It is ordinarily a two-year program, but students in the Logic and Computation major are able to complete the additional requirements in one year. Interested students are invited to contact the department for further information and to apply to the program in their senior year. Details can be found on the department's website: www.cmu.edu/dietrich/philosophy.

The Major in Philosophy

Joel Smith, *Director*
Location: Baker Hall 161C
joelms@cmu.edu
www.cmu.edu/dietrich/philosophy/undergraduate/philosophy

The Major in Philosophy is intended to be flexible and to facilitate additional majors in other fields (including majors with a strong professional focus). It provides students with a broad humanities education and sharpens their analytical skills. We encourage, but do not require, students to choose a thematic concentration through their electives. Sample curricula emphasizing Pre-Law, Metaphysics and Epistemology, Ethics and Social Philosophy, and Philosophy of Mind are suggested below. However, alternative emphases can be proposed and approved by the Director. The Major in Philosophy is a B.A. degree.

Curriculum

In addition to the general education requirements for the student's college, Philosophy primary majors and additional majors must complete 80-100 Introduction to Philosophy and nine Philosophy courses in the Areas listed below. The 80-100 requirement must be fulfilled before the first semester of the junior year. Only two of the remaining nine courses may be at the 100-level, and two of the nine courses must be at the 300-level or higher. All ten courses, if taken at CMU, must be taken for a letter grade and passed with a grade of "C" or above. Courses from other universities, as well as an 80-100 skills test, may be substituted with permission of the Director. Students are to choose one course out of each of the Areas 1-4, two courses out of Area 5, and may freely select three courses in Area 6. Students may double count any course for the major with another major or minor. As per the requirement of Dietrich College, a student's Freshman Seminar course may not count toward the fulfillment of the major requirements.

Introduction to Philosophy — 9 units

80-100	Introduction to Philosophy	9

Area 1: Values and Normative Theory — 9 units

One of the following:

80-130	Introduction to Ethics	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-248	Engineering Ethics	9
80-249	AI, Society, and Humanity	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-430	Ethics and Medical Research	9
80-447	Global Justice	9

Area 2: Philosophy of Mind/Language/Metaphysics — 9 units

One of the following:

80-180	Nature of Language	9
80-270	Philosophy of Mind	9
80-271	Philosophy and Psychology	9
80-276	Philosophy of Religion	9
80-280	Linguistic Analysis	9
80-281	Language and Thought	9
80-282	Phonetics and Phonology I	9
80-283	It Matters How You Say It	9
80-284	Invented Languages	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-288	Intonation: Transcription and Analysis	9
80-371	Philosophy of Perception	9
80-380	Philosophy of Language	9
80-381	Meaning in Language	9
80-382	Phonetics and Phonology II	9
80-383	Language in Use	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9
80-580	Seminar on the Philosophy of Language	9

Area 3: Logic/Philosophy of Mathematics — 9 units

One of the following:

80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-214	Computing, AI, and Philosophy	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
80-312	Mathematical Revolutions	9
80-314	Causal Discovery, Statistics, and Machine Learning	9
80-315	Modal Logic	9
80-411	Proof Theory	9
80-413	Category Theory	9
80-419	Interactive Theorem Proving	9
80-513	Seminar on Philosophy of Mathematics	9
80-514	Categorical Logic	9

Area 4: Epistemology — 9 units

One of the following:

80-150	Nature of Reason	9
80-201	Knowledge and Justified Belief	9
80-208	Critical Thinking	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-222	Measurement and Methodology	9
80-223	Causality and Probability	9
80-224	Race, Gender and Science	9
80-226	Revolutions in Science	9
80-305	Choices, Decisions, and Games	9
80-321	Causation, Law, and Social Policy	9
80-322	Philosophy of Physics	9
80-323	Philosophy of Biology	9
80-324	Philosophy of Economics	9
80-327	Philosophy of Neuroscience	9
80-405	Game Theory	9
80-515	Seminar on the Foundations of Statistics	9
80-516	Causality and Learning	Var.
80-520	Seminar on Philosophy Science	9
80-521	Seminar on Formal Epistemology	9

Area 5: History of Philosophy — 18 units

Two of the following:

80-150	Nature of Reason	9
80-226	Revolutions in Science	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-252	Kant	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism	9
80-256	Modern Moral Philosophy	9
80-257	Nietzsche	9
80-261	Experience, Reason, and Truth	9
80-263	Approaching Chinese Philosophy: Basic Texts and Implications	9
80-358	Hume	9
80-362	Russell	9
80-363	19th Century Foundations of Science	9

Area 6: Elective — 27 units

Three other philosophy courses, or appropriate courses from other departments, with the permission of the Director.

Sample Curricula

Here are four sample curricula, reflecting different emphases.

1. For an emphasis on Law & Social Policy, a student might take:

Area 1		
80-335	Social and Political Philosophy	9
Area 2		
80-180	Nature of Language	9
Area 3		
80-211	Logic and Mathematical Inquiry	9
Area 4		
80-208	Critical Thinking	9
Area 5		
80-150	Nature of Reason	9
80-250	Ancient Philosophy	9
Area 6		
80-321	Causation, Law, and Social Policy	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

2. For an emphasis on Philosophy of Science, a student might take:

Area 1		
80-136	Social Structure, Public Policy & Ethics	9
Area 2		
80-371	Philosophy of Perception	9
Area 3		
80-211	Logic and Mathematical Inquiry	9
Area 4		
80-220	Philosophy of Science	9
or 80-221	Philosophy of Social Science	
Area 5		
80-250	Ancient Philosophy	9
80-226	Revolutions in Science	9
Area 6		
80-150	Nature of Reason	9
80-221	Philosophy of Social Science	9
80-322	Philosophy of Physics	9
80-323	Philosophy of Biology	9

3. For an emphasis on Ethics and Social Philosophy, a student might take:

Area 1		
Area 2		
80-276	Philosophy of Religion	9
Area 3		
80-110	Nature of Mathematical Reasoning	9
Area 4		
80-221	Philosophy of Social Science	9
or 80-321	Causation, Law, and Social Policy	
Area 5		
80-250	Ancient Philosophy	9
Area 6		
80-321	Causation, Law, and Social Policy	9

4. For an emphasis on Philosophy of Mind, a student might take:

Area 1		
80-130	Introduction to Ethics	9
Area 2		
80-270	Philosophy of Mind	9
Area 3		
80-211	Logic and Mathematical Inquiry	9
Area 4		
80-201	Knowledge and Justified Belief	9
Area 5		
80-251	Modern Philosophy	9
Area 6		
80-257	Nietzsche	9
80-371	Philosophy of Perception	9
80-521	Seminar on Formal Epistemology	Var.

Additional Major

Students who want an additional major in Philosophy must fulfill the same departmental requirements as primary majors in Philosophy. Students can double count any course for the major with another major or minor.

The M.A. Program in Philosophy

The Department of Philosophy also offers a graduate M.A. degree in Philosophy, which culminates with the writing of a master's thesis. It is ordinarily a two-year program, but students in the Philosophy major are able to complete the additional requirements in one year. Interested students are invited to visit the department's homepage (http://www.cmu.edu/dietrich/philosophy) for further information.

Philosophy Department Minors

All majors in the Department allow for minors; in addition, there is a Minor in Ethics and an interdepartmental minor in Linguistics. The requirements are again designed to be flexible and to allow students to tailor courses to their special interests, while providing some breadth.

The Minor in Ethics

With the explosive growth of science and technology have come both new possibilities and new problems. Developments in medicine, in biology, in chemistry, in nuclear engineering or in computer science all have costs as well as benefits, and they present us with many hard choices. Some of the hardest of these new problems are moral problems.

The Philosophy Department's Minor in Ethics introduces students to central ethical concepts and theories proposed and defended by the great philosophers of the past; it provides an understanding of how these theories and concepts can be applied to practical problems. This background in ethical theory and its applications should help students to respond more sensitively and appropriately to the new and unavoidable ethical problems that technologies, businesses, unions, and branches of government must face.

Curriculum

Ethics minors must complete five philosophy courses in the areas listed below. All five required courses, if taken at CMU, must be taken for a letter grade and passed with a grade of a "C" or above, except 80-294 Ethics Internship / Practicum, which may be taken pass/fail.

Ethics Core Courses — 27 units

Complete three courses from any of the following areas with at least two courses at the 200-level or higher.

80-130	Introduction to Ethics	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-241	Ethical Judgments in Professional Life	9
80-242	Conflict and Dispute Resolution *	9
80-243	Ethics of Leadership *	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-248	Engineering Ethics	9
80-249	AI, Society, and Humanity	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-430	Ethics and Medical Research	9
80-431	Meta-ethics	9
80-447	Global Justice	9

Ethics Electives — 18 units

Complete two courses at the 200-level or higher. These courses may be additional courses from Ethics Core list above. Other applicable philosophy courses include the following: 80-294 or 80-495

Appropriate courses in ethics from other departments may count with the permission of the faculty advisors for this minor.

*Courses typically only offered on the CMU-Q campus.

The Minor in Linguistics

The Interdepartmental Minor in Linguistics is jointly sponsored with the departments of English, Modern Languages, and Psychology. It synthesizes the linguistics related offerings in these departments and provides students with an academic experience that reflects both the interdisciplinary character of the subject and its cross-departmental representation in Dietrich College. Students who wish to receive a minor in Linguistics must complete six courses: the introductory linguistics course; two fundamental skills courses; and three additional electives. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Introductory Course — 9 units

80-180	Nature of Language	9

Fundamental Skills — 18 units

Take **one** course from **two** of the following core subject areas:

Sounds		
80-282	Phonetics and Phonology I	9
Structure		
76-389	Rhetorical Grammar	9
80-280	Linguistic Analysis	9
80-285	Natural Language Syntax	9
Meaning		
80-381	Meaning in Language	9
80-383	Language in Use	9
76-385	Introduction to Discourse Analysis	9
or 76-484	Discourse Analysis	

Electives — 27 units

Take three additional linguistics courses. These can be additional courses from the Fundamental Skills categories above, or any other course that is approved by the Director as a Linguistics elective. For electives taught on a regular basis, see the courses listed as Breadth or Electives in the Undergraduate Catalog for the Linguistics major.

The Minor in Logic and Computation

The Minor in Logic and Computation provides students with general course work in logic, the theory of computation, and philosophy. Students must complete six courses, among them the following three core courses.

Logic and Computation Core Courses — 27 units

80-150	Nature of Reason	9
80-211	Logic and Mathematical Inquiry	9
or 80-210	Logic and Proofs	
80-310	Formal Logic	9
or 80-311	Undecidability and Incompleteness	

Logic and Computation Electives — 27 unts

Students must take two courses in the Philosophy Department at the 300-level or higher, in subjects related to logic and computation, and an additional course at the 300-level or higher in an area that uses logical and computational tools, such as philosophy, computer science, linguistics, mathematics, psychology, or statistics. The choice of electives must be approved by the program director.

The Minor in Philosophy

The Minor in Philosophy allows students to complement their primary majors with a broad philosophical grounding.

Logic/Methodology Requirements — 9 units

Complete one course:		Units
80-110	Nature of Mathematical Reasoning	9
80-210	Logic and Proofs	9

80-211	Logic and Mathematical Inquiry	9
80-214	Computing, AI, and Philosophy	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-222	Measurement and Methodology	9
80-223	Causality and Probability	9
80-226	Revolutions in Science	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
80-312	Mathematical Revolutions	9
80-314	Causal Discovery, Statistics, and Machine Learning	9
80-315	Modal Logic	9
80-321	Causation, Law, and Social Policy	9
80-322	Philosophy of Physics	9
80-323	Philosophy of Biology	9
80-324	Philosophy of Economics	9
80-411	Proof Theory	9
80-413	Category Theory	9
80-513	Seminar on Philosophy of Mathematics	9
80-514	Categorical Logic	9
80-515	Seminar on the Foundations of Statistics	9
80-516	Causality and Learning	Var.
80-520	Seminar on Philosophy Science	9
80-521	Seminar on Formal Epistemology	Var.

History of Philosophy Requirements 18 units

Complete two courses:		Units
80-150	Nature of Reason	9
80-226	Revolutions in Science	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-252	Kant	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism	9
80-256	Modern Moral Philosophy	9
80-257	Nietzsche	9
80-261	Experience, Reason, and Truth	9
80-263	Approaching Chinese Philosophy: Basic Texts and Implications	9
80-358	Hume	9
80-362	Russell	9
80-363	19th Century Foundations of Science	9

Philosophy Electives 18 units

Complete 18 units in the Philosophy department at the 200-level or higher.

The Honors Program

The Dietrich College Senior Honors Program provides recognition of outstanding performance by students majoring in Philosophy, Logic and Computation or Ethics, History, and Public Policy. Students have the opportunity to develop their skills and to apply their knowledge through completion of an honors thesis in their senior year. By completing the thesis, students earn 18 units of credit and qualify for graduation with College Honors. To qualify for the honors program, students must maintain a quality point average of at least 3.50 in the major and 3.25 overall, and be invited by the department to become a participant.

Undergraduate Research Fellows

Qualified upper level undergraduates, preferably majors in one of the Philosophy Department's programs, may apply to serve in their junior or senior years as fellows in the Laboratory for Symbolic and Educational Computing (LSEC). Applications are reviewed in the fall. Visit LSEC from the Department's website at www.cmu.edu/dietrich/philosophy/research/lsec/fellowships.html, or contact Professors Joseph Ramsey or Wilfried Seig for additional information.

Faculty

JEREMY AVIGAD, Professor of Philosophy – Ph.D., University of California, Berkeley; Carnegie Mellon, 1996–

STEVEN AWODEY, Professor of Philosophy – Ph.D., University of Chicago; Carnegie Mellon, 1997–

ADAM BJORNDAHL, Assistant Professor of Philosophy – Ph.D., Cornell University; Carnegie Mellon, 2014–

SIMON CULLEN, Assistant Teaching Professor of Philosophy – Ph.D., Princeton University ; Carnegie Mellon, 2018–

DAVID DANKS, L.L. Thurstone Professor of Philosophy & Psychology, Department Head – Ph.D., University of California, San Diego; Carnegie Mellon, 2003–

B. R. GEORGE, Assistant Professor of Philosophy – Ph.D., University of California, Los Angeles; Carnegie Mellon, 2014–

MARALEE HARRELL, Teaching Professor of Philosophy – Ph.D., University of California, San Diego; Carnegie Mellon, 2003–

KEVIN T. KELLY, Professor of Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 1985–

ALEX JOHN LONDON, Clara L. West Professor of Ethics and Philosophy – Ph.D., University of Virginia; Carnegie Mellon, 2000–

RICHARD SCHEINES, Professor of Philosophy, Bess Family Dean's Chair of the Dietrich College of Humanities and Social Sciences – Ph.D., University of Pittsburgh; Carnegie Mellon, 1987–

TEDDY I. SEIDENFELD, Herbert A. Simon Professor of Philosophy and Statistics – Ph.D., Columbia University; Carnegie Mellon, 1985–

WILFRIED SIEG, Patrick Suppes Professor of Philosophy – Ph.D., Stanford University; Carnegie Mellon, 1985–

MANDY SIMONS, Professor of Philosophy – Ph.D., Cornell University; Carnegie Mellon, 1998–

JOEL SMITH, Distinguished Career Teaching Professor of Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 2000–

PETER L. SPIRTES, Professor of Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 1987–

DANIELLE WENNER, Assistant Professor of Philosophy – Ph.D., Rice University; Carnegie Mellon, 2013–

THOMAS WERNER, Assistant Teaching Professor of Philosophy – Ph.D., Rutgers University; Carnegie Mellon, 2003–

KUN ZHANG, Assistant Professor of Philosophy – Ph.D., The Chinese University of Hong Kong; Carnegie Mellon, 2015–

KEVIN ZOLLMAN, Associate Professor of Philosophy – Ph.D., University of California, Irvine; Carnegie Mellon, 2009–

Special Faculty

CHRISTINA BJORNDAHL, Teaching Instructor – Ph.D. Candidate, Cornell University; Carnegie Mellon, 2014–

DERRICK GRAY, Teaching Instructor – Ph.D., Rice University; Carnegie Mellon, 2013–

JOSEPH RAMSEY, Director of Research Computing – Ph.D., University of California, San Diego; Carnegie Mellon, 2006–

PATRICK WALSH, Assistant Teaching Professor of Philosophy, Carnegie Mellon-Qatar – Ph.D., Carnegie Mellon; Carnegie Mellon, 2019–

Affiliated Faculty

WAYNE WU, Associate Professor and Associate Director of CNBC – Ph.D., University of California, Berkeley; Carnegie Mellon, 2010–

Emeriti Faculty

ROBERT CAVALIER, Teaching Professor (Emeritus) – Ph.D., Duquesne University; Carnegie Mellon, 1987–

CLARK GLYMOUR, Alumni University Professor of Philosophy (Emeritus) – Ph.D., Indiana University; Carnegie Mellon, 1984–

DANA S. SCOTT, Hillman University Professor of Mathematical Logic, Computer Science and Philosophy (Emeritus) – Ph.D., Princeton University; Carnegie Mellon, 1981–

Department of Philosophy Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

80-100 Introduction to Philosophy
All Semesters: 9 units
In this introductory course we will explore three major areas of Philosophy: Ethics, Metaphysics, and Epistemology. Accordingly the course is divided into three sections. In each section we will read primary sources and discuss some of the main philosophic problems associated with that area. These will include: moral problems (Ethics), problems rising from the debates about free-will, personal identity or intelligence (Metaphysics), and inquiries about the scope and limits of human knowledge (Epistemology). We will then introduce some theories designed to solve such problems, and try to understand the strengths and weaknesses of these theories. We will apply different techniques and theories to issues that we might encounter in the real world. We will use class discussions, homeworks and papers to learn skills for evaluating arguments. These skills include: how to present a philosophic argument, what are the assumptions that justify it, what are its weaknesses and its strengths, whether such weaknesses can be resolved and, if they cannot be resolved, why.

80-110 Nature of Mathematical Reasoning
Intermittent: 9 units
This course focuses on understanding the principles and problems at the root of mathematical reasoning; it is not a course on any specific mathematical theory, like linear algebra or topology. We will explore the foundations of mathematics, both in terms of their historical origin and their modern purpose as a base for the study of mathematics. Then we will see how problems which seem to have no intuitive solution look simple after being put in the right mathematical form, but also consider the limitations this type of approach. We will treat such issues as they arise both in applied fields (policy decision-making, physics, computer science) and as more recreational, speculative and abstract (Conway's game of life, the works of Escher, music). The course is aimed for students at the freshman and sophomore level who do not necessarily intend to pursue a mathematically intense major.

80-130 Introduction to Ethics
Intermittent: 9 units
Philosophical ethics, or moral philosophy, covers a lot of ground. It asks and tries to answer questions like: What's good in life? What matters? What should I (and others) do? How should I (and others) act? What kinds of things out there must be treated ethically? Do we have moral duties to (at least some) non-human animals? Is morality subjective? Are there actually any objective moral truths? Morally speaking, what (if anything) is the difference between killing someone, and simply letting them die? In trying to answer these questions (and others), we'll engage in some wonderfully weird thought experiments, class discussions, smaller group discussions, debates, etc. We'll study and critique several moral theories which try to explain and help guide our moral judgments, and we'll try to apply these theories to real-life moral controversies. Past classes covered topics including drug prohibition, abortion, euthanasia, and physician-assisted suicide. This is an introductory philosophy class, so you'll be learning how to read, critique, do, and write philosophy generally, not just ethics. Considerable time and effort, both in lectures and in recitations, will be spent helping you learn to recognize and evaluate philosophical arguments, as well as empowering you to create, improve, and defend your own arguments in class assignments.

80-135 Introduction to Political Philosophy
Intermittent: 9 units
As an introductory course, we will seek to trace out the historical and philosophical dimensions of the polis from its origins in Ancient Greece to its current manifestation in present-day society. Special emphasis will be placed on the concept and practice of "democracy." We'll begin with the history of political philosophy from Plato and Aristotle (two of the early critics of democracy) to the modern period and the arguments in support of "republicanism" as found in the Federalist Papers (Madison, Jay, Hamilton). These historical moments cast light on the philosophy behind the development of the US constitution. Following Ketcham, we'll discuss the debate between the "ancients and moderns," enlightenment ideas regarding liberty and equality as well as the distinction between private rights and public goods. After presenting some fundamental justifications for democracy and our current models of democratic governance, we'll study the basic political frameworks of our day through a thorough-going analytic analysis of the writings and arguments of recent and contemporary political philosophers such as John Rawls, Ronald Dworkin, Robert Nozick, Charles Talyor, Michael Sandel, and Annette Baier. The course will end with a discussion of the theory and practice of deliberative democracy and a chance for students to engage in this model of democracy through the activities of an ersatz "deliberative poll."

80-136 Social Structure, Public Policy & Ethics
Intermittent: 9 units
The course will consider ethical questions surrounding social structure and public policy. It will analyze the role of political institutions and individual citizens in dealing with some of the greatest challenges facing our world: Global health crises, the spread of (and threats to) democracy worldwide, and world poverty. Some of the questions we will consider include: Are developed countries obligated to ameliorate poverty by providing foreign aid? What is democratic governance, and what do democratic representatives owe to their constituents? Should wealthy nations and corporations assist in the fight against life-threatening diseases worldwide? The course uses ethical and political theory, case studies, and empirical evidence to consider these questions.

80-150 Nature of Reason
Intermittent: 9 units
This course offers an intellectual history of philosophical views regarding the nature of human reasoning in mathematics and the sciences, from ancient to modern times. The first part of the course traces the search for deductive methods for obtaining certain knowledge, starting with Aristotle and Euclid, and continuing through the Middle Ages and late Renaissance thought, to the work of Boole and Frege in the nineteenth century. The second part of the course considers the history of skepticism about empirical knowledge, covering Plato, Sextus Empiricus, Descartes, Pascal, and Hume, along with replies to skepticism in the works of Bayes and Kant. The third part of the course discusses theories of the nature of mind, culminating in the computational conception of mind that underlies contemporary cognitive science.

80-180 Nature of Language
Fall and Spring: 9 units
Language is used to talk about the world or to describe it, but how do we go about describing language itself? Linguistics is the name given to the science of language, whose task it is to give such a description. The discipline of linguistics has developed novel tools for describing and analyzing language over the last two hundred years and in this course we learn what these tools are and practice applying them. Sub-areas of linguistics which we study include phonetics (the study of speech sounds), phonology (the study of sound systems), morphology (the study of parts of words), and syntax (the study of combinations of words). Beyond this, we look at changes in language over time, and we consider the puzzle of linguistic meaning. The methods of linguistics are useful in the study of particular languages and in the study of language generally, so this course is useful for students of foreign languages as well as those interested in going on to study language acquisition, psycholinguistics, sociolinguistics, philosophy of language, and computer modeling of language.

80-201 Knowledge and Justified Belief
Intermittent: 9 units
What does it mean to have knowledge? How do we know things, and what can be known? These are some of the central questions in the discipline of epistemology ("the theory of knowledge"). The answers to these questions are not as obvious as some casual thought may suggest. If you think the senses provide us with knowledge, how will you know when your senses deceive you? If you think knowledge is gained through reasoning, where will you start reasoning? This course investigates these questions, focusing on both classic questions and treatments and more recent work in the field of social epistemology. There are no prerequisites, but students may find previous experience with philosophical reasoning to be helpful. Students both with and without such experience are encouraged to take the class.

80-208 Critical Thinking
Intermittent: 9 units
This course is an introduction to practical reasoning. The course will contain an elementary introduction to concepts important for reasoning and decision making, such as validity, probability, and utilities. Students will extensively practice critically analyzing and evaluating a wide variety of arguments found in newspapers, magazines, and elementary accounts of scientific reasoning. In order to help students develop the skills to analyze and evaluate arguments, the course will introduce several software packages recently developed at CMU that help students diagram arguments and causal reasoning; these packages have been shown to improve students critical reasoning skills. In addition, students will learn about a wide variety of statistical, logical, psychological, and causal fallacies that are used to mislead people.

80-210 Logic and Proofs
All Semesters: 9 units
This web-based course introduces students to central issues in logic and develops their ability for constructing and refuting arguments. It addresses the question: How can one analyze the structure of rational discourse or, more specifically, the logical structure of argumentation? An answer to this question requires: (i) uncovering the logical form of statements; (ii) defining the correctness of logical steps; (iii) formulating inference rules for the logical forms; (iv) designing strategies for argumentation with the inference rules. The course takes these steps for both sentential and quantificational logic. Presentation: The material is presented on-line, though some exercises must be done with pen and paper. Additional reading of historical and philosophical character complements the systematic on-line presentation. Weekly small discussion meetings with collaborative reviews, substantive discussions and critical reflections supplement the on-line material.

80-211 Logic and Mathematical Inquiry
Intermittent: 9 units
Since ancient times, mathematical arguments have served as a paradigm for rational inquiry. This course studies the structure of such arguments and their applications. We will study foundational mathematical concepts and informal proofs, as they appear in everyday mathematics. At the same time, in parallel, we will study mathematical logic, which provides formal symbolic languages for mathematics. The course will make use of a computational "proof assistant" to develop fully rigorous, machine-checked proofs. This course prepares students to take the 310-311 series on the fundamental (in)completeness and (un)decidability theorems of modern logic.

80-214 Computing, AI, and Philosophy
Intermittent: 9 units
The aim of the course is to give an interdisciplinary introduction to computation, artificial intelligence, and philosophical questions regarding them. It will also include historical and sociological issues concerning these topics as well as their representation in the arts. The course does not require a background in mathematics, computer science or philosophy.

80-220 Philosophy of Science
Intermittent: 9 units
In this course, we will examine some historical case studies (e.g., the Copernican revolution in astronomy) against which we will assess views pertaining to the significance, justification, and production of scientific knowledge. For example, should scientific theories be understood literally or as computational devices for deriving new predictions? How can universal conclusions ever be justified by a finite data set? Does explanation contribute to a theory's confirmation by the evidence? Does science aim to find the truth? Is probability in the world or only in our minds? Is explanation a matter of finding causes or are causes whatever it is that explains? Is scientific rationality objective or culture-relative?

80-221 Philosophy of Social Science
Spring: 9 units
This course will explore various philosophical issues germane to social science. The central question of the course asks whether we can use traditional scientific tools to understand social phenomena, e.g. wars and religions, in the same way that we use them to understand natural phenomena, e.g. gases, lasers and planetary orbits. Some of the more specific questions we address: Because humans possess free will and act with intentions while light rays and planets in motion do not, are we forced to use logically different species of explanations in the two cases? How can we explain social institutions that depend upon cooperation? Whereas natural scientists actively conduct experiments, social scientists can often only collect statistical data. Does this difference prevent social scientists from inferring causal relations? Is our understanding of social phenomena always value laden?

80-222 Measurement and Methodology
Spring: 9 units
This is intended as an introduction to the theory of measurement. How are units chosen? Under what conditions do qualitative relationships determine quantitative ones? We shall investigate theories of extensive measurement, with and without error. Applications will be taken from the natural and social sciences. Prerequisites: None specifically; however, students should have background in elementary logic and be comfortable with taking mathematical approaches to conceptual problems.

80-223 Causality and Probability
Intermittent: 9 units
Does smoking cause cancer? What causes global warming? Would World War II happen if World War I had never happened? In our daily life and science, people often attempt to answer such causal questions, and probability theory, as a mathematical model of uncertainty, serves as a fundamental tool. This course explores the history of causality and probability and the basic methodologies for causal inference and statistical analysis. In particular, we will study what causality is, how it is related to and different from correlation, the relationship between causality and regression, the benefit of using causal knowledge, the classical ways to find causal relations, when it is possible to achieve so from purely observational data, and machine learning methods for discovering causal structure.

80-224 Race, Gender and Science
Intermittent: 9 units
In this course, we will focus on the interplay between science, technology, & medicine, on the one hand, and race & gender on the other. Taking up a series of controversial issues and cases from the past and the present, we will consider the implications of developments in the life sciences for politics, social identity, and cultural belonging. In our readings and discussions, we will examine the roles of science, technology, and medicine in defining and redefining race and gender; the ways in which cultural beliefs about race and gender have influenced scientific research and the development of knowledge; and the efforts by individuals and social movements to challenge scientific institutions and assert new claims about identity, difference, and inequality.

80-226 Revolutions in Science
Intermittent: 9 units
Science is an ever-changing enterprise. Most scientific advances, though significant, occur within a stable framework of accepted theories and data. A few episodes of change in the history of science involve discarding and replacing fundamental theories of the world. These are often accompanied by significant changes in the vocabulary in which those theories are expressed, the tools used by scientists, the phenomena on which scientists focus, and the kinds of explanations they consider acceptable. A very small number of these episodes change the way humanity views its ability to know the natural world and its place in universe. The latter two kinds of change in science have often been called "scientific revolutions." We will focus on three such radical transformations: The "Copernican Revolution" (or "the Scientific Revolution") of the 16th and 17th centuries, the Darwinian revolution of the 19th century, and the quantum revolution of the late 19th and 20th centuries. This course has two intertwined components: history of science and philosophy of science. In the historical component, we will examine in some detail the three major scientific revolutions. The philosophical components will help us understanding the reasoning involved in scientific theory change. This course does not required detailed knowledge of any of the sciences used in examples of revolutionary change.

80-241 Ethical Judgments in Professional Life
Intermittent: 9 units
This is a multimedia, hybrid course that examines the numerous ethical issues, problems and dilemmas that confront professionals in such areas as medicine, law, engineering, the media, government and the natural and social sciences. As a hybrid course, it includes educational materials in video streaming format, an audio CD, an electronic discussion board and web-based "guided inquiries" that students navigate and complete. Topics discussed include: Responsibility in the professions, obligations to clients, conflicts of interest, Whistleblowing, codes of ethics and ethics in engineering, medicine, law, media, computer science and business among others. This course meets one day a week and employs a case study discussion format during class.

80-242 Conflict and Dispute Resolution
Intermittent: 9 units
Conflict is an intractable feature of human life, whether occurring between family members, friends, coworkers, political organizations, nations, and even within oneself. You must then be prepared to negotiate with others to get your job done, to advance your career, and even to maintain meaningful personal relationships with your family and friends. The purpose of this course is to help prepare you for these negotiations. In particular, in this course, you will reflect on your current approaches to conflict, study the nature of conflict and why it tends to escalate, and develop your own skills for principled negotiation. Throughout the course you will also participate in negotiation simulations exercising your powers of communication and persuasion while practicing conflict resolution tactics. My goal is that you finish this course a more reflective and effective negotiator, better prepared to handle the conflicts you will inevitably face.

80-243 Ethics of Leadership
Intermittent: 9 units
From business operations to international affairs, leadership concerns the use of power or influence to coordinate a group towards common purpose. However, leadership also requires the acceptance of responsibilities not shared with the other group's members. Given their distinctive role and responsibilities, leaders must be prepared to face a unique host of moral problems and dilemmas. In this course, we will pursue the question of what makes a morally good leader, as opposed to a merely effective one. To that end, we will critically examine various competing theories of leadership while considering the moral challenges that arise when power, self-interest, justice, and the collective good collide.

80-244 Environmental Ethics
Intermittent: 9 units
In this class, we'll try to figure out what obligations we might have to the natural environment and the non-human living beings within it, as well as what justice requires of us in our use of natural resources given the needs of other human beings. Among other things, we'll spend considerable time on animal ethics: What moral obligations do we have to non-human animals? Is it morally OK to eat them? Does a dog count (morally speaking) as much as a human? Does a factory-farm chicken count as much as a wild endangered tiger? Then, given that many of the most pressing environmental problems¿like climate change¿are collective action problems, we'll consider why these problems are so sticky, what obligations we have as individuals in dealing with these problems, and what a just collective solution might look like. To that end, we'll examine the processes fueling climate change, we'll look at who is responsible for these processes, and we'll try to determine whether any current proposal to deal with climate change is an effective, just response to the problem.

80-245 Medical Ethics
Fall: 9 units
This course provides an introduction to core ethical issues in health care, medical research, and public policy. Topics include: the moral responsibilities of health care providers to patients and various third parties such as the government or insurance companies, the status of health as a social good, and questions of individual liberty and social responsibility at the ends of life including issues such as abortion, physician assisted suicide, and the definition of death. We will also examine specific ethical issues in the conduct of medical research and look at the impact of technological innovation on our notions of health, disease, life, death, and the family. If time permits, we may also discuss issues related to genetics and cloning. While the course engages such substantive ethical issues it also attempts to sharpen students' skills in practical reasoning through argument analysis, analogical reasoning, and the application of theory and principles to particular cases.

80-246 Moral Psychology
Intermittent: 9 units
Moral psychology is the study of how we think about morality, make moral judgments, and behave in moral situations. This has important implications for how we should think about morality, make moral judgments, and behave in moral situations. In this course we will examine empirical research on moral thinking and behavior by psychologists, neuroscientists, economists, and philosophers and discuss the implications this research has for issues in ethics. We will address questions such as: What motivates our moral behavior? Do we ever act altruistically or do we only do the right thing because it's somehow in our own interest? Is it even possible to tell what people's real motivations are? How do we make moral judgments and decisions? What roles do reason, intuition, and emotion play in our moral judgments? What role should they play? What role should a person's beliefs, desires, and intentions play in our judgments of how blameworthy the person is or of how much punishment he or she deserves? What role should the outcomes of the person's actions play in our judgments of him or her? Should we hold people responsible for things that are not entirely under their control?

80-248 Engineering Ethics
Fall: 9 units
This course provides an introduction to core ethical issues in engineering research and practice. Topics include: the moral responsibilities of engineers to clients and various third parties such as the government or insurance companies, conflicts of interest, whistleblowing, codes of ethics, and the status of engineering projects as social goods. While the course engages such substantive ethical issues it also attempts to sharpen students' skills in practical reasoning through argument analysis, analogical reasoning, and the application of theory and principles to particular cases. This course meets two days a week and employs a case study discussion format during class.

80-249 AI, Society, and Humanity
Intermittent: 9 units
AI and robotic technologies are rapidly developing and spreading, with corresponding social and human impacts & opportunities. Understanding these potential risks and benefits requires a multidisciplinary approach, drawing from ethics, philosophy, psychology, sociology, economics, and more. These diverse perspectives can help us to ensure that new technologies support and advance human and social values & interests. In this course, we will study relevant disciplinary methods & frameworks through a series of case studies of current or near-future AI and robotic technologies. We will learn to apply those techniques to analyze and understand the challenges & opportunities presented by novel technology.

80-250 Ancient Philosophy
Intermittent: 9 units
This course will cover Ancient Greek philosophy from the pre-Socratics to the later Hellenistic writers. We will prepare the background for Socrates and Plato by tracing the various historical and intellectual movements that led up to and through the flourishing and downfall of Periclean Athens. A study of Socrates (as represented in Aristophanes' comedy and Plato's early dialogues) will lead to an in-depth reading of Plato's Gorgias, Symposium and sections of the Republic. We will approach Aristotle through his 'practical philosophy' as presented in the Nicomachean Ethics. The final sections will discuss the Epicurean, Skeptic, and Stoic movements as well as the work of Cicero. Excerpts from other works of Plato and Aristotle as well as Martha Nussbaum's recent work on Aristotle and Hellenistic philosophy will accompany selected parts of the course.

80-251 Modern Philosophy
Intermittent: 9 units
Descartes' project to doubt all received knowledge and begin from scratch marked the beginning of an intellectual upheaval, helping to launch what is now called the Modern period of philosophical thought; the Western world is today the heir of modernism. Locke, Leibniz, Hume, and Kant are several of the most important figures of this period. We will examine works of these thinkers, exploring both the new sorts of questions that these philosophers raised and their new methods of doing philosophy, which together mark a fundamental break with the traditions that preceded them. We will devote special attention to the new theories of knowledge they proposed and to their works in ethics and political philosophy. The philosophical revolution of the 17th and 18th centuries occurred during a time of great scientific progress and political upheaval in Europe; as part of our course we will consider the relation of certain of these developments to the new questions and methods of the modern philosophers and to their works in ethics and political philosophy.

80-252 Kant
Intermittent: 9 units
Immanuel Kant's 'Critical philosophy' may be seen as the result of his attempts to determine the sources of human knowledge, and to find metaphysical foundations for Newton's mechanics. This course will involve readings in Kant's /Critique of Pure Reason/ and other texts. Emphasis will be placed on understanding Kant's thought in the context of contemporary intellectual developments and on his theory of human cognition.

80-253 Continental Philosophy
Intermittent: 9 units
This course provides students with an overview of key movements in European Philosophy. The historical background covers Descartes, Kant, Kierkegaard, and Nietzsche. The central tenets of phenomenology and existentialism (e.g., intentionality, Being-in-the-World, Bad Faith) will be discussed in the context of selected works from Husserl, Heidegger, Sartre and Merleau-Ponty. The course will conclude with the background for and current work of Habermas.

80-254 Analytic Philosophy
Intermittent: 9 units
This course examines the revolutionary impact of philosophy at the turn of the 20th century on contemporary thought and progress. By the 1920s some scientists and philosophers became hopeful that the end of the long tradition of philosophical deadlock was finally within reach. Buoyed in particular by Einstein's theory of relativity and the invention of modern logic, they created a new kind of philosophy with the goal of applying logical and empirical methods to philosophical problems. This new approach led to new puzzles and paradoxes, along with a focus on the age old question of what can be known and what is meaningful. The modern fields of linguistics, cognitive science, and information and computer sciences all owe a debt to these sources, as does of course contemporary philosophy. Our quest will be to understand both what authors like Frege, Russell, and the Vienna Circle were up to in the first place, and how their work contributed to the world we live in today.

80-255 Pragmatism
Intermittent: 9 units
American Pragmatism represents an energetic attempt to bridge the divergent cultures of science and the humanities. The movement's founder, C.S. Peirce, was trained in chemistry and worked as a physicist, but he was also deeply concerned with the contemporary philosophical portrayal of science, which distinguished sharply between theoretical knowledge and practice. Peirce responded by constructing a comprehensive philosophy emphasizing the scientific importance of community, fallibility, and action. Pragmatism was also developed and vigorously popularized by William James, who aspired to be a painter and ended up as an acknowledged founder of modern empirical psychology. James extended Peirce's position by defending the role of values in even the purest of empirical sciences. John Dewey, who is also well-known for his role in education, interpreted science as an evolving social system and developed a theory of aesthetics based on what we now call the psychology of problem solving. The pragmatists made and continue to make lasting contributions to modern statistics, logic, and social science and their emphases on community, fallibility, action, and value in science are still of primary importance in philosophy and in the ongoing dialogue between the scientific and humanistic cultures.

80-256 Modern Moral Philosophy
Intermittent: 9 units
This course will follow moral theory through the modern era (roughly 1600-1900), with special emphasis on the works of Hobbes, Hume, and Kant, as well as the development of utilitarianism. Since moral theorizing was only one part of these thinkers? larger systems of philosophy, it cannot be fully separated from questions of metaphysics and epistemology (e.g. free will, determinism, materialism, etc.), and we'll spend some time situating their ethical thought within their larger projects. In doing so, we'll also examine these theories within the context of the rapidly changing social, political, and scientific landscape of the modern period.

80-257 Nietzsche
Intermittent: 9 units
During his life in the late 19th-century, Friedrich Nietzsche was a relatively obscure German philosopher. Since his death, however, he has become deeply influential and well-known, and was a source of inspiration for many important 20th-century thinkers. Despite this popularity, Nietzsche's philosophy remains relatively mysterious, and often misunderstood. Much of his writing consisted of aphorisms, rather than more traditional prose and arguments, and many of his positions seem to contradict one another. This course will cover a broad range of Nietzsche's writings, focusing on such central concepts as the will to power, eternal recurrence, and the oft-misunderstood Ubermensch ("overman"). Throughout, we will focus on developing a consistent interpretation of an enigmatic philosopher whose views have been mischaracterized and misappropriated throughout the past century.

80-261 Experience, Reason, and Truth
Intermittent: 9 units
A central issue in Western philosophy has been whether reason or experience (or some of both?) provides the foundations for human knowledge. This course explores that question by looking at various "empiricist" vs. "rationalist" debates from the 17th century to the present day. We will focus on the problems encountered in trying to give an adequate account of the our knowledge of the external world, the structure of our minds, and the nature and limitations of human knowledge. The scope of our investigation will extend to the nature of mathematical knowledge, to "thought experiments" in both science and philosophy, and to "nativism" vs. "empiricism" issues in contemporary cognitive science and moral theory. The course has two main goals: (1) to study key metaphysical and epistemological issues surrounding the nature of human knowledge and (2) to help improve our analytical and critical skills by extracting and evaluating various relevant philosophical arguments.

80-263 Approaching Chinese Philosophy: Basic Texts and Implications
Intermittent: 9 units
This course focuses on ancient texts of Chinese philosophy, which have had a foundational role in Chinese society and culture. We will look at original texts from the Chinese classics, including the I Ching (Book of Changes) and the Tao Te Ching (basic treatise on Taoism). We will consider the role and place of science and explanation in Chinese society. We will also discuss the difficulty of translation from one language to another or from the writings of one era into another. The course will seek to connect the ancient literature and practice with modern perspectives on science, metaphysics, mind/body dualism, and causation. We will take the ancient texts in their original form as points of departure for our exploration. No prior knowledge of the Chinese language is assumed. The course is relevant for cultural and language studies, as well as studies in history and philosophy of science.

80-270 Philosophy of Mind
Intermittent: 9 units
The mind poses one of the greatest challenges to understanding how the world works. What is a mind? What is consciousness? What is sensing? What is agency? How are these facets of subjectivity related to the objective, physical world? In this course, we tackle these challenging questions with a philosophical approach that highlights analysis and argument, though we will also bring in relevant empirical understanding of the mind and brain to enrich our discussion (a complementary course, Philosophy and Psychology, is taught in alternate years where the empirical issues are the focus with enrichment from philosophy). A central practical aim of this course is to promote development of analytical skills through practice engaging with arguments.

80-271 Philosophy and Psychology
Intermittent: 9 units
This course has two parts. First, we will look at basic concepts used in psychology (and cognitive science broadly) through the lens of philosophy including: representation, computation, information, explanation, modularity, attention, automaticity and control. Having some concrete proposals about these ideas will allow us to formulate psychological claims more concretely. Second, we will reverse course and look at traditional philosophical problems through the lens of psychology focusing on three topics: consciousness, agency, and perception. Specifically: what is consciousness, what is it to be an agent, what is it to perceive?

80-275 Metaphysics
Intermittent: 9 units
The topical agenda of this course will vary. Typical topics include the problem of personal identity, the nature of human freedom, the nature of the self, the nature of reality and being, the nature of causality, and the question of whether solutions to such problems can be given. Classical as well as contemporary philosophic texts will be studied. For Spring 2011: Issues we will consider, in no particular order, include: Do properties exist? Why should you think there is an external world? What is a number? Why should you think other people have mental states? What are natural kinds? What constitutes the identity of things through time? What constitutes the identity of persons through time? What does determinism mean? Is there freedom of the will? What is possibility? What is necessity? Are there other possible worlds? When does one event cause another, and what does that mean? What could a deity be, and should you think there is one?

80-276 Philosophy of Religion
Intermittent: 9 units
While many interesting questions about religion are belief-specific, we will strive in this course to keep a global perspective. We will begin by considering a concept at the center of Western religion — God — as it presents itself in various traditions. We will then move to consider major Eastern religions, with a focus on their influence on philosophical thought. In both of these studies, we will emphasize the relationship between language and religion. We will conclude the course by considering commonalities between Eastern and Western religious thought. The student should leave the course with 1) the tools to consider religious text and rhetoric philosophically, and 2) a sharpened idea of what 'religion' is (though this might differ from my own!).

80-280 Linguistic Analysis
Intermittent: 9 units
At one level, language is constituted by nothing but sounds, or marks on paper. How can such physical objects be used to create or transmit meaning? The answer assumed in this course is that objects with specific physical features are assigned symbolic or linguistic values on the basis of those features. By the juxtaposition of such objects (phonemes or graphemes), larger symbolic objects are created (morphemes). Morphemes have the special property that they can be associated in a consistent way with meanings. In a progressive fashion, words are built from morphemes, phrases from words, and sentences from phrases. Sentences have different moods, and these moods correspond to their function with respect to the encoding and transmission of information. Indicative sentences carry information, interrogative sentences request information, imperative sentences demand action, conditional and modal sentences present alternative possibilities, and so on. The goal of this course is to investigate the structure of the linguistic entities by which these communicative functions are realized. Building on material taught in Nature of Language, we look in detail at the morphology and syntax of human languages, paying special attention to cross-linguistic variety.
Prerequisite: 80-180

80-281 Language and Thought
Intermittent: 9 units
The goal of this course is to provide students with the opportunity to creatively explore some difficult questions about the relationship between language and thought, questions such as: How does the human capacity to use language relate to the human capacity to think? Does the language that a person speaks affect the way she thinks? If meaning is in the head, how can we succeed in communicating with each other? How is our ability to reason related to our ability to successfully communicate? None of these questions have definite answers; throughout the course, we will draw on work in philosophy, psychology and linguistics to try to understand some of the possible answers that might be entertained. Students in the course should be prepared for extensive reading, writing and peer discussion assignments.

80-282 Phonetics and Phonology I
Fall: 9 units
This course aims to provide students with practical tools for the study of speech sounds. The acoustic properties of sounds are examined using spectrograms and other devices, with emphasis on vowels and sonorant consonants. Following this, basic phonological notions are covered, tracing their development in the twentieth century up through optimality theory. In optimality theory, contrast and allophonic variation are explained in terms of an input-output device which selects the most harmonic candidate still faithful to phonemes in the input. The course should be relevant not only to linguistics students, but to students of language generally, with applications to sociolinguistics, child language development, speech recognition technologies, and the study of foreign languages.
Prerequisite: 80-180

80-283 It Matters How You Say It
Intermittent: 9 units
Why do languages give us multiple ways to say the same thing? Given that in English we can say "My dog ate my homework," why do we sometimes prefer "My homework got eaten by my dog"? Why do we sometimes choose to refer to someone with just a pronoun ("he"), and sometimes choose their full name ("Charles Dickens")? What's the difference between telling someone: "This expensive coffee is tasteless," or telling them: "This tasteless coffee was expensive"? This course is about the choices that languages give us for conveying a particular message, and the communicative effects of those choices. We will see that it is both the words you use and the way you put them together that determines the total communicative effect of your utterance. While the course will focus on English, students will have an opportunity to work on another language of interest in their final project.

80-284 Invented Languages
Intermittent: 9 units
Language is normally something that develops and and changes organically within human communities, without much in the way of organized design or invention. Over the centuries, however, many have succumbed to what J. R. R. Tolkien called the "secret vice" of language creation. The purposes of these invented languages have been diverse. Some, like Tolkien's Elvish languages, Okrand's Klingon, and Peterson's Dothaki and Trigedasleng have been designed for artistic or entertainment purposes: they have set out to be "natural" languages within fictional worlds. Others, like Zamenhof's Esperanto, Brown's Loglan, and Elgin's Láadan have tried to address perceived inadequacies of the natural languages that their creators saw in the world around them. The of study language invention is thus both the study of a distinctive art form, and an exploration of the history of how people have thought about language in different ages and societies. In this course, we will explore the linguistic considerations involved in language invention, and the linguistic lessons of the history of invented languages, with a particular emphasis on applying these insights to our own language invention projects. Over the course of the semester, students will be expected to develop invent their own languages, and to complete various shorter assignments to supplement relevant ideas and skills. This course does not assume any background in linguistics, and is intended to accommodate both newcomers and advanced students.

80-285 Natural Language Syntax
Fall: 9 units
This course is intended to provide an introduction to the methods of syntactic analysis, and to some major themes of contemporary syntactic theory, following up on syntactic concepts introduced in 80180, Nature of Language. A primary theme of the course is the structural constituency of a sentence, and the course will address some of the following questions. What are syntactic constituents? Do all aspects of syntax manipulate the same kinds of structural units, or do different grammatical processes rest on incompatible notions of constituency? How do other syntactic relations connect with constituent structure? To the extent that there is mismatch between different notions of syntactic structure, how can it be reconciled within a theory of grammar? These questions are engaged in through the diagnostics and techniques of modern syntactic analysis and argumentation. Those tools will allow us to explore the striking ways in which syntactic theory unifies diverse grammatical phenomena in terms of a common notion of phrase structure. The course complements 80280, Linguistic Analysis, building on but not presupposing syntactic analyses developed in that class.

80-286 Words and Word Formation: Introduction to Morphology
Intermittent: 9 units
How many words do you know? Is 'gonna' one word or two? How many meanings does 'unlockable' have? If someone can be 'inept', why can't they be 'ept'? In this course we study the lingusitics of words and word formation, known as morphology. We begin by asking what a word is, about the internal structure of words, and how new words are formed. Throughout, we will consider these questions from a cross-linguistic perspective, looking at morphological data from a wide range of languages. We will also consider how morphology interacts with other subfields of linguistics, including phonology, syntax and semantics. Finally, we will survey morphological questions from the perspectives of language acquisition, psychology, and cognitive science.
Prerequisite: 80-180

80-287 Language Variation and Change
Intermittent: 9 units
This course explores language variation across space and time. Our experience of language is full of direct and indirect evidence of language change and variation, and of the ways that these interact and intersect with other historical and social phenomena. How do languages change over time, and what kinds of factors influence this change? How do we determine whether, say, Farsi and Nepali (or Farsi and English) were at some point in the past the same language, before different changes took them in different directions? If they are, how do we investigate what that past language might have sounded like? What are the sources of variation within and between languages, and how can we investigate the nature of this variation? How can an understanding of language change help us to make sense of language variation, and how can an understanding of language variation help us to make sense of language change? How do issues of social status and political power affect language variation and change? What happens when languages come into contact? How can linguistic theory inform the study of variation and change, and what insights can the study of these phenomena contribute to linguistic theory? This course is intended to provide students with the tools to begin to explore and address these kinds of questions.
Prerequisite: 80-180

80-288 Intonation: Transcription and Analysis
Intermittent: 9 units
Intonation is the melody of speech: how a speaker's pitch changes over the course of an utterance, along with the placement of emphasis, or sentence-level stress. Intonation and stress contribute to the interpretation of utterances in multiple ways. For example, the questions "Did BOB go to the store?" and "Did Bob go to the STORE?" contain the same words, but request different information. Similarly, whether the sentence "Bob went to the store" is interpreted as a statement or as a question, and whether as expressing certainty or uncertainty on the part of the speaker, depends on its intonation. Features of intonation can also convey information about the speaker's attitudes and affect: sarcasm and irony, for example, may be signaled by intonation. The goal of this course is two-fold. First, students will learn about the phonetic correlates of intonation and stress, and learn how to analyze intonation as a system of high and low tones, using the intonation transcription system ToBI. This will enable students to accurately describe the intonation pattern of an utterance. Second, students will learn how intonation is used to convey semantic and pragmatic information. The course will focus primarily on English, but other languages will be explored to serve as a basis of comparison. There is no prerequisite, and no familiarity with either phonetics or semantics is assumed. The course will be of interest to students interested in learning some of the intricacies of face-to-face linguistic communication. Students in the departments of English, Modern Languages, Language Technology, Human-Computer Interaction, and Psychology will find material relevant to their major topics. The course serves as an elective for the Linguistics Major, and is a natural companion to other courses on the expression of linguistic meaning: Meaning in Language, Language in Use, and Syntax and Discourse.

80-292 Learning Science Principles
Spring: 12 units
The ability to learn - that is, to change and adapt to one's environment - is one of the hallmarks of intelligence, whether in humans, animals, or machines. In this course, we will examine the nature, components, and significance of learning in many different manifestations, with a particular focus on the fundamental concepts that underlie the ways in which we understand the concept of learning in different disciplines. This course will thus focus more on concepts and foundations, rather than technical aspects of learning, whether mathematical, experimental, or computational. This course will be almost entirely project-based: you will work in groups (with students from different backgrounds) to identify opportunities for learning media, and then develop designs that appropriately address those opportunities. In the course of developing these media designs, you will learn, and come to understand, concepts and principles of learning from different disciplines. The emphasis throughout will be on careful conceptualization, description, and design of the learning through and about media. This course will work in tandem with 05-292 Learning Media Methods. To waive an IDeATe portal course requirement, students should have prior project-based coursework in design, social science research methods, or interactive prototyping experience.

80-294 Ethics Internship / Practicum
Intermittent: 9 units
Internship

80-296 Impacts of AI: AI and Intelligence
Fall and Spring: 3 units
AI and robotic technologies are rapidly developing and spreading, with corresponding social and human impacts & opportunities. In this course, we will consider the impacts of AI and ethical issues of advancing technologies. This Micro course will run between 5-6 weeks. The instructor will fly into Doha for a short period of face-to-face classes, centered around a Saturday. Enrolled students should expect two 90-minute face-to-face classes during the week before or after this Saturday date, as well as four 90-minute evening (6-7:30 pm) video classes over the duration of the Micro course (typically two before the campus visit, and two after, although instructors can change this). Specific dates will be confirmed in the syllabus closer to fall semester.

80-297 Impacts of AI: AI and Ethics
Fall and Spring: 3 units
AI and robotic technologies are rapidly developing and spreading, with corresponding social and human impacts & opportunities. In this course, we will consider the impacts of AI and what it means to be human. This Micro course will run between 5-6 weeks. The instructor will fly into Doha for a short period of face-to-face classes, centered around a Saturday. Enrolled students should expect two 90-minute face-to-face classes during the week before or after this Saturday date, as well as four 90-minute evening (6-7:30 pm) video classes over the duration of the Micro course (typically two before the campus visit, and two after, although instructors can change this). Specific dates will be confirmed in the syllabus closer to fall semester.

80-298 Impacts of AI: AI and Society
Fall and Spring: 3 units
AI and robotic technologies are rapidly developing and spreading, with corresponding social and human impacts & opportunities. In this course, we will consider the societal impacts of AI. This Micro course will run between 5-6 weeks. The instructor will fly into Doha for a short period of face-to-face classes, centered around a Saturday. Enrolled students should expect two 90-minute face-to-face classes during the week before or after this Saturday date, as well as four 90-minute evening (6-7:30 pm) video classes over the duration of the Micro course (typically two before the campus visit, and two after, although instructors can change this). Specific dates will be confirmed in the syllabus closer to fall semester.

80-305 Choices, Decisions, and Games
Intermittent: 9 units
This course is an introduction to formal models of choice and decision-making. We begin by examining choice under certainty, developing both qualitative and quantitative models of preference. We then expand our analysis to take into account uncertainty, focusing on the von Neumann-Morgenstern theory of expected utility and Savage's classic axioms. Empirical challenges to models are emphasized throughout, in response to which we will consider a variety of alternative representations of uncertainty (e.g., Dempster-Shafer belief functions, non-unique probability measures) and preference (e.g., framing effects, prospect theory).

80-310 Formal Logic
Fall: 9 units
Among the most significant developments in modern logic is the formal analysis of the notions of provability and logical consequence for the logic of relations and quantification, known as first-order logic. These notions are related by the soundness and completeness theorems: a logical formula is provable if and only if it is true under every interpretation. This course provides a formal specification of the syntax and semantics of first-order logic and then proves the soundness and completeness theorems. Other topics may include: basic model theory, intuitionistic, modal, and higher-order logics.
Prerequisites: 15-251 or 21-127 or 80-211 or 80-210

80-311 Undecidability and Incompleteness
Spring: 9 units
U & I focuses on two fundamental results: the undecidability of logic (established by Alonzo Church and Alan Turing) and the incompleteness of mathematical theories (discovered by Kurt Gödel). The proofs of these results require a novel metamathematical perspective, but also striking logical concepts and fascinating mathematical techniques. In this course, the theorems are not just formulated but actually proved. We begin with the axiomatic development of elementary set theory that allows, at the same time, the formal representation of informal mathematics like number theory. With this basis, one can show that syntactic notions concerning set theory are representable in the very theory. It is then easy to prove that set theory is incomplete. To show that logic is undecidable, the crucial concept of computation is introduced via Turing machines. The two concepts - proof and computation - are fundamental for mathematics, computer science and, in particular, artificial intelligence. The undecidability and incompleteness results are among the most significant contributions of modern logic to the foundations of mathematics. They provide also the beginnings of a deeper understanding of mental processes in cognitive science and, thus, of the human mind. To understand the latter connections, we will read about and discuss historical as well as philosophical aspects of the subject.
Prerequisites: 15-251 Min. grade C or 21-300 Min. grade C or 80-210 Min. grade B or 80-310 Min. grade C or 80-211 Min. grade C

80-312 Mathematical Revolutions
Intermittent: 9 units
Mathematics is a central part of our intellectual experience. It is connected to sophisticated philosophical perspectives, say, in the work of Plato, Descartes, Leibniz, Kant, as well as in contemporary analytic philosophy; it is equally connected to fundamental views in the sciences, say, in the work of Ptolemy, Galileo, Newton, Einstein, as well as in contemporary cosmology. The common view that mathematics - if not directly "static", is evolving in a linear fashion - does not withstand historical scrutiny. Indeed, there are many dramatic conceptual changes concerning the very nature and object of mathematics. We examine three episodes in the relatively recent past that reflect radical transformations of the subject. They are closely associated with three mathematicians in whose work those revolutionary changes come to the fore most poignantly. The three episodes are framed by a discussion, at the beginning, of the axiomatic method and, at the end, of contemporary computational models of mathematical thinking. The episodes fall within the period from 1854 to 1954, but have deep roots in the past. The first episode deals with the shift from geometry to arithmetic as the foundational discipline for mathematics. The accompanying change in the methodological perspective is expressed in Hilbert's Foundations of Geometry, the center of the second episode. When joined with contemporaneous logical developments, that perspective underlies the formalization of mathematics. Gödel's incompleteness theorems imposed theoretical limits on that work. However, given Turing's analysis of computations, the question remains, how much of mathematical reasoning can be accomplished by computing machines. Completing a full circle, we incorporate central features of the axiomatic method into computational models of mathematical thinking.

Course Website: https://goo.gl/0fMpQQ

80-314 Causal Discovery, Statistics, and Machine Learning
Intermittent: 9 units
Statistics and Machine Learning have made tremendous strides in recent years in solving a wide variety of regression and classifiction problems. However, causal discovery problems (i.e. discovery of which variables are affected by a given variable that undergoes change due to an external intervention, either man-made or natural, and to what extent other variables are affected by such a change) are distinct and more difficult problems. Causal discovery problems arise not only in scientific contexts (e.g. discovering which genes regulate which other genes) but also in some machine learning contexts (e.g. transfer learning problems). This course will (i) describe how causal discovery problems differs from regression and classification problems in goals, methods, and fundamental assumptions, (ii) descibe recent advances in modifying machine learning and statistical algorithms to deal with causal discovery problems involving such difficulties as latent confounders, measurement error, selection bias, etc., and (iii) what the outstanding problems in causal discovery are and future directions the field might take. Students should have taken at least one course in statistics or machine learning, or obtain the permission of the instructor.

80-315 Modal Logic
Fall: 9 units
This course is an introduction to mathematical modal logic and its applications in philosophy, computer science, linguistics, and economics. We begin with a rigorous development of propositional modal logic: the basic language, interpretation in relational structures, axiom systems, proofs, and validity. We prove soundness and completeness of various systems using the canonical model method, study model equivalences and expressivity results, establish the finite model property, and discuss decidability and basic complexity results. We also consider topological semantics as an alternative to relational semantics, and investigate the connection between the two. Finally, we introduce modal predicate logic, incorporating first-order quantification into the system. In the latter part of the course we turn our attention to more specialized logical systems and their applications, as determined by the interests of the class. Topics may include: epistemic and doxastic logics, multi-agent systems and the notion of common knowledge (with applications to game theory), deontic logics, logics for reasoning about counterfactuals, temporal and dynamic logics, public announcement logic, justification logic, and others.Some mathematical experience/maturity (e.g., 15251 or 21127 or 80211 or 80210 or 80212), or permission of the instructor.
Prerequisites: 21-127 or 80-212 or 80-210 or 80-211 or 15-251

80-317 Introduction to Ramsey Theory
Intermittent: 6 units
While working on the decision problem for first order logic, Frank Ramsey [1930] developed a combinatorial approach that now bears his name. For one example of his idea, imagine that we construct an undirected graph on K-many nodes, connecting each pair of nodes with edges of one of two colors, red or blue. How many nodes K3,2 does it take to insure that, no matter how we color the graph, there will be a trio of points each connected by the same color? How large do we need to make K to guarantee a homogeneous subgraph of 3 nodes in 2 colors? K = 5 will not do, as this picture reveals. See image here: https://goo.gl/txagIS A 2-coloring of 5 nodes with no homogeneous subgraph of 3 nodes. In this introduction we will consider some of the fundamental theorems of Ramsey Theory and a family of applications to logic, graph theory, number theory, and ergodic theory.

80-321 Causation, Law, and Social Policy
Intermittent: 9 units
Policy makers face causal questions. For example, does violence on TV cause violence in life, and if so, what policies can we institute that will actually curb it? Does the death penalty actually deter criminals? Do tough drug laws reduce drug use? This course investigates how scientists establish causal claims, and how policy makers and the courts rely on or systematically ignore such science. We examine what causal claims mean and how they connect to statistical data, and we discuss the limits of standard techniques for establishing causal claims. We will consider all of these issues first theoretically, and then in the context of several case studies chosen mostly by the students.
Prerequisite: 36-201

80-322 Philosophy of Physics
Intermittent: 9 units
Philosophical problems in the development of modern physics. Topics include the philosophical significance of Einstein's theory of relativity, interpretations of quantum mechanics, and the relationship between these two theories. Other topics may include the philosophy of space and time, the epistemology of geometry, the significance of modern cosmology, and chaos theory.

80-323 Philosophy of Biology
Intermittent: 9 units
This course will examine a range of foundational problems in evolutionary biology, as well as the implications of evolutionary biology for some basic topics in philosophy. Issues to be discussed include the meanings and roles of a variety of central concepts (such as species, fitness, function and adaptation) and controversies over adaptationism, genetic information, units of selection and the evolutionary explanation of human behavior. This course will be accessible both to philosophers interested in the epistemological and metaphysical status of evolutionary biology, and to biologists interested in better understanding the foundations of their field. Although there are no formal prerequisites for this course, students will be expected to have taken courses in either philosophy or biology.

80-324 Philosophy of Economics
Intermittent: 9 units
The science of economics has come to occupy a central position in contemporary society. Because of this central position in political decision making, economics is intertwined with a number of other philosophical issues surrounding justice, rights, and fairness. The central theme of this course will be on the arguments in favor and against markets as effective solutions to political problems. This issue will allow us to analyze a wide number of foundational issues in economics including the testability of economic claims, the use of "rationality" postulates, the foundation of the right to property, and measuring the success or failure of an economy.

80-327 Philosophy of Neuroscience
Intermittent: 9 units
400 years ago Rene Descartes claimed that the body is a machine manipulated via the pineal gland by a thinking soul with free will. At about the same time, Thomas Hobbes claimed the mind is the product of the brain, and the brain is a calculating device. Most of Descartes view endures to this day in popular belief, but something more like Hobbes opinion has come to dominate science. This historical part of the course will contrast Descartes The Passions of the Soul, with the contemporary scientific view of mind and brain in Patricia Churchlands Touching a Nerve. The course will describe the vision of a materialist, deterministic physiology of mind developed by Helmholtz, Freud and others in the 19th century, and opposition by the most influential psychologist of the time, William James. The main focus of the course will turn on how that scientific perspective has developed in classical and contemporary neuropsychology; on how new kinds of measurement of brain activities do or do not provide understanding of the mechanisms of thought and emotion; on how theories of mental functioning are argued for (or against); and on ethical issues posed by the advance of neuroscience. No philosophical background will be assumed of students. A previous course in neuroscience would be helpful, but is not required.

80-330 Ethical Theory
Spring: 9 units
Every day, even in very subtle ways, we make judgments of value that shape our lives and our conduct. This course will examine four influential attempts at providing a systematic account of the source and nature of moral value, its relationship to other kinds of value, and the practical implications of different answers to these questions. This focus on the fundamental structure of moral value will frequently engage topics such as the nature of the good, subjectivist and objectivist accounts of value, forms of moral naturalism verses attempts at moral constructivism, and will draw on historical as well as more contemporary sources. Particular attention will be paid to articulating the specific sources of disagreement that distinguish competing moral theories in order to facilitate our ability to adjudicate between them on a reasoned basis.

80-335 Social and Political Philosophy
Intermittent: 9 units
Broadly speaking, political philosophers are interested in whether, and to what extent, government use of coercion can be justified, and how social and political institutions should be structured in order to be legitimate. This is an advanced course in social and political philosophy, aimed at providing students with a more in-depth familiarity with classic and contemporary questions both theoretical and applied. The course is topical, and course topics will vary from year to year. Typically 4-5 topics are covered in a term. Previous years' topics have included the nature and value of freedom, social contract theory, racial and epistemic injustice and the nature of white ignorance, the intersecting concepts of justice and equality, structural injustice, responsibility for injustice, and immigration. Students are expected to come away from the course with a strong understanding of some of the major debates in social and political theory as well as the tools to analyze ongoing debates within contemporary US and global politics regarding the appropriate way to organize our social and political reality. This course is primarily conducted as a seminar and is discussion- rather than lecture-based.

80-336 Philosophy of Law
Intermittent: 9 units
In recent years, the U.S. legal system has been beset by claims of overcriminalization, racially discriminatory enforcement, and inadequate or unequal protection of individual civil rights. What should we make of these claims, and what, if anything, would be implied by their truth? In seeking to answer these questions, this course will examine the nature of the law and its enforcement. We will begin by discussing the issue of criminalization and whether the expansion of the criminal law is or is not problematic. From there, we will turn to the more foundational questions of what, precisely, the law is, and what its connection to morality is or should be. Are we obligated to obey the law, and if so, why? Finally, we will ask whether it is possible for the law to remain neutral with regards to morality and politics, and whether the supposed "neutrality" of the law may itself be an instrument of oppression. If the legal system lacks the kind of neutrality that many legal theorists claim for it, what (if anything) does that license us (as citizens) to do?

80-341 Computers, Society and Ethics
Intermittent: 9 units
This course explores many of the social and ethical issues that have emerged in the wake of the significant advances that we have witnessed in computer science and information technology (IT). Computers and communications technologies have had an increasing impact on the whole of society and have raised new and difficult ethical questions. In turn, these ethical issues have spurred the need for a consideration of new policies and regulations. In this new world of IT, some are concerned about the protection of their privacy while others find problems of censorship and, more generally, restrictions on information access to be their main focus as a problematic social issue. This course will address these and other issues such as: questions of free speech, surveillance in the workplace, intellectual property and copyright, information acquisition and ethics and the Internet.

80-344 Management, Environment, and Ethics
Intermittent: 9 units
This course examines and poses answers to the following question: "What are the legitimate environmental responsibilities of organizational managers from the private, public and nonprofit sectors and how can they be best fulfilled?" This query will provide the course with its major theme and framework. But in order to do justice to it, three interrelated areas that are presupposed by this question will need to be explored first. These areas are: 1) applied ethics, 2) management ethics and 3) environmental ethics. The first half of the course will concentrate upon these three areas. The second half of the course will focus upon management and the environment employing the insights gained during the first half. Here students will review and evaluate past and current management practices with respect to the environment, organizational policies dealing with the environment and the role of government in the process of determining environmental responsibilities in management. Environmental concerns on the international level and their impact upon organizational management, the emergence of the "environmental affairs manager" within organizations, balancing environmental responsibilities with other management responsibilities and examples of management responses to the environmental crises will also be examined during this portion of the course.

80-348 Health, Human Rights, and International Development
Fall: 9 units
Approximately 767 million people, or more than 10% of the world's population, live in a condition the World Bank refers to as "extreme poverty". Those who live in extreme poverty frequently lack effective access to proper nutrition, adequate shelter, safe drinking water, and sanitation. As a result, they also bear the greatest burdens of famine and epidemic disease and frequently face social and political conditions of unrest and systematic oppression. This course aims to introduce students to the problem of global public health and its intersection with claims of human rights. We will focus on theoretical accounts of human rights and questions arising from them: What constitutes a human right, and on what basis or bases might the existence of human rights be defended? If human rights exist, whose responsibility is it to see that they are defended/provided/not violated, and why? What is the relationship between health deficits and human rights deficits, and what would a "human right to health" look like? Are global institutions such as the protection of strong intellectual property rights consistent with respect for a human right to health?

80-358 Hume
Intermittent: 9 units
This course will investigate the philosophy of David Hume. We will focus on his philosophical thought expressed in the book A Treatise of Human Nature. Hume was an influential philosopher who wrote on many issues ranging from skepticism, to ethics, to the philosophy of science, and his views continue to be influential today. In this course we will attempt to understand Hume's philosophy on all of these subjects both to better understand his contribution to the philosophy of his day, but also to see what his arguments can contribute to contemporary thought.

80-362 Russell
Intermittent: 9 units
Near the start of the 20th Century, Bertrand Russell helped to create what today we call "Analytic Philosophy." We will study Russell's contributions to this important approach to Philosophy by using his 1912 book, "The Problems of Philosophy" as a springboard to other readings, many of which are found in his collection, "The Basic Writings of Bertrand Russell." The issues we'll cover include several specific challenges in the Theory of Knowledge and Perception, and some of his contributions to Logic and Mathematics. For example, What is the difference between appearance and reality, and can we tell? Also, we'll consider issues that stem from reflecting on our thinking. For example, What constitutes a philosophical question? And we'll review Russell's paradox about the set of all sets, his attempts at a resolution, and how those affect contemporary set theory.

80-363 19th Century Foundations of Science
Intermittent: 9 units
Why do contemporary philosophers of science worry about the relationship between theory and evidence, or what is it for some event to cause another? These issues are not new, but have a rich history in the debates among philosophers and scientists in the 19th and early 20th century. This course will explore the roots of contemporary debates in the works of Mill, Herschel, Whewell, Poincare; Maxwell, Hertz, Duhem, and Mach. We will examine the issues of theories and evidence, scientific realism, the role of models in science, the role of mathematics in science, concepts of space and time, and ascription of causal relationships. The specific direction taken by the class will be determined, in part, by the interests of the students who enroll.

80-371 Philosophy of Perception
Fall: 9 units
This will be a course that covers the philosophy of perception from an empirical perspective. The first third of the course will begin with the problem of perception: how to account for the subjective quality of perception. We will explore theoretical challenges to providing an explanation of this feature (which we can call consciousness) and canvas theories that try to provide explanations. In the last two-thirds of the course, we focus on the science as a way of understanding subjective experience. We look carefully at color perception, olfaction, integration in the senses and the role of attention. This course will be a joint seminar between CMU and Pitt and will be co-taught with students from both campuses attending. It will be an upper level course meeting once a week and a high level of discussion, writing and preparation is expected. While there are no prerequisites, students might be aided by having at least one course in philosophy (preferably philosophy of mind or philosophy and psychology) or coursework in perceptual psychology or neuroscience.

80-380 Philosophy of Language
Intermittent: 9 units
Questions about language, meaning, and communication have a central place in both the history of analytic philosophy and the life of human societies. What do our words mean? What do we do by speaking them? What is the relationship between what our words literally mean and what we use them to communicate? What is it for a statement to be true but misleading? In what sense is it possible to experience a distinctively linguistic injustice? Should philosophers approach ordinary language as a cause of needless confusion, an indispensable source of insight, or both? In what ways is the study of language about the individual mind, in what ways is it about the speaker community? In spring 2020 this course will explore some major themes from the last century's debates in the philosophy meaning and communication, with attention to how these topics connect with social and political questions and with work in feminist philosophy. Students who do not meet the prerequisites but have an interest in the topic are strongly encouraged to reach out to the instructor about exceptions.
Prerequisites: 80-180 and 80-100

80-381 Meaning in Language
Intermittent: 9 units
Human language involves an association between arbitrary signs and meaning. The study of meaning in language, semantics, is a recently developed subfield of linguistics, since it presupposes advances in phonology, morphology, and syntactic structure. In addition, semantics faces the conceptual challenge of saying what meaning is. This course will reflect the history of semantics within linguistic theory and examine solutions to the problem of the definition of meaning. The course begins with the meanings of words and examines how these meanings combine to give the meanings of sentences, based on the notion of truth conditions for indicative sentences. That notion of meaning is then extended to sentences in other moods, and to sentences that do not simply describe how the world is, including sentences which are modal, conditional, or simply fictional. Semantics is a subject that can be developed in a highly formal way, but here it will be presented to make it accessible to students with varied backgrounds and interests. The components of the resulting theory will apply to any human language, and be an important component in the toolkit of any student of language.
Prerequisite: 80-180

80-382 Phonetics and Phonology II
Intermittent: 9 units
This course is a continuation of Phonetics and Phonology I (80-282), and is designed to expand upon the phonetic and phonological skills and knowledge developed in that course. Students will carry out an acoustic study designed by the instructor; the particular topic varies from semester to semester. As co-researchers, students will be involved in all aspects of data collection and analysis. Lessons in phonetics will be designed to train students on the necessary skills and concepts required, including understanding the articulatory and acoustic bases of the phenomenon under investigation, recording techniques, how to take appropriate acoustic measurements, and interpretation of the results. A presentation session will be organized for the end of the semester. In tandem with the acoustic study, a related phonological phenomenon will be investigated throughout the semester. This phenomenon will be explored by using a set of case studies that can be investigated through various phonological and psycholinguistic perspectives. We will cover major developments in phonological theory, including SPE-style features, feature geometry/autosegmental phonology, and Optimality Theory. We will also consider these phenomena in light of more recent approaches to phonological representation, including Exemplar Theory and Articulatory Phonology. Assessment of phonetics will primarily come from the research project and in-class lab work, but will be supplemented with quizzes and a test to ensure that core concepts are acquired. Assessment of phonology will primarily come from problem sets. Students will finish this course with a solid understanding of how to do phonetic research, and an appreciation of how various theoretical frameworks have attempted to account for phonological phenomena.
Prerequisites: 80-282 and 80-180

80-383 Language in Use
Intermittent: 9 units
The meaning of a sentence depends only on the meanings of the words it contains, and how they are put together in a syntactic structure. But the meaning of an utterance "a linguistic expression produced by a speaker in a particular context" depends on both sentence meaning and on features of the context and of the discourse itself. This course focuses on the analysis and description of utterance meaning. We will develop a treatment of context as a linguistically relevant notion and explore how linguistic analysis can be expanded from the domain of the sentence to the domain of connected discourse. In addition, the course will be concerned with the treatment of linguistic items (words and constructions) whose meaning can only properly be characterized in terms that make essential reference to context, to ongoing discourse, or to the speaker.
Prerequisites: 80-100 or 80-180

80-384 Linguistics of Turkic Languages
Intermittent: 9 units
In this course we look at languages from within a single language group, Turkic. Turkic languages are spoken across continental Asia and include such languages as Turkmen, Tatar, Kazakh, Uighur, and Uzbek. In this course we concentrate especially on Yakut (Sakha) and Azerbaijani. Modern Turkish will provide a reference language. We look at various linguistic systems within each language (phonology, morphology, syntax, and writing systems) both to understand each particular language and to see how the languages are related. We consider the impact of diachronic factors on the synchronic study of language. This course can be seen as an extended case-study for applying concepts and analytical strategies from basic linguistics, as taught in Nature of Language, Phonetics and Phonology, Invented Languages, and other relevant courses.
Prerequisite: 80-180

80-385 Linguistics of Germanic Languages
Intermittent: 9 units
The Germanic languages include English, Dutch, Frisian, German, Pennsylvanisch, Afrikaans, Yiddish, Icelandic and the Scandinavian languages, excluding Finnish. The course will serve as an extended case-study for the application of concepts and analytical strategies taught in basic linguistics courses to some of these languages. Specifically, we take a bottom-up approach to Dutch, Frisian, Icelandic, and Danish, starting with raw language material whenever possible, which we progressively analyze in terms of phonetics and phonology, morphology, and syntax. These case studies lead to comparisons between the languages and insight into their development and divergence over time. We follow this hands-on approach with historical and grammatical overviews, touching on some of the outstanding issues in Germanic linguistics. The approach should also help bring out the relevance of diachronic factors in the synchronic study of language, with historical forms of English being open to investigation, as these often reflect patterns found in contemporary Germanic languages.
Prerequisite: 80-180

80-388 Linguistic Typology: Diversity and Universals
Intermittent: 9 units
What is the most common word order? What is the rarest consonant? What kinds of case marking are attested in the world's languages? Which linguistic structures tend to co-occur? What can we learn by looking at the rarity of linguistic structures? These are the kinds of questions central to linguistic typology, the study and classification of languages based on their structural properties. In this course we will look at the variety of linguistic structures attested in several linguistic subfields, including phonology, morphology, syntax, and semantics. Understanding linguistic diversity is closely tied with the search for linguistic universals, since there appear to be some ways in which linguistic structures seem to be limited. But what are the nature of those limits (if they truly exist), and what do they tell us? We will also look at methodological issues that arise in comparing languages and forming meaningful generalizations. Prerequisites: 80-180, and one of 80-280, 80-282, 80-285 or permission of the instructor.
Prerequisites: 80-180 and (80-282 or 80-285 or 80-280)

80-405 Game Theory
Intermittent: 9 units
Game theory is the study of interactive decision-making: making choices in the context of other agents who are also making choices. Famous examples include the "Prisoner's Dilemma" (pitting rational self-interest against the benefits of cooperation), and the "Cournot duopoly" (a basic model of market competition and supply-and-demand). Game theory has been applied to situations as diverse as traffic flow, auctions, the search and competition for scarce resources, and bargaining. This course will develop conceptual and technical facility with the mathematical tools used to model and analyze such situations. We will cover games in strategic and extensive form and games of perfect and imperfect information; we'll also study solution concepts such as Nash equilibrium and rationalizability. Finally, throughout the course we will take the opportunity to actually play several of the games we study to help build intuitions and foster insights into the formal mathematical models we develop.

80-411 Proof Theory
Intermittent: 9 units
An introduction to the general study of deductive systems and their properties. Topics include the natural deduction and sequent calculi; cut-elimination and normalization theorems; metamathematical properties of first-order logic and theories of arithmetic; and conservation theorems.
Prerequisites: 21-300 or 80-310 or 80-311

80-413 Category Theory
Intermittent: 9 units
Category theory is a formal framework devoted to studying the structural relationships between mathematical objects. Developed in the mid-20th century to attack geometrical problems, subsequent progress has revealed deep connections to algebra and logic, as well as to mathematical physics and computer science. The course emphasizes two perspectives. On one hand, we develop the basic theory of categories, regarded as mathematical structures in their own right. At the same time, we will consider the application of these results to concrete examples from logic and algebra. Some familiarity with abstract algebra or logic required.

Course Website: http://www.andrew.cmu.edu/user/jonasf/80-413-713/index.html

80-419 Interactive Theorem Proving
Intermittent: 9 units
Interactive theorem proving involves using computational proof assistants to verify that mathematical proofs are correct, or to verify that hardware and software designs meet their formal specifications. This course uses a new interactive theorem prover, Lean, to explore this new technology and its logical foundations. We will study dependent type theory, a powerful and expressive language for representing mathematical objects, algorithms, and proofs. We will also consider automated methods that can be used in support of formal verification, including propositional, equational, first-order, and higher-order methods, as well as decision procedures for real and integer arithmetic.
Prerequisites: 80-211 or 21-300 or 15-317 or 80-310

Course Website: http://www.andrew.cmu.edu/user/avigad/itp/

80-430 Ethics and Medical Research
Intermittent: 9 units
Ethics & Medical Research: This course covers foundational issues in the ethical evaluation and regulation of research involving human subjects. It begins with a historical overview of the origins of research ethics after World War II as a response to high profile cases of abuse or scandal. This unit covers "classic cases" including the Tuskegee syphilis study, the Willowbrook hepatitis study, the Jewish Chronic Disease Hospital Case, and others. It also covers seminal documents such as the Nuremberg Code, the Belmont Report, and the current federal regulations known as the Common Rule. Against this historical backdrop, the course then examines foundational philosophical issues in human-subjects research including ethical issues in clinical trial design, the concept of equipoise and the use of placebo controls, the requirements of justice in the research context, and the values of privacy and informed consent.

80-431 Meta-ethics
Fall: 9 units
First we will survey of proposals for necessary and sufficient conditions for "x is a morally permissible act". Then we will consider T.S. Scanlon's claim that metaethics is immune from criticism from other subjects. We will then consider moral voting rules—varieties of consequentialism and Scanlon's winner take all method of reasons. We will take up arguments that there are, or are not moral facts, and moral particularism—the doctrine that while there are moral facts, there are no informative true moral generalizations. Finally, we will consider biological accounts of the sources of morality and agency by Binmore, Kitcher, Churchland and others, and there force, if any, against the very idea of normative ethics.

80-447 Global Justice
Intermittent: 9 units
Until recently, the dominant view of international relations has been that the governments and citizens of one country have no moral obligations to those beyond their borders. With the rapid growth in globalization has come a drastic shift in attitudes about our obligations to those with whom we share global institutions of trade but neither legal systems nor national identities. This course aims to introduce students to the problem of global distributive justice in the context of a globalized world, with emphases on both theoretical accounts of justice and the practical implications of those accounts for important current issues. Theoretical topics will include the nature of justice, the sources and limits of our moral obligations, and how and whether those notions of justice extend to global society; while applied topics will include our obligations with regard to the environment, human rights deficits, the status of women, and global economic policy.

80-449 EHPP Project Course
Fall: 12 units
The Ethics, History and Public Policy Project Course is required for the Ethics, History and Public Policy major and is taken in the fall semester of the senior year. In this capstone course, Ethics, History and Public Policy majors carry out a collaborative research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis for a chosen client. The students develop an original research report based on both archival and contemporary policy analysis and they present their results to their client and a review panel.

80-484 Language and Thought
Intermittent: 9 units
The goal of this course is to provide students with the opportunity to creatively explore some difficult questions about the relationship between language and thought, questions such as: How does the human capacity to use language relate to the human capacity to think? Does the language that a person speaks affect the way she thinks? If meaning is in the head, how can we succeed in communicating with each other? How is our ability to reason related to our ability to successfully communicate? None of these questions have definite answers; throughout the course, we will draw on work in philosophy, psychology and linguistics to try to understand some of the possible answers that might be entertained. Students in the course should be prepared for extensive reading, writing and peer discussion assignments.

80-495 Independent Study
Fall and Spring
Independent Study

80-501 Philosophy Senior Honors Thesis I
Fall: 9 units
Philosophy Department majors with outstanding academic records and intellectual promise will be given the opportunity to earn Dietrich College Honors by engaging in original research under the direction of an individual faculty member. Research topics are selected by student. Students must submit a proposal to the Dean's Office for permission.

80-502 Philosophy Senior Honors Thesis II
Spring: 9 units
Philosophy Department majors with outstanding academic records and intellectual promise will be given the opportunity to earn Dietrich College Honors by engaging in original research under the direction of an individual faculty member. Research topics are selected by student. Students must submit a proposal to the Dean's Office for permission.

80-511 Thesis Seminar
Spring: 6 units
This course provides a forum for the presentation and detailed discussion of research done by students, be they undergraduates working on their Senior Thesis or graduate students engaged with their M.S. thesis.

80-513 Seminar on Philosophy of Mathematics
Intermittent: 9 units
The "linguistic turn" in twentieth century philosophy lets us think about mathematics as a collection of linguistic rules and norms that helps us reason effectively and make sense of our experiences. The advent of computational proof assistants, which use stylized languages to convey mathematical content, provides new perspectives on these rules and norms. This seminar will explore ways these formal models of mathematical language and inference can be brought to bear on traditional questions in the philosophy of mathematics.

80-514 Categorical Logic
Intermittent: 9 units
This course focuses on applications of category theory in logic and computer science. A leading idea is functorial semantics, according to which a model of a logical theory is a set-valued functor on a category determined by the theory. This gives rise to a syntax-invariant notion of a theory and introduces many algebraic methods into logic, leading naturally to the universal and other general models that distinguish functorial from classical semantics. Such categorical models occur, for example, in denotational semantics. e.g. treating the lambda-calculus via the theory of cartesian closed categories. Higher-order logic is treated categorically by the theory of topoi. We will also consider the categorical semantics of type theory via locally cartesian closed categories. A prerequisite for this course if familiarity with basic category theory (as treated in the course 80-413/713), but depending on demand the course can start with a quick refresher of the central concepts.

80-515 Seminar on the Foundations of Statistics
Intermittent: 9 units
This decision-theoretic seminar is organized in three parts. 1. In the first we examine Savage's theory of subjective expected utility, primarily chapters 2-5 of his classic book, The Foundations of Statistics. 2. In the second part of the course, we focus on the following issues: 2.1. A comparison of Savage's theory and deFinetti's criteria of coherence. 2.2. Personal vs. group decisions. Topics to include: Arrow's impossibility theorem, consensus, and Savage's position in §7.2 & §13.5 of his book. 2.3. Contemporary theories that highlight violations of the sure-thing principle — violations of Savage's postulate P2. 3. For the third part, we discuss issues related to Indeterministic and/or Imprecise Probability [IP] theory. The seminar explores some of the ongoing research programs falling under IP, mostly as reflected in the Society for Imprecise Probability: Theories and Applications (www.sipta.org).

80-516 Causality and Learning
Fall
Causal connections are usually more informative and helpful than associational information, especially in understanding, control, decision-making, and prediction in changing environments. In the past decades, interesting advances were made in machine learning and statistics for tackling long-standing causality problems, such as how to discover causal knowledge from purely observational data and how to infer the effect of interventions using such data. Furthermore, recently it has been shown that causal information can facilitate understanding and solving various machine learning problems. This course explores how causality is different from and related to association, recent machine learning methods for causal discovery, and why and how the causal perspective helps in machine learning.

80-518 Seminar on Topics in Logic
Intermittent: 9 units
Topic: Introduction to Homotopy Type Theory Homotopy Type Theory (HoTT) is a new field of mathematics that extends Martin-Löf's dependent type theory by the addition of the univalence axiom and higher inductive types. In HoTT we think of types as spaces, dependent types as fibrations, and of the identity types as path spaces. We will see that many spaces that are familiar to topologists can be represented as higher inductive types, and we will develop the basic theorems and constructions in HoTT to reason about them.

80-519 Seminar on Computability: History and Analysis
Spring: 9 units
The history of computability is presented in the context of pertinent developments in mathematics and the sciences, in particular, in astronomy. The analysis of the notion takes seriously normative philosophical considerations, starting with Leibniz and Descartes. Complementary developments in mathematics and logic during the second half of the 19th century led to fundamental issues in logic during the first half of the 20th century. A certain "resolution" of those issues was achieved in the work of Post and, in particular, Turing. The seminar will end with a brief discussion of the abstract notion of "computable dynamical system" and its use in the discussion surrounding the "Church-Turing Thesis".

80-520 Seminar on Philosophy Science
Intermittent: 9 units
In the past 25 years there has been a great deal of research in Machine Learning, Statistics, and Philosophy on inferring graphical causal models from both experimental and non-experimental data, under a variety of different background assumptions. The goals of this course are (i) to give students enough background to be able to read, understand, and contribute to the current literature on topics in the representation, use of, and inferences about causal graphs of various kinds; (ii) to relate the current computer science/statistics literature on causation to the philosophical literature on related topics. The broad topics of the course will be: 1. How to use various kinds of graphs for representation of probabilities, causal models, actual causation, and counterfactuals 2. How to use graphs to answer questions about conditional probabilities, the effects of manipulations, and counterfactuals. 3. Assumptions relating probabilities to causation.

80-521 Seminar on Formal Epistemology
Spring: 9 units
This seminar will focus on dynamic and epistemic logics, with special emphasis on the use of topological tools in such settings. No background in topology is necessary, though some familiarity with modal logic will be very helpful. We will begin with a review of foundational and introductory works and then progress to contemporary research articles. Core topics include public announcement logic, action logic, propositional dynamic logic (for nondeterministic program executions), dynamic topological logic, and evidence models. Additional topics will be chosen based on the interests and suggestions of those in the seminar. The format will be presentation-style: each student will be expected to prepare (in consultation with the professor) and present approximately two papers over the course of the semester.

80-524 Topics in Formal Epistemology: The Topology of Learning
Intermittent: 9 units
When faced with a question concerning learning or scientific method, one habitually reaches for logic and probability theory. But sometimes habits should be questioned. There is increasing awareness, scattered across philosophy, informatics, mathematical statistics, that the the relevant issues are more fundamentally topological. That may sound shocking: what could rubber geometry have to do with learning or inductive inference? The answer is that the set of empirically verifiable propositions over a set of possibilities automatically satisfies the axioms of a topological space over possible worlds. Once that is recognized, there is a systematic translation between topology and familiar concepts and issues in learning, statistics and the the philosophy of science. This seminar will introduce the relevant topological concepts and will explore the methodological correspondences in detail. Topics covered include Hume's problem of induction, the problem of non-refutable theories and paradigm choice, convergence to the truth, simplicity and Ockham's razor, statistical model selection, causal discovery, and computability. The class will place students at the cutting edge of research in this fresh and exciting new area, and will provide them with a high-level, explanatory perspective that unifies much of the detail encountered in standard statistics and machine learning curricula.

80-529 Incommensurability: Ethics and Philosophy of Science
Intermittent: 9 units
Claims that certain things are incommensurable are common in several areas of philosophical discourse. In the philosophy of science, for example, it has been claimed that different scientific theories, or particular claims or terms within these theories, are incommensurable. In ethics, some have argued that different types of values (rights, utility, personal commitments, individual identities) are incommensurable. In many cases, incommensurability is treated as a problem that needs to be surmounted in order for agents to make rational decisions to compare alternative theories or to evaluate acts or policies that implicate different kinds of value. The first part of this course examines what incommensurability is supposed to be, how it supposedly arises in various fields, and what kind of challenge it poses for theories of rationality and rational choice. In the second part of the course we examine theories in which incommensurability is not a problem to be overcome, but a kind of moral requirement in itself. For instance, the injunction at the heart of Kantian ethics not to treat agents (with dignity) like things (with a price) requires that these entities not be brought into certain kinds of comparative relationship. Similar claims seem to be at work in certain liberal political theories (Walzer and Rawls), in views that seek to limit the scope of goods that can be distributed in markets, and in views of science that treat conceptual diversity as an source of important social benefit. A goal of the course is to show how a variety of issues across diverse philosophical contexts have a common structure and how formal work in social choice (e.g., Arrovian impossibility results), and decision theory (e.g., theories of choice that relax the ordering assumption) can help to clarify and resolve important problems.

80-530 Seminar on Ethical Theory
Intermittent
This seminar will focus on classic and contemporary accounts of moral and political autonomy and their application to current topics in ethics, political philosophy, and global justice. We will pay especial attention to the neorepublican notion of freedom as non-domination, how and to what extent this concept interacts with competing conceptions of autonomy, and what can be gained or lost by applying the neorepublican framework to various debates.

80-536 Ethics & Policy of AI
Intermittent: 9 units
AI, robots, and other autonomous technologies are having deep and wide impacts on individuals, communities, and societies. In this seminar, we will examine the ethical & policy dimensions of these novel (autonomous) technologies. We will emphasize analyses of current and near-future systems, grounded in the actual technological details. Students will be expected to have either prior ethics or prior policy familiarity/experience.

80-537 Seminar on Research Ethics: Philosophical Foundations
Intermittent: 9 units
This course covers foundational issues in the ethical evaluation and regulation of research involving human subjects. It begins with a brief overview of the historical origins of research ethics after World War II and the development of the regulatory system for oversight of research with humans in the US. It then examines philosophical questions such as: whether there is a moral imperative to conduct research and, if so, what such an imperative justifies; whether the system of prospective review of research is necessarily paternalistic or whether it can be grounded in alternative norms; how to think about and regulate risk in research; what is the nature and purpose of informed consent and under what conditions can it be waived; and what requirements should be imposed on research sponsored by entities from high-income countries that is carried out in low or middle-income countries. In addition, the course covers ethical issues in clinical trial design, the concept of equipoise, the use of placebo controls, and the requirements of justice in the research context.

80-580 Seminar on the Philosophy of Language
Intermittent: 9 units
Seminar on Coherence The goal of this seminar is to explore models of coherence in the linguistic and cognitive realms, drawing on work in those areas and also in machine learning, Bayesian decision theory, formal epistemology, and other computational frameworks. The model (or models) we will develop will be informed by the effects of coherence constraints in linguistic interpretation and in cognition. In the linguistic realm, interpretation typically involves constructing representations that are richer than the content that is linguistically encoded, and this enrichment is plausibly the result, in part, of the expectation of coherence. This expectation has far reaching effects, including on the assignment of referents to pronouns, the interpretation of definite and indefinite noun phrases, assignment of temporal relations, and the identification of Gricean conversational implicatures. In the cognitive realm, coherence is widely recognized as a factor in various learning & reasoning processes, including conceptual integration, belief adjustment, sequential decision-making, and even less rational processes such as rationalization. In the first part of the seminar, we will develop an understanding of the linguistic and cognitive phenomena relating to coherence in its many manifestations. In the mid-part of the seminar, students will present models and frameworks of coherence from other fields, and examine ways to model various linguistic and cognitive phenomena using these approaches. In the concluding section of the seminar, we will focus on particular linguistic/cognitive phenomena and try to modify the various models to (hopefully) find characterizations and explanations of the diverse phenomena.

80-595 Senior Thesis
Fall and Spring
Philosophy Department majors writing a senior thesis, and are not participating in the Dietrich College Senior Honors Program, are given the opportunity to engage in original research under the direction of an individual faculty member. Research topics are selected by student.

Department of Psychology

Michael Tarr, Department Head

Erik Thiessen, Director of Undergraduate Education in Psychology, Baker Hall 342D

Emilie O'Leary, Undergraduate Coordinator, Baker Hall 339
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www.cmu.edu/dietrich/psychology

Can newborn infants perceive the world as we do, or is it just "a blooming buzzing confusion"? Do personality, beliefs and social factors influence health? How do scientists and young children make discoveries, and what abilities make these insights possible? How does brain activity reveal differences in thinking? Can computers think the way people do?

These are some of the questions that psychologists at Carnegie Mellon are trying to answer.

For the student who is majoring in Psychology, Cognitive Science or Neuroscience, studying with faculty who are on the leading edge of research on questions like the above can be a very exciting experience.

The Psychology Department at Carnegie Mellon has long been noted as one of the pioneering Psychology Departments in the world, particularly in such areas as cognitive psychology, cognitive science, social psychology, developmental psychology, cognitive neuroscience, and health psychology. The Psychology Department offers 5 majors: B.A. and B.S. degrees in Psychology, as well as a B.S. degree in Cognitive Science and together with the Department of Biological Sciences, a unified B.S. double major in Psychology and Biological Sciences, and an Intercollege major in Neuroscience.

The Major in Psychology

Psychology is a discipline that embraces both biological and social sciences. It is a science concerned with establishing principles and laws regarding the ways in which people think and behave through the scientific study of human behavior.

The orientation of the Carnegie Mellon Psychology curriculum is toward developing highly skilled and knowledgeable graduates. About half of our graduates go on to graduate or professional school. The remainder seek to expand their problem-oriented analytic skills to qualify themselves for job opportunities beyond those typically open to liberal arts students.

Majors in the department are expected not only to learn about findings already established by psychologists, but also to become proficient in the investigation and analysis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analysis, and writing reports. The department has many resources for students to use in acquiring these skills. For instance, students interested in child development may be involved in the child development laboratory and observational facilities which are a part of the Carnegie Mellon Children's School which operates under the department's aegis. Students interested in health or clinical psychology might have opportunities to do internships in applied settings, and all Psychology majors have access to extensive computer facilities for data analysis and simulation work. The department also has a state of the art set of undergraduate research laboratories and computer clusters, and through the Scientific Imaging & Brain Research Center, a magnet is in use for conducting brain imaging studies using fMRI.

In addition to formal class work, students are encouraged to participate in research projects where they may register and receive credit for freshmen research experience course 85-198 Research Training: Psychology, 85-506 Readings in Psychology, Fall research experience in 85-507 Research in Psychology or Spring research experience in 85-508 Research in Psychology. In the research in psychology course, the student may work on an ongoing research projects or develop and carry out a new research project with a faculty member. There is university and departmental funding available to help support student-initiated research projects and student travel to present research results at scientific meetings and conferences. In the Readings courses, the student reads extensively on a particular topic. The faculty member and student meet to discuss the readings, and the student writes a paper on the topic selected. The Psychology Department Website (http://www.cmu.edu/dietrich/psychology), provides descriptions of faculty research interests (http://www.cmu.edu/dietrich/psychology/research-areas) that the student can use in determining who should be approached to supervise a particular research or reading project.

Students interested in gaining field work experience via a number of internship opportunities available to them can receive credit through 85-482 Internship in Psychology, 85-480 Internship in Clinical Psychology or 85-484 Practicum in Child Development. Clinical internships are available with a variety of clinical settings including the prestigious Western Psychiatric Institute and Clinic (the teaching hospital of the Department of Psychiatry at the University of Pittsburgh Medical School). During the internship, students get first-hand experience with different clinical populations. Developmental Practicum experience is available in the department-run CMU Children's School (http://www.cmu.edu/dietrich/psychology/centers-and-facilities).

Bachelor of Arts in Psychology

Mathematics — 10-20 units

21-111-21-112	Differential Calculus - Integral Calculus	20
or		
21-120	Differential and Integral Calculus *	10

*Students who place out of 21-120 with AP credit will have successfully completed the calculus requirement

Statistics Sequence — 9 units

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	

Psychology Surveys — 27 units

85-102	Introduction to Psychology *	9

Survey Courses - Complete Two		Units
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	
85-219	Biological Foundations of Behavior	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9

* Introduction to Psychology cannot be substituted; AP credit does not count towards this requirement

Research Methods — 18 units

Complete two courses.		
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

Advanced Courses — 18 units

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-349. Exceptions for the advanced course requirement are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Psychology Breadth, Depth, and Application Electives — 27 Units

Three courses from at least two of the Breadth, Depth and Application Categories. Please Consult the psychology department undergraduate website for approved Breadth Electives.

Depth

Any Psychology course between 85-300-85-499.
Exceptions for the course requirement
are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Application

85-198	Research Training: Psychology	9
85-294	Teaching Assistantship	Var.
85-480	Internship in Clinical Psychology	Var.
85-482	Internship in Psychology	Var.
85-484	Practicum in Child Development	Var.
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
85-601	Senior Thesis	9
85-602	Senior Thesis	9
66-501	H&SS Senior Honors Thesis I	9
66-502	H&SS Senior Honors Thesis II Must receive a B or higher; 9 units min	9

Breadth

Any 200 level Psychology survey course.		
85-261	Abnormal Psychology	9
85-271	Animal Minds	9

or

Choose from a list of courses found outside of the department with departments including Biological Sciences, History, English, HCI, Philosophy, Social Decision Sciences and Statistics. The elective list may change and for the most up to date list please either contact Emilie O'Leary at emilier@andrew.cmu.edu or visit the psychology undergraduate website: www.cmu.edu/dietrich/psychology/undergraduate/current-students/academics.

Computer Science Requirement

15-110	Principles of Computing	10
or 88-300	Programming and Data Analysis for Social Scientists	

Natural Science Requirement (B.A. 18 units of which include 9 units of Gen Ed Science)

The B.A. in psychology requires one course beyond the General Education requirement in natural science.

These courses can be selected from the following areas:

- 03-XXX Biology*
- 09-XXX Chemistry
- 33-XXX Physics

* Given the growing relevance of biology to psychology, it is strongly recommended to take a course in Biological Sciences

Bachelor of Science in Psychology

Mathematics 10-20 units

21-111-21-112	Differential Calculus - Integral Calculus	20

or

21-120	Differential and Integral Calculus *	10

***Students who place out of 21-120 with AP credit will have successfully completed the calculus requirement**

Statistics Sequence 9 units

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	

Psychology Surveys 27 units

85-102	Introduction to Psychology *	9

Survey Courses - Complete Two		Units
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	
85-219	Biological Foundations of Behavior	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9

* Introduction to Psychology cannot be substituted; AP credit does not count towards this requirement

Research Methods 18 units

Complete two courses.		
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

Advanced Courses 27 units

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-349. Exceptions for the advanced course requirement are:85-480,85-482,85-484,85-506,85-507,85-508,85-601,85-602,66-501,66-502.

Psychology Breadth, Depth, and Application Electives 27 Units

Three courses from at least two of the Breadth, Depth and Application Categories. Please Consult the psychology department undergraduate website for approved Breadth Electives.

Depth

Any Psychology course between 85-300–85-499. Exceptions for the course requirement are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Application

85-198	Research Training: Psychology	9
85-294	Teaching Assistantship	Var.
85-480	Internship in Clinical Psychology	Var.
85-482	Internship in Psychology	Var.
85-484	Practicum in Child Development	Var.
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
85-601	Senior Thesis	9
85-602	Senior Thesis	9
66-501	H&SS Senior Honors Thesis I	9
66-502	H&SS Senior Honors Thesis II Must receive a B or higher; 9 units min	9

Breadth

Any 200 level Psychology survey course.		
85-261	Abnormal Psychology	9
85-271	Animal Minds	9

or

Choose from a list of courses found outside of the department with departments including Biological Sciences, History, English, HCI, Philosophy, Social Decision Sciences and Statistics. The elective list may change and for the most up to date list please either contact Emilie O'Leary at emilier@andrew.cmu.edu or visit the psychology undergraduate website: www.cmu.edu/dietrich/psychology/undergraduate/current-students/academics.

Computer Science Requirement 10 units

15-110	Principles of Computing	10
or 88-300	Programming and Data Analysis for Social Scientists	

NATURAL SCIENCE REQUIREMENT (B.S. 27 UNITS OF WHICH INCLUDE 9 UNITS OF GEN ED SCIENCE)

The B.S. in psychology requires two courses beyond the General Education requirement in natural science.

- 03-xxx Biology*
- 09-xxx Chemistry
- 33-xxx Physics

* Given the growing relevance of biology to psychology, it is strongly recommended to take at least one course in Biological Sciences

Additional Major in Psychology

In order to complete an additional major in Psychology, a student must fulfill all of the Psychology major requirements within the department -- in other words, the breadth requirement, computing requirement, three survey courses at the 200-level, two research methods courses, and two advanced courses. These courses must include at least 81 units, plus calculus prerequisites and the 36-200 statistics course or equivalent and 36-309 . In addition, B.S. candidates must take the three-course science requirement and B.A. candidates complete one science course beyond the GenEd requirement.

Concentrations within the Psychology Major

Students who wish to focus their Psychology program on a specific area can do so either by the careful selection of Psychology elective courses focusing on their area of interest or by pursuing one of the following concentrations. Students must obtain a concentration form from the Undergraduate Program Coordinator, Emilie O'Leary, receive approval from their psychology faculty advisor, then returning the signed copy to Emilie in Baker Hall 339. The completion of a concentration will be recognized in the Psychology Graduation Program.

Health-Psychology Concentration

For Psychology majors who wish to have a focus of their study on Health Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the natural science requirement, choose two of the following		Units
03-121	Modern Biology	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9

As part of the psychology breadth requirement:

85-219	Biological Foundations of Behavior	9
85-241	Social Psychology	9

As part of the psychology Research Methods requirements:

85-340	Research Methods in Social Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:

85-442	Health Psychology	9
85-443	Social Factors and Well-Being	9
85-446	Psychology of Gender	9
85-501	Stress, Coping and Well-Being	9
85-362	Seminar on Addiction	9

As part of the Breadth, Depth and Application requirement, at least one of the following

85-480	Internship in Clinical Psychology	9
85-507	Research in Psychology	9
85-508	Research in Psychology	9
85-482	Internship in Psychology	9

or an additional advanced psychology seminar from the list above

Cognitive-Neuroscience Concentration

For Psychology majors who wish to have a focus of their study be on Cognitive Neuroscience, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the natural science requirement, choose two of the following		Units
03-121	Modern Biology	9
03-363	Systems Neuroscience	9
03-366	Biochemistry of the Brain	9

As part of the psychology Breadth requirement:

85-211	Cognitive Psychology	9
85-219	Biological Foundations of Behavior	9

As part of the Research Methods requirement:

85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9

As part of the advanced coursework in psychology requirement, at least two of the following:

85-356	Music and Mind: The Cognitive Neuroscience of Sound	9
85-359	Introduction to Music Cognition Research	9
85-370	Perception	9
85-385	Auditory Perception: Sense of Sound	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-407	Neuroscience of Concepts	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-429	Cognitive Brain Imaging	9
85-435	Neural and Cognitive Models of Adaptive Decisions	9

As part of the Breadth, Depth and Application requirement, at least one of the following

85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
88-342	The Neuroscience of Decision Making	9

Or an additional advanced psychology seminar from the list above

Behavior and Developmental Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Behavior and Developmental Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the B.S. science requirement, choose one of the following		Units
03-121	Modern Biology	9
03-364	Developmental Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9

As part of the psychology Breadth requirement:

85-211	Cognitive Psychology	9
85-221	Principles of Child Development	9

As part of the psychology Research Methods Requirement:

85-310	Research Methods in Cognitive Psychology	9
85-320	Research Methods in Developmental Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:

85-350	Psychology of Prejudice	9
85-352	Evolutionary Psychology	9
85-354	Infant Language Development	9
85-363	Attention, Its Development and Disorders	9
85-390	Human Memory	9
85-408	Visual Cognition	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-438	Educational Goals, Instruction, and Assessment	9

As part of the Breadth, Depth and Application requirement, at least two of the following

85-294	Teaching Assistantship	Var.
85-484	Practicum in Child Development	Var.
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
76-420	The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process	9
05-418	Design Educational Games	12
57-331	Principles of Education	9

Or an additional advanced psychology seminar from the list above

Cognitive Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Cognitive Psychology and/or Cognitive Modeling, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the B.S. science requirement:		Units
03-121	Modern Biology	9

As part of the psychology Breadth requirement:		
85-211	Cognitive Psychology	9

As part of the psychology Research Methods requirement:		
85-310	Research Methods in Cognitive Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:		
85-356	Music and Mind: The Cognitive Neuroscience of Sound	9
85-359	Introduction to Music Cognition Research	9
85-370	Perception	9
85-385	Auditory Perception: Sense of Sound	9
85-390	Human Memory	9
85-395	Applications of Cognitive Science	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-407	Neuroscience of Concepts	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-421	Language and Thought	9
85-429	Cognitive Brain Imaging	9
85-435	Neural and Cognitive Models of Adaptive Decisions	9

As part of the Breadth, Depth and Application requirement, at least one of the following		
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
76-420	The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process	9
05-391	Designing Human Centered Software	12
05-413	Human Factors	9
80-305	Choices, Decisions, and Games	9
80-380	Philosophy of Language	9
80-484	Language and Thought	9
Or an additional advanced psychology seminar		

Social-Personality Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Social and/or Personality Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the Psychology Breadth requirement:		Units
85-241	Social Psychology	9
85-251	Personality	9

As part of the Psychology Research Methods requirement:		
85-340	Research Methods in Social Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:		
85-350	Psychology of Prejudice	9
85-357	Navigating Race and Identity in America: The Role of Psychology in Racial Intera	9
85-358	Pro-Social Behavior	9
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-443	Social Factors and Well-Being	9
85-444	Relationships	9
85-446	Psychology of Gender	9
85-501	Stress, Coping and Well-Being	9

As part of the Breadth, Depth and Application requirement, at least one of the following		
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
85-482	Internship in Psychology	Var.
05-320	Social Web	12
Or an additional advanced psychology seminar from the list above		

Clinical/Counseling Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Clinical/Counseling Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the Psychology Breadth requirement at least one of the following:		Units
85-241	Social Psychology	9
85-251	Personality	9

Required additional coursework:		
85-261	Abnormal Psychology	9
85-422	Clinical Psychology: Science and Practice	9
85-480	Internship in Clinical Psychology	Var.

As part of the Psychology Research Methods requirements:		
85-340	Research Methods in Social Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:		
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-414	Cognitive Neuropsychology	9
85-442	Health Psychology	9
85-443	Social Factors and Well-Being	9
85-444	Relationships	9
85-446	Psychology of Gender	9
85-501	Stress, Coping and Well-Being	9

Neuroscience Major

The Psychology Department at Carnegie Mellon University has a major focus on the role of the brain and nervous system in cognition and behavior, including biological approaches involving the health impact that arises from the interaction of behavior with the nervous, endocrine, and immune systems. These interests are manifested in faculty research (http://www.cmu.edu/dietrich/psychology/research-areas), departmental and university centers that operate from or heavily involve the department (e.g., the Center for Cognitive Brain Imaging (http://www.ccbi.cmu.edu), and the Center for the Neural Basis of Cognition (http://www.cnbc.cmu.edu)) as well as undergraduate coursework (http://www.cmu.edu/dietrich/psychology/undergraduate) and graduate coursework.

For undergraduates, there are a number of ways in which students with an interest in these approaches can pursue that interest in an organized fashion. Major requirements for the Bachelor of Science in Neuroscience can be found under Intercollege Programs (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#bachelorofscienceinneurosciencetext).

Carnegie Mellon University recently launched *BrainHub* – an initiative designed to leverage its core strengths in cognitive science, engineering, and computer science, and our emerging excellence in biological sciences, to harness the technology that helps the world explore brain and behavior. Students will be able to take advantage of exciting opportunities such as lectures hosted on various topics, newly funded CMU campus research projects trying to answer pressing questions in brain science and the many global partnerships with other institutions all with the same motivating goal to enhance and increase research in brain sciences.

Finally, for any interested student, there is a Minor in Cognitive Neuroscience (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/departmentofpsychology/#minortext) available through the Psychology department.

The Major in Cognitive Science

The Psychology Department offers a B.S. degree in Cognitive Science. The field of cognitive science has grown out of increasingly active interaction among psychology, linguistics, artificial intelligence, philosophy, and neuroscience. All of these fields share the goal of understanding intelligence. By combining these diverse perspectives, students of cognitive science are able to understand cognition at a deep level. Because this major is administered by the Psychology Department, it focuses on human cognition and the experimental study of the human mind as illuminated by the techniques of the above disciplines.

Cognitive Science Curriculum

The Cognitive Science major is only offered as a B.S. degree. Candidates should complete before the junior year the two-semester calculus sequence 21-120 /21-256 (or alternatively 21-120/21-122)* and a statistics sequence (36-200 or equivalent and if possible, 36-309). In addition, candidates complete 15-112 Fundamentals of Programming and Computer Science, as their departmental computing course.

Because of the number and sequential nature of required courses, prospective Cognitive Science majors are encouraged to begin course work for the major prior to junior year. In particular, completion of calculus, 36-200, and 85-211 or 85-213 before the junior year will enable students to complete 85-310 and 36-309 and by the Fall semester of their sophomore or junior year and, if interested, to then take advantage of research opportunities in the department.

*The 3-Semester sequence 21-111 /21-112/21-256 may be substituted by students who have already taken 21-111 before deciding on the major.

Computing Prerequisite — 10 units

15-112	Fundamentals of Programming and Computer Science	12

Mathematics — 29-30 units

21-111-21-112	Differential Calculus - Integral Calculus	20

or

21-120	Differential and Integral Calculus *	10
21-127	Concepts of Mathematics	10

*Students who place out of 21-120 will have fulfilled the calculus requirement

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Statistics Sequence — 18 units

36-200	Reasoning with Data	9
36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	

Computational/Cognitive Modeling Core — 29–31 units

Two of the following:		Units
15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
15-251	Great Ideas in Theoretical Computer Science	12

Plus one of the following:		Units
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-435	Neural and Cognitive Models of Adaptive Decisions	9

Cognitive Psychology Core — 27 units

		Units
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	
85-310	Research Methods in Cognitive Psychology	9
or 85-314	Cognitive Neuroscience Research Methods	

Plus two of the following (one of which must be 85-3xx or 85-4xx):		Units
85-219	Biological Foundations of Behavior	9
85-359	Introduction to Music Cognition Research	9
85-370	Perception	9
85-390	Human Memory	9
85-395	Applications of Cognitive Science	9
85-408	Visual Cognition	9
85-414	Cognitive Neuropsychology	9
85-421	Language and Thought	9
80-381	Meaning in Language	9
80-310	Formal Logic	9
80-314	Causal Discovery, Statistics, and Machine Learning	9
80-315	Modal Logic	9
80-383	Language in Use	9

Cognitive Science Concentration

(3 courses, concentration approval required)

These three courses are chosen in conjunction with your advisor to form a coherent area of concentration from the course list under "Cognitive Science Concentration" in the current Undergraduate Catalog. Before proceeding with the choice of courses, students must fill out the concentration form, obtained from Emilie O'Leary in Baker Hall 339, with a description of the concentration area and the planned set of three courses. Courses not represented on the list may, with pre-approval of advisor and department, be used to satisfy part of this requirement. **The three courses are not required to be within any single category below but be coherent within the major and the focus may vary across disciplinary boundaries.** Courses taken for the major requirements can not be double counted in the concentration.

Computer Science — 36 units

16-385	Computer Vision	12
15-453	Formal Languages, Automata, and Computability	9
10-601	Introduction to Machine Learning (Master's)	12
05-410	User-Centered Research and Evaluation	12
05-432	Personalized Online Learning	12

Psychology

85-219	Biological Foundations of Behavior	9
85-352	Evolutionary Psychology	9
85-354	Infant Language Development	9
85-370	Perception	9
85-375	Crosscultural Psychology	9
85-380	In Search of Mind: The History of Psychology	9
85-390	Human Memory	9
85-392	Human Expertise	9
85-395	Applications of Cognitive Science	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-421	Language and Thought	9
85-423	Cognitive Development	9
85-426	Learning in Humans and Machines	9
85-429	Cognitive Brain Imaging	9

Philosophy

80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-220	Philosophy of Science	9
80-254	Analytic Philosophy	9
80-255	Pragmatism	9
80-270	Philosophy of Mind	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9

80-314	Causal Discovery, Statistics, and Machine Learning	9

Linguistics

80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-281	Language and Thought	9
80-315	Modal Logic	9
76-385	Introduction to Discourse Analysis	9

Decision Sciences

88-302	Behavioral Decision Making	9
88-355	Social Brains: Neural Bases of Social Perception and Cognition	9
88-380	Dynamic Decisions	9
88-388	Psychological Models of Decision Making	9
88-402	Modeling Complex Social Systems	9

Neurosciences

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
42-202	Physiology	9
15-386	Neural Computation	9
15-883	Computational Models of Neural Systems	12

Science Requirement

The Cognitive Science program requires two additional science courses beyond the college's one course Science General Education requirement.

These can be selected from any one of the following areas.	
03-xxx	Biology *
09-xxx	Chemistry
33-xxx	Physics

* Those interested in a cognitive neuroscience focus are recommended to take biology courses, including if possible, 03-362, or 03-363.

Additional Major in Cognitive Science

In order to complete a double major in Cognitive Science, a student must fulfill the major requirements as listed under the Cognitive Science major. These include the programming requirement (15-112), the Mathematics and Statistics prerequisites, Computational/Cognitive Modeling Core, The Cognitive Psychology Core, the Cognitive Science Concentration Requirement, and the Supplementary Science Requirement. Students will be assigned a department advisor to help plan their program of studies in Cognitive Science.

Unified Double Major in Psychology & Biological Sciences

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/#hampssgeneraleducationprogram160) and MCS (http://coursecatalog.web.cmu.edu/melloncollegeofscience) are found on their respective Catalog pages.

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	General Biology Elective [1]	9
03-3xx	Advanced Biology Elective [1]	18
Total Biology units		78

[1] Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Mathematics, Statistics, Physics and Computer Science		Units
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10
or 21-122	Integration and Approximation	
36-247	Statistics for Lab Sciences	9
or 36-200	Reasoning with Data	
36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	
33-121	Physics I for Science Students [2]	12
or 33-141	Physics I for Engineering Students	
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
or 02-201	Programming for Scientists	
99-101	Computing @ Carnegie Mellon	3
Total Science units		63-65

[2] MCS students must also complete 33-122 Physics II for Biological Sciences and Chemistry Students.

Chemistry		Units
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
or 09-219	Modern Organic Chemistry	
09-218	Organic Chemistry II	9
or 09-220	Modern Organic Chemistry II	
09-207	Techniques in Quantitative Analysis	9-12
or 09-221	Laboratory I: Introduction to Chemical Analysis	
09-208	Techniques for Organic Synthesis and Analysis	9-12
or 09-222	Laboratory II: Organic Synthesis and Analysis	
Total Chemistry units		56-62

Psychology Courses		Units
85-102	Introduction to Psychology	9
85-219	Biological Foundations of Behavior	9
85-2xx	Survey Psychology Courses *	18
85-310	Research Methods in Cognitive Psychology	9
or 85-340	Research Methods in Social Psychology	
or 85-320	Research Methods in Developmental Psychology	
or 85-314	Cognitive Neuroscience Research Methods	
or 85-330	Analytic Research Methods	
85-3xx	Advanced Psychology Electives	18
Total Psychology units		63

* Excluding 85-261 Abnormal Psychology

Additional Advanced Elective 9 units

(Choose one of the following courses)		
85-3xx	Advanced Psychology Elective	9
or		
03-3xx	Advanced Biology Elective	9

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)		
03-344	Experimental Biochemistry	12
03-345	Experimental Cell and Developmental Biology	12
03-346	Experimental Neuroscience	12
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-340	Research Methods in Social Psychology	9

Elective Units	Units
Free Electives	33-36
MCS Nontechnical Breadth or DC General Education requirements	36-48
Total Elective units	69-84

Minimum number of units required for degree: 360

Minors in Psychology and Cognitive Neuroscience

Minor in Psychology 72 units

I. Introductory course		
85-102	Introduction to Psychology *	9

*A survey course can be taken in place of 85-102.

II. Area Survey courses

Complete two courses.		
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	
85-219	Biological Foundations of Behavior	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9

III. Statistics		
36-200	Reasoning with Data	9
36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	

27 unitsUpper Level Courses

Complete three courses from categories IV and V, with at least one course from each.

IV. Research Methods Courses * (minimum 9 units)		
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

* Prerequisites for all Research Methods courses: 36-309 and the appropriate survey course.

V. Advanced courses (minimum 9 units)

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-350. Exceptions for the advanced course requirement are: 85-480, 85-482, 85-484, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Minor in Cognitive Neuroscience 63 units

The minor in Cognitive Neuroscience offered by the Department of Psychology is similar to the Neuroscience Minor offered by the Department of Biological Sciences. The differences between the two forms of the minor are determined by one required course, and additionally, by the students' choice of distribution electives. The requirements for the Cognitive Neuroscience Minor include 7 courses: four required courses, and three distribution and elective courses.

Because of the curriculum within this minor may overlap with some degree requirements, no more than 2 courses fulfilling Neuroscience or Cognitive Neuroscience Minor requirements may count towards a student's major or other minor requirements.

Cognitive Neuroscience Curriculum

Required Coursework

03-121	Modern Biology	9
03-363	Systems Neuroscience	9
85-219	Biological Foundations of Behavior	9
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	

Distribution Requirements

Three courses, including at least 1 from each of the following categories

Approaches to Cognitive Neuroscience		
85-314	Cognitive Neuroscience Research Methods	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-429	Cognitive Brain Imaging	9
15-386	Neural Computation	9
15-883	Computational Models of Neural Systems	12
36-746	Statistical Methods for Neuroscience and Psychology	12

Cognitive Neuroscience Electives		
03-133	Neurobiology of Disease	9
03-362	Cellular Neuroscience	9
03-364	Developmental Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
85-356	Music and Mind: The Cognitive Neuroscience of Sound	9
85-370	Perception	9
85-385	Auditory Perception: Sense of Sound	9
85-390	Human Memory	9
85-406	Autism: Psychological and Neuroscience Perspectives	9

The Honors Program

The Honors Program provides recognition of outstanding performance by students in the Psychology department. Participation enables students to pursue their own research ideas through completion of an honors thesis. The honors thesis is completed during the senior year. By completing a thesis, the student earns 18 units of credit and qualifies for graduation with "College Honors." To qualify for the Honors Program, the student must maintain a quality point average of at least 3.50 in the major and 3.25 overall. More information on the Honor program can be found here (http://www.cmu.edu/dietrich/undergraduate/programs/shp).

A year long departmental senior thesis course exists (66-501 and 66-502) for students interested in pursuing a sizable research project who do not qualify for the honors program. More information can be obtained by contacting Emilie O'Leary at emilier@andrew.cmu.edu.

Faculty

JOHN R. ANDERSON, Richard King Mellon University Professor of Psychology and Computer Science – Ph.D., Stanford University; Carnegie Mellon, 1978–

MARLENE BEHRMANN, Thomas S. Baker Univ Professor of Psychology and Cognitive Neuroscience – Ph.D., University of Toronto; Carnegie Mellon, 1993–

JESSICA CANTLON, Ronald J. and Mary Ann Zdrojkowski Associate Professor of Developmental Neuroscience – PhD, Duke University; Carnegie Mellon, 2007–

SHARON CARVER, Teaching Professor, Psychology; Associate Dean of Student Affairs, Dietrich College – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1993–

SHELDON COHEN, Robert E. Doherty University Professor of Psychology – Ph.D., New York University; Carnegie Mellon, 1982–

CHANTE COX-BOYD, Associate Teaching Professor – Ph.D., University of North Carolina at Chapel Hill; Carnegie Mellon, 1999–

DAVID CRESWELL, Associate Professor – Ph.D., University of California, Los Angeles; Carnegie Mellon, 2008–

KASEY CRESWELL, Associate Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2012–

BROOKE C. FEENEY, Professor of Psychology – Ph.D., State University of New York at Buffalo; Carnegie Mellon, 2001–

ANNA FISHER, Associate Professor – Ph.D., The Ohio State University; Carnegie Mellon, 2006–

VICKI S. HELGESON, Professor of Psychology – Ph.D., University of Denver; Carnegie Mellon, 1990–

LAURIE HELLER, Teaching Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 2009–

LORI L. HOLT, Professor of Psychology – Ph.D., University of Wisconsin; Carnegie Mellon, 1999–

MARCEL A. JUST, D. O. Hebb University Professor of Psychology – Ph.D., Stanford University; Carnegie Mellon, 1972–

ROBERTA KLATZKY, Charles J. Queenan Jr., Professor of Psychology – Ph.D., Stanford University; Carnegie Mellon, 1993–

KENNETH R. KOEDINGER, Professor of HCII – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2001–

MARSHA C. LOVETT, Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2000–

BRIAN MACWHINNEY, MacWhinney, Brian Teresa Heinz Professor of Cognitive Psych – Ph.D., University of California, Berkeley; Carnegie Mellon, 1981–

BRADFORD MAHON, Associate Professor – PhD, Harvard University ; Carnegie Mellon, 2009–

KODY MANKE, Assistant Teaching Professor – Ph.D, Standford University; Carnegie Mellon, 2016–

BONNIE NOZARI, Associate Professor – PhD, University of Illinois at Urbana-Champaign; Carnegie Mellon, 2011–

DAVID PLAUT, Professor of Psychology – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1994–

DAVID RAKISON, Associate Professor – D.Phil., University of Sussex; Carnegie Mellon, 2000–

LYNNE M. REDER, Professor of Psychology – Ph.D., University of Michigan; Carnegie Mellon, 1978–

MICHAEL F. SCHEIER, Scheier, Mike Walter van Dyke Bingham Professor of Personality and Health Psychology – Ph.D., University of Texas; Carnegie Mellon, 1975–

MICHAEL TARR, Professor & Dept Head and Kavčić-Moura Professor of Cognitive and Brain Science – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2009–

ERIK D. THIESSEN, Associate Professor, Director of Undergraduate Education in Psychology – Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 2004–

TIMOTHY VERSTYNEN, Associate Professor – Ph.D., University of California, Berkeley ; Carnegie Mellon, 2006–

DAN YUROVSKY, Assistant Professor – PhD, Indiana University; Carnegie Mellon, 2012–

Department of Psychology Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

85-102 Introduction to Psychology
Fall and Summer: 9 units
This course examines major areas of scientific psychology in some depth, the attempt being to develop basic models of our behavior and thought that explain wide areas of our functioning. The primary focus is on the areas of neural and motivational control of behavior, memory and thought, social interaction, and psychological development. Specific topics within these areas include brain function, motivational control systems, learning, cognitive and perceptual information processing, problem solving, obedience and conformity, social interaction, emotion, attitude consistency and change, how our social, cognitive and language functions develop, the importance of childhood to adult functioning, and psychopathology. In addition to the lecture, the course includes a weekly recitation section meeting and weekly short WEB-based laboratory experiences in which students get to perform actual experiments, interpret real data, and experience many psychological phenomena.

85-198 Research Training: Psychology
Fall and Spring: 9 units
See https://www.cmu.edu/dietrich/students/undergraduate/programs/research-training-program.html and click on (forms and guides informational handout page) then click on current freshman-sophmore research training courses for listing of research training course descriptions.

Course Website: https://www.cmu.edu/dietrich/students/undergraduate/programs/research-training-program.html

85-211 Cognitive Psychology
Fall and Spring: 9 units
How do people perceive, learn, remember, and think? This course will consider perception, language, attention, learning, memory, reasoning, and decision making. Experimental findings and formal models will be discussed in each part of the course.

85-213 Human Information Processing and Artifical Intelligence
Fall: 9 units
This class will review various results in cognitive psychology (attention, perception, memory, problem solving, language) and use of artificial intelligence techniques to simulate cognitive processes.
Prerequisites: 15-122 or 15-150

85-219 Biological Foundations of Behavior
Fall: 9 units
This course will provide students with a general introduction to the underlying biological principles and mechanisms which give rise to complex human cognitive, perceptual and emotional behavior. Topics to be covered include: the anatomical structure of nerve cells and how they communicate, properties of brain organization and function, processing in sensory and motor systems, biological characteristics of human cognition, and neural and hormonal influences on health and emotion. This course will focus on how emerging methods and approaches are beginning to make it possible for psychologists, computer scientists, and biologists to gain an integrated understanding of complex behavior.

85-221 Principles of Child Development
Fall and Spring: 9 units
This course is about normal development from conception through adolescence. Topics include physical, perceptual, cognitive, emotional and social development. Students will learn facts about children at various points in development, theories about how development works, and research methods for studying development in infants and children. Students will be encouraged to relate the facts, theories and methods of developmental psychology to everyday problems, social issues and real world concerns.

85-241 Social Psychology
Fall and Spring: 9 units
The focus of this course will be on how peoples behavior, feelings and thoughts are influenced or determined by their social environment. The course will begin with lectures and readings on how social psychologists go about studying social behavior. Next, various topics on which social psychologists have done research will be covered. These topics will include: person perception, prejudice and discrimination, the nature of attitudes and how attitudes are formed and changed, interpersonal attraction, conformity, compliance, altruism, aggression, group behavior, and applications of psychology to problems in health care, law, politics, and the environment. Through readings and lectures on these topics, students will also be exposed to social psychological theories.

85-251 Personality
Intermittent: 9 units
The primary purpose of personality psychology is to understand human uniqueness—how and why it is that one person differs from others, in terms of the ways he or she thinks, feels, and acts. Students in the course will be exposed to several broad theoretical perspectives, each of which attempts to capture and understand the origins and consequences of individual distinctiveness from a slightly different vantage point. Included among these approaches are the dispositional or trait, psychoanalytic, learning, humanistic, and cognitive self regulation perspectives. This is a survey course and is intended to provide students with a broad background of theory and research in the area. Class meetings consist primarily of lecture, but there is some discussion too. Students will be given the opportunity to assess their own personalities during the course. A consistent theme throughout the course is the relationships between aspects of one's personality and physical health. https://www.cmu.edu/dietrich/psychology/pdf/syllabi-2018-spring/85-251%20Scheier%20revised.docx

85-261 Abnormal Psychology
Intermittent: 9 units
The study of psychopathology is not an exact science; nor are there many clear-cut parameters with which to differentiate "normal" and "abnormal" behavior. This course will focus on learning about and understanding the range of behaviors which fall within the province of "abnormal" psychology. Its approach will be descriptive, empirical, theoretical, and conceptual. Students will examine definitions of "abnormality" in a historical and contemporary context, explore issues relevant to diagnosis and patient care, be introduced to various psychological diagnostic categories, and develop an appreciation of the range of empirically-supported treatments for these disorders.

85-271 Animal Minds
All Semesters: 9 units
With intricate cultures, impressive technology, and layered social lives, humans seem to stand apart from their animal kin. However, humans and non-human animals share many aspects of their mental lives, and, upon closer inspection, some animals even reveal cognitive abilities far beyond the capacities of humans. Through comparing and contrasting human and non-human cognition, we can learn about human psychological uniqueness and its evolutionary origins, and fundamental properties of cognitive processes in general

85-281 Introduction to Clinical Psychology
Spring: 9 units
This course is designed to introduce students to a wide variety of concepts in the area of clinical psychology. We will explore clinical psychology in an historical perceptive, ethics related to the practice of psychology, and various theories of psychotherapy (Incluing psychoanalytic, psychodynamic, existential, and cognitive behavioral). Also, we will look at group theories underlying group therapy and family/systems therapy.
Prerequisites: 85-261 or 85-251

85-294 Teaching Assistantship
Intermittent
This course is designed to provide students with an apprenticeship in the practice of teaching through one-on-one interaction with a faculty member in the design, administration, and teaching of a course. The student should have previous coursework in the topic domain of the course to ensure that they have the basic skills and background necessary to contribute to the course. The Teaching Assistantship will be supervised by a faculty member, and should result in a concrete, measurable contribution to a course (such as the design of assignments or exams) and/or a reflection on the practical and pedagogical considerations of course design (such as a paper). It is the student's responsibility to make independent arrangement for independent course study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 9, depending on the amount of work done.

85-309 Experimental Design for Behavioral & Social Sciences - Psychology
Spring: 9 units
tba

85-310 Research Methods in Cognitive Psychology
Fall and Spring: 9 units
This is a course in which students develop the research skills associated with cognitive psychology and cognitive science. Students learn how to design and conduct experiments, and analyze and interpret the data they collect. The course covers a variety of experimental designs, e.g., factorial, Latin Squares. Analyses of response times, qualitative data, and signal detection are also covered. Cognitive modeling will also be discussed. Topics include mental imagery, memory, and perception. The class format consists of lectures, discussions and student presentations.
Prerequisites: (36-309 and 85-211) or (36-309 and 85-213) or (85-211 and 36-202)

85-314 Cognitive Neuroscience Research Methods
Intermittent: 9 units
This is a hands-on laboratory course designed to foster basic skills in the empirical approaches used in cognitive neuroscience research. Students will learn how to evaluate which cognitive neuroscience method is best suited to a research question, basic experimental design and analysis, and how to formally present empirical results. The course will focus on functional MRI, but will also cover structural MRI (diffusion imaging) and EEG, and survey various other methods. Students will work with actual datasets using the current software used by cognitive neuroscience researchers. You must have taken 36-309 previously, as well as one of the following: 85-310, 85-320, 85-330, 85-340, 09-207, or 03-124. A background in basic neurobiology, such as 85-219, and comfort with using research software such as SPSS as well as basic programming are encouraged but not required.
Prerequisites: 36-309 and (85-219 or 85-211)

85-320 Research Methods in Developmental Psychology
Fall and Spring: 9 units
This is a laboratory course, in which the student will have direct experience working with children, as well as writing research reports and designing and critiquing research in child development. The purpose of the course is to develop research expertise that will assist the student both in carrying out research and in evaluating the research of others. Special emphasis will be given to the unique methodological problems associated with the study of development. Students must be sure they are also available to attend the Children's School during specific blocks in addition to the class meeting times. Either MW 8:30-10:30am, TR 8:30-10:30am, MW 12:30-2:15pm or MW 12:30-2:15pm.
Prerequisites: 85-221 and 36-309

85-330 Analytic Research Methods
Intermittent: 9 units
This class will teach students how to apply six major non-experimental research methods used in analytic behavioral analysis. Protocol Analysis. This method is used to study patterns and changes in problem-solving and their matches to theoretical models, including computational models. Corpus Analysis. This method is used to isolate patterns of behavioral and communication usage and change, as revealed through the study of the world-wide web and large computerized databases such as CHILDES, TalkBank, or the British National Corpus. Tools here include text searches and data-mining. Conversation Analysis. This is a microanalytic method used to examine sequencing, repair, and orientation in closely transcribed recordings of spoken interactions, as made available through systems such as the CABank database, as well as recorded programs on YouTube and elsewhere. Coding Systems. This approach seeks to capture interactional and behavioral structures in writing, teaching, interview, and other interactions. Here, there will be a special emphasis on the coding of instructional interactions. Gesture Analysis. This microanalytic method seeks to track patterns in gestural and nonverbal communication, often in association with spoken messages. Profile Analysis. This approach studies differences across learners at various ages and ability levels and group differences involving aphasia, autism, stuttering, dementia, and other individual differences. Students will work with data already available from previous studies, and will also learn to collect their own new datasets. Although the data being examined have been generated through naturalistic processes, they can be analyzed quantitatively using time-series analyses, non-parametric statistics, error matrices, and neural network simulations. In these various analyses, we will also consider how behavioral patterns are shape
Prerequisites: 85-320 or 85-340 or 85-310

85-340 Research Methods in Social Psychology
Fall and Spring: 9 units
This course is designed to provide students with the necessary knowledge to evaluate research, make transitions between theory and the operations that test the theory, and to design and carry out original research. Topics will include the nature of proof and causal inference, manipulation of indepen-dent variables, measurement of dependent variables, questionnaire design, experimental ,and quasi-experimental, design and ethical issues involved in doing research. Survey, observational and experimental techniques as applied in both field and laboratory settings will be covered. Students will be expected to criticize completed research. They are also expected to design measures and complete their own original studies. During the course of the semester students will also be expected to design and carry out an original research project as well.
Prerequisites: (85-251 and 36-309) or (36-309 and 85-241) or (36-202 and 85-251) or (85-241 and 36-202)

85-341 Team Dynamics and Leadership
Spring: 9 units
Much of the work in groups and organizations consists of communication. You communicate to get information that will be the basis of decisions, to provide a vision for the people who work for and with you, to coordinate activity, and to sell yourself and your work. The goal of this course is to identify sources of communication problems within an organization and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. This course is not a practicum in public speaking or writing, although you will get some experience writing, speaking, and managing impressions. Rather the intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly do when you return to work. Readings come from both the research and the managerial literatures. Among the topics considered are managerial communication, persuasion and conformity, self presentation and person perception, social networks. Cases and group projects give you an opportunity to apply what you've learned.
Prerequisites: 36-201 or 70-207 or 36-247 or 36-225 or 36-207 or 36-217 or 36-220

85-345 Meaning in Mind and Brain
Intermittent: 9 units
What does it mean to say that an object, word, event or sentence means something? What is the nature of semantic representations that are activated in the brain during comprehension, and how are they related to perceptual, linguistic, mnemonic and motor representations? How do these representations emerge over the course of development, and how can they be selectively impaired by brain damage? This course examines these and related questions by drawing on findings from a broad range of methodologies, including developmental studies of young children, behavioral studies of adults, neuropsychological studies of brain-damaged patients, neurophysiology and functional brain imaging, and computational modeling. The course will take a seminar format in which students read, present and discuss the current literature.
Prerequisites: 85-213 or 85-211 or 85-219

85-350 Psychology of Prejudice
Spring: 9 units
This course is devoted to the study of both traditional and more modern forms of prejudice and discrimination and the psychological processes that can arise from categorizations and stereotyping. The class provides an overview of the cognitive and emotional underpinnings of prejudice and discrimination as it pertains to many forms of inequality. The psychological theories underlying these behaviors will be examined as well as their impact on the lives of stigmatized individuals. Its goal is to examine a number of social differences and understand how prejudice can impact many areas of society. In addition to the traditional forms of prejudice based on such things as race, gender and age; other inequalities that result from less traditional groupings such as social class, appearance, and disability and will be explored. Research on issues of social identity, intergroup relations and the reduction of prejudice will be examined through readings and class activities.
Prerequisite: 85-241

85-352 Evolutionary Psychology
Intermittent: 9 units
This course will cover both the fundamentals of evolutionary psychology, including the theories of natural and sexual selection, with the overarching aim of providing an overview of the field at an advanced level. We will examine the relevance of evolutionary thinking to a range of psychological phenomena including problems of survival, long-term mating strategies, short-term sexual strategies, parenting, kinship, cooperative alliances, aggression and warfare, conflict between the sexes, and prestige, status, and social dominance. We will also examine evolutionary approaches to sensation and perception, development, consciousness, cognition, language, and abnormal behavior. Juniors and Seniors only or permission of instructor. Pre req: 85-102, 85-211, 85-221, 85-241 or 85-251
Prerequisites: 85-251 or 85-241 or 85-221 or 85-102 or 85-211

85-353 Mindfulness: Science and Practice
Intermittent: 9 units
This course will focus on blending first-person experience with mindfulness practices (including mindfulness meditation) and learning about the scientific research on mindfulness. Students will engage in guided mindfulness exercises, develop a daily mindfulness practice, and try out different mindfulness training traditions. In addition, much of this course will be focused on applying a critical eye to the theory, measures, mechanisms, and effects of mindfulness (and mindfulness training interventions) across multiple domains cognition, social processes, behavior, biological mechanisms, and health. As such, this will be a small seminar course focused developing first-person experiences of mindfulness and on discussing the debates and opportunities related to the emerging science of mindfulness.
Prerequisites: 85-314 or 85-340 or 85-310 or 85-320

85-354 Infant Language Development
Intermittent: 9 units
While adults struggle to learn languages, almost all infants acquire language with seemingly little effort. This course examines infants' learning abilities and language milestones with a focus on several different theoretical accounts of language development, and the way empirical data can be used to assess those theories. The course is reading intensive, and evaluation will be based on both written assignments and oral participation.
Prerequisite: 85-221

85-356 Music and Mind: The Cognitive Neuroscience of Sound
Intermittent: 9 units
This course will take a multidisciplinary approach to understand the neural systems that contribute to auditory perception and cognition, using music and speech as domains of inquiry. Students will master topics in acoustics, psychophysics, cognitive psychology, cognitive development, neurophysiology, and neuropsychology. The early part of the course will provide students with a common foundation in acoustics, signal processing, and auditory neuroscience. Later in the semester, the focus will turn to developing analytical skills through critical evaluation of primary-source experimental literature. Hands-on laboratories and homework sets in sound manipulation and experimentation also will constitute a means of learning about auditory cognitive neuroscience. Throughout, the focus will be upon understanding general cognitive and perceptual challenges in perceiving and producing complex sounds like speech and music. Topics may include biological vs. cultural influences, development in infancy, perception versus production, time perception, effects of experience on perceptual processing, comparative studies of animals, attention, development of expertise, effects of brain damage, and emotional expression. Topics will be addressed from the perspective of cognitive neuroscience, in that we will attempt to understand the neural processes that give rise to auditory perception and cognition.
Prerequisites: (85-370 or 85-211 or 85-219) and (85-310 or 85-340 or 85-320)

85-357 Navigating Race and Identity in America: The Role of Psychology in Racial Intera
Intermittent: 9 units
How have social institutions and historical factors led to the belief systems and stereotypes that shape how race is experienced in American society, and how do these belief systems affect the way individuals within racial groups come to view and define themselves? This course will serve as an introduction to how people's psychologyhow they think, feel, and actshapes their experience of race and identity in America. After a brief discussion about the structural and systemic origins of the racial status quo, we will examine the way that individuals navigate the social and racial landscape of modern-day America. Complementing courses that take sociological approaches to race in America, this course will focus on how individuals' perceptions and thoughts about the world affect how they interpret and respond to social situations. For example, the course will address: how stereotypes about one's race or identity can cause individuals to feel threatened, and can undermine health, feelings of belonging, and academic performance how an individual's concerns about the thoughts and beliefs of others can radically affect identity formation, particularly during adolescence how individuals have to navigate multiple cultural identities, especially as minority group members contending with mainstream ideas that differ from their own how majority group members (e.g., Whites) view their role in racial systems, and how they deal with concerns about being or appearing prejudiced how interventions can use social psychological concepts to mitigate negative outcomes of racial inequality We will then use our understanding of these concepts to examine and consider different racial situations thoughout American society and to understand how individuals navigate and experience race and identity. Throughout the course, we will watch films, read literature, and analyze music and art that reflect the experience of race and identity.

85-358 Pro-Social Behavior
Fall: 9 units
This course is an advanced seminar that focuses on social psychological research involving the examination of pro-social behavior. A heavy emphasis will be placed on classic research on helping (which investigates how, when, and why we help strangers), as well as the wide body of literature on social support (which investigates how we help, and seek help from, those who are closer to us). Research on both help-seeking and help-provision will be covered, as well as the implications of this type of pro-social behavior for relationships and health. The course also will cover research on other types of pro-social behavior such as empathy, altruism, forgiveness, and cooperation. This is an advanced seminar in which you will be expected to read original research articles and chapters on assigned topics and come to class prepared to discuss the material. Readings will consist of theoretical and empirical articles from psychology journals and related sources. Additional course requirements will involve short, weekly writing assignments, student presentations of research articles, and a written research proposal. Over the course of the semester, students will design and carry out a small-scale, original investigation on a topic of interest.

85-359 Introduction to Music Cognition Research
Intermittent: 9 units
This course explores the roles of cognitive processes in the experience of music with a focus on carrying out a collaborative laboratory project in order to understand first-hand the challenges of the experimental study of music. In readings, lectures, discussions, and demonstrations we will become acquainted with the relevant psychological theories of perception, memory and learning, and review and critically analyze selected experimental findings on the psychology of music. We will examine the use of psychological principles (e.g. Gestalt laws of perception, limitations on working memory, categorical perception, chunking, schemas, modularity) to explain musical phenomena. The emphasis will be on applying an experimental approach to music perception and cognition, but we will also consider ongoing debates about larger issues (such as music¿s adaptive value to the human species, and the determinants of musical taste).
Prerequisite: either Harmony 1 or Intro to Cognitive Psychology.
Prerequisites: 57-149 or 85-211 or 57-152

85-362 Seminar on Addiction
Intermittent: 9 units
This seminar will explore various topics central to the study of drug addiction, with a primary emphasis on psychological and neurobiological theories of drug addiction. We will also discuss research and clinical techniques related to the assessment, diagnosis, and treatment of substance use disorders and related problems. Emphasis will be on alcohol and tobacco, but other drugs will be discussed as well. The main course objective is to provide a unifying model for understanding the fundamental aspects of addiction.
Prerequisites: 85-320 or 85-340 or 85-314 or 85-310

85-363 Attention, Its Development and Disorders
Intermittent: 9 units
TThis seminar will discuss a broad range of topics pertaining to the study of human attention, including: theoretical frameworks and biological foundations of human attention; interrelationship between attention and other aspects of cognition (such as perception, memory, and executive functions); development of attention in infancy and childhood; biological and psychological foundations of attention disorders. Students will be expected to read original research articles, lead and participate in class discussions, and complete a term paper.
Prerequisites: 85-221 or 85-211

85-370 Perception
Fall: 9 units
Perception, broadly defined, is the construction of a representation of the external world for purposes of thinking and acting. Although we often think of perception as the processing of inputs to the sense organs, the world conveyed by the senses is ambiguous, and cognitive and sensory systems interact to interpret it. In this course, we will examine the sensory-level mechanisms involved in perception by various sensory modalities, including vision, audition, and touch. We will learn how sensory coding interacts with top-down processing based on context and prior knowledge and how perception changes with learning and development. We will look at methods of psychophysics, neuroscience, and cognitive psychology. The goals include not only imparting basic knowledge about perception but also providing new insights into everyday experiences.

85-375 Crosscultural Psychology
Intermittent: 9 units
Human beings share a common genetic inheritance, but our cultural institutions differ in a bewildering variety of ways. This course explores the many different cultural expressions of basic human cognitive and social abilities and needs, We will look at cultural variations in child rearing, mother-child attachment, language socialization, categorization, reasoning, problem-solving, architecture, music, politics, warfare, food-gathering, sex roles, mental disorders, and altered states of consciousness, all with the goal of understanding how the shape of social systems and symbolic expression reflects the economic and adaptive needs of the culture and its people. Among the approaches to these phenomena we will consider are symbolic interaction, cognitive anthropology, dialectic materialism, and modern ethnology.
Prerequisites: 85-198 or 85-261 or 85-251 or 85-100 or 85-102 or 85-211 or 85-219 or 85-221 or 85-241

85-377 Attitudes and Persuasion
Intermittent: 9 units
This advanced undergraduate course will focus on the topic of attitude change and how various persuasive techniques are used to shape human response. The dynamics of propaganda and what makes the techniques effective on social and consumer decisions will be addressed. The primary goals of the course are to 1) understand the dynamics of attitude change; 2) explore the mechanism by which attitude change techniques operate and 3) examine relevant theories and research in persuasion. Examples of topics covered include the origins of attitudes, how attitudes influence judgments, social power and attitude change, and how individual decisions are influenced by the mass media. Classic and contemporary research in the area of persuasion will be examined in the form of course readings and assignments.
Prerequisite: 85-241

85-380 In Search of Mind: The History of Psychology
Intermittent: 9 units
This course will focus on three aspects of the origin and growth of experimen-tal psychology. The first is the prehistory of psychology, where the connection of the discipline to the development of modern science, and in particular, its origins in philosophy and physiology, is examined. The second focus of the course is on the different approaches and attempts to define the field that have contested for dominance during much of the life of the discipline. The final major focus of the course is on the modern period (roughly the last forty years) where the influences that brought about the modern counter-revolution in psychology will be examined, and where some conjecture about likely future directions will occur. Two prior courses in psychology.

85-385 Auditory Perception: Sense of Sound
Intermittent: 9 units
This course explores how our sense of hearing allows us to interact with the world. Students will learn about basic principles of sound, spatial sound, sound quality, hearing impairment, auditory perception, interactions with other modalities, and auditory cognition. Topics may also include musical acoustics, basic auditory physiology, sound-semantic associations, acoustic analysis, and sound-making gestures. We will consider not only simple laboratory-generated signals, but also more complex sounds such as those in our everyday environment, as well music and speech. Students will gain some in-class experience with generating sounds and analytic listening. After students reach a sophisticated level of understanding of the auditory fundamentals, they will apply their knowledge to the study of several current issues in auditory research.
Prerequisites: 85-211 or 85-102

85-390 Human Memory
Intermittent: 9 units
Without memory, people would barely be able to function: we could not be able to communication because we would not be able to remember meanings or words, nor what anyone said to us; we could have no friends because everyone would be a stranger (no memory of meeting anyone); we could have no sense of self because we could not remember anything about ourselves either; we could not predict anything about the future because we would have no recollections of the past; we would not know how to get around, because we would have no knowledge of the environment. This course will discuss issues related to memory at all levels: the sensory registers, i.e., how we perceive things; working or short-term memory; long-term memory or our knowledge base. We will discuss the differences between procedural/skill knowledge, and declarative/fact knowledge. The topics of memory monitoring, feeling and knowing, spread of activation within memory (priming), implicit memory, and amnesia will also be covered.
Prerequisites: 85-213 or 85-340 or 85-211

85-391 Psychology of Sleep
Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course is an advanced seminar that focuses on the biology, psychology, and social factors of sleep and dreaming. The course will go over the history behind the scientific study of sleep, as well as the cultural and psychological underpinnings of dreaming. Students will also delve into the neuroscience and abnormal psychology of sleep. Emphasis will be placed on reading, presenting and analyzing empirical research articles. Students will also be required to fill out sleep logs and a dream diary, culminating in a final research paper analyzing their semester long sleep patterns and dreams based on research discussed in class.
Prerequisites: 85-102 and 85-211

85-392 Human Expertise
Intermittent: 9 units
The process of becoming an expert involves many changes, some quantitative and some qualitative. This course will provide an up-to-date account of the theory and data concerning the development of expertise. Questions addressed include the following. What does it take to become an expert? Are experts born or made? Is the process of acquiring expertise common across different domains from music to sports to science? Research studied in the course will employ a variety of methodologies, from case studies to protocol analysis to computational modeling.
Prerequisites: 85-213 or 85-211

85-395 Applications of Cognitive Science
Spring: 9 units
The famous psychologist George Miller once said that Psychology should "give itself away." The goal of this course is to look at cases where we have done so — or at least tried. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se. That impact can take the form of a product, a change in practice, or a legal statute. The application should have a theoretical base, as contrasted, say, with pure measurement research as in ergonomics. Examples of applications are virtual reality (in vision, hearing, and touch), cognitive tutors based on models of cognitive processing, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measurses of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students.

85-406 Autism: Psychological and Neuroscience Perspectives
Fall: 9 units
Autism is a disorder that affects many cognitive and social processes, sparing some facets of thought while strongly impacting others. This seminar will examine the scientific research that has illuminated the nature of autism, focusing on its cognitive and biological aspects. For example, language, perception, and theory of mind are affected in autism. The readings will include a few short books and many primary journal articles. The readings will deal primarily with autism in people whose IQ's are in the normal range (high functioning autism). Seminar members will be expected to regularly enter to class discussions and make presentations based on the readings. The seminar will examine various domains of thinking and various biological underpinnings of brain function, to converge on the most recent scientific consensus on the biological and psychological characterization of autism. There will be a special focus on brain imaging studies of autism, including both structural (MRI) imaging of brain morphology and functional (fMRI and PET) imaging of brain activation during the performance of various tasks.
Prerequisites: 85-213 or 85-219 or 85-355 or 85-429 or 85-211

85-407 Neuroscience of Concepts
Intermittent: 9 units
Conceptual knowledge underpins all aspects of everyday experience, from language, to thinking, to recognizing familiar objects, people and places. This seminar will survey major theories and findings about how the brain represents 'meaning.' The course will emphasize research using neuropsychological methods in brain-damaged patients and functional neuroimaging in healthy participants. Students will read primary empirical and theoretical review articles to develop an understanding of both classic findings and recent discoveries about how the human brain represents meaning.
Prerequisites: (85-219 or 85-211) and (36-200 or 36-201)

85-408 Visual Cognition
Intermittent: 9 units
Recognizing an object, face or word is a complex process which is mastered with little effort by humans. This course adopts a three-pronged approach, drawing on psychological, neural and computational models to explore a range of topics including early vision, visual attention, face recognition, reading, object recognition, and visual imagery. The course will take a seminar format.
Prerequisites: 85-213 or 85-219 or 85-211

85-412 Cognitive Modeling
Spring: 9 units
This course will be concerned with modeling of agent behavior in a range of applications from laboratory experiments on human cognition, high-performance simulations such as flight simulators, and video game environments like Unreal Tournament. The first half of the course will teach a high-level modeling language for simulating human perception, cognition, and action. The second half of the course will be a project in which students develop a simulated agent or agents for the application of their choice.
Prerequisites: 15-150 or 15-210 or 15-251 or 15-122

85-414 Cognitive Neuropsychology
Spring: 9 units
This course will review what has been learned of the neural bases of cognition through studies of brain-damaged patients as well as newer techniques such as brain stimulation mapping, regional metabolic and blood flow imaging, and attempt to relate these clinical and physiological data to theories of the mind cast in information-processing terms. The course will be organized into units corresponding to the traditionally-defined subfields of cognitive psychology such as perception, memory and language. In each area, we will ask: To what extent do the neurological phenomena make contact with the available cognitive theories? When they do, what are their implications for these theories (i.e., Can we confirm or disconfirm particular cognitive theories using neurological data?)? When they do not, what does this tell us about the parses of the mind imposed by the theories and methodologies of cognitive psychology and neuropsychology?
Prerequisites: 85-211 or 85-219

85-418 Contributions of Psychological Research to Education
Intermittent: 9 units
The main goal of this course is for students to learn about what psychological research has to say regarding how to improve education. We will examine basic principles arising out of cognitive and developmental psychology that can inform educational practice; application of these principles to reading, writing, and mathematics; and policy issues, including ones involving universal preschool education, the Common Core State Standards, and whether college inculcates critical thinking skills.

85-419 Introduction to Parallel Distributed Processing
Spring: 9 units
This course provides an overview of Parallel-Distributed-Processing/neural-network models of perception, memory, language, knowledge representation, and learning. The course consists of lectures describing the theory behind the models as well as their implementation, and their application to specific empirical domains. Students get hands-on experience developing and running simulation models.
Prerequisites: 21-120 or 21-124 or 21-115 or 21-111 or 21-112

85-421 Language and Thought
Intermittent: 9 units
This course allows the student to explore ways in which the mind shapes language and language shapes the mind. Why are humans the only species with a full linguistic system? Some of the questions to be explored are: What kinds of mental abilities allow the child to learn language? What are the cognitive abilities needed to support the production and comprehension of sentences in real time? How do these abilities differ between people? Are there universal limits on the ways in which languages differ? Where do these limitations come from cognition in general or the specific language facility? Why is it so hard to learn a second language? Are there important links between language change and cultural change that point to links between language and culture?
Prerequisites: 85-211 or 85-213 or 80-150 or 80-180

85-422 Clinical Psychology: Science and Practice
Intermittent: 9 units
In this course, students will be exposed to the science and practice of clinical psychology, with a particular emphasis on the synergistic relationship between clinical psychological research and clinical practice. We will focus on the four major activities that clinical psychologists engage in (research, assessment, diagnosis, and psychotherapy). Students will learn about the clinical characteristics of major psychological disorders and the empirically-validated treatments available for these conditions. We will make frequent use of research findings and the scientific method to evaluate and understand concepts in clinical psychology. Critical thinking will be emphasized as we explore the scientific strengths and limitations of various treatments for psychological disorders. This course is designed to be a smaller seminar course for juniors and seniors considering graduate school in clinical psychology.
Prerequisites: 85-320 or 85-314 or 85-310 or 85-340 or 85-261

85-423 Cognitive Development
Intermittent: 9 units
The general goals of this course are that students become familiar with the basic phenomena and the leading theories of cognitive development, and that they learn to critically evaluate research in the area. Piagetian and information processing approaches will be discussed and contrasted. The focus will be upon the development of childrens information processing capacity and the effect that differences in capacities have upon the childs ability to interact with the environment in problem solving and learning situations.
Prerequisite: 85-221

85-424 Hemispheric Specialization: Why, How and What?
Intermittent: 9 units
The brain is divided into two hemispheres, raising a host of questions about brain organization, hemispheric specialization and laterality. Despite all the research devoted to these questions, our understanding of the behavioral significance and neural basis of laterality remains limited. This course will address the questions of "why", "how" and "what". We will review the latest data and empirical results but will also develop a coherent theoretical perspective, moving from molecular, genetic and evolutionary considerations to cognitive and clinical factors in the understanding of one of the most fascinating phenomena in neuroscience, neuropsychology, psychiatry, neurology, and cognitive sciences. In addition to tackling a major text in the field (The Two Halves of the Brain Edited by Hugdahl and Westerhausen), we will read the latest papers in the field. The class will be almost entirely discussion-based and students will be responsible for doing the readings ahead of time and being prepared for the discussion.
Prerequisites: 85-221 or 85-241 or 85-251

85-425 Child Psychopathology and Treatment
Intermittent: 9 units
The first half of this course will focus on understanding the etiology and epidemiology of child and adolescent psychopathology. Special emphasis will be placed on conditions that are first diagnosed during childhood (e.g., ADHD, Autism, Eating Disorders) as well as understanding how child and adult psychopathology differ. The second half of this course will focus on treatment interventions for youth with psychopathology. Students will learn about how interventions for adults with psychopathology are altered to be developmentally appropriate for children, and methods of intervention commonly used with children but less so with adults(e.g., family therapy, play therapy). For students who have completed abnormal psychology and the psychology breadth requirement but not the other course pre-requisite, 85102, please see Theresa Kurutz to register for this course in BH 343.
Prerequisites: 85-261 and 85-102

85-426 Learning in Humans and Machines
Spring: 9 units
This course explores how probabilistic methods can help to explain cognition and to develop intelligent machines. The applications discussed include perception, language, memory, categorization, reasoning, decision-making, and motor control.
Prerequisite: 15-112

85-429 Cognitive Brain Imaging
Spring: 9 units
This seminar will examine how the brain executes higher level cognitive processes, such as problem-solving, language comprehension, and visual thinking. The topic will be addressed by examining what recent brain imaging studies can tell us about these various kinds of thinking. This new scientific approach has the potential of providing important information about how the brain thinks, indicating not only what parts perform what function, but also how the activity of different parts of the brain are organized to perform some thinking task, and how various neurological diseases (e.g. aphasia, Alzheimer's) affect brain activity. A variety of different types of thinking will be examined, including short-term working memory storage and computation, problem solving, language comprehension, visual thinking. Several different technologies for measuring brain activity (e.g. PET and functional MRI and also some PET imaging) will be considered, attempting to relate brain physiology to cognitive functioning. The course will examine brain imaging in normal subjects and in people with various kinds of brain damage.
Prerequisites: 85-412 or 85-414 or 85-213 or 85-211 or 85-419

85-435 Neural and Cognitive Models of Adaptive Decisions
Intermittent: 9 units
Humans and other mammals exhibit a high degree of control when selecting actions in noisy contexts, quickly adapting to unexpected outcomes in order to better exploit opportunities arising in the future. This course will explore both the cognitive and neurobiological systems of adaptive decision-making, through a mixture of readings, lectures, and hands-on modeling projects (in Python and Matlab).
Prerequisites: (85-211 or 85-213) and (21-120 or 21-115 or 21-111)

85-438 Educational Goals, Instruction, and Assessment
Fall: 9 units
This course will meet in TQ 1308 The aim of this course is to teach students how to develop educational goals based on a detailed task analysis of the knowledge, skills, and dispositions required for mastery of a particular aspect of a domain. Goals for early childhood, elementary, middle school, and high school will be discussed and related to the state and national standards. A comprehensive understanding of student achievement will be developed. The importance of matching the instructional program and its assessment to goals will be discussed and demonstrated. Assessment that focuses on covering the full range of specified goals will be studied along with diverse approaches for valid assessment. Other topics include making instructional material choices, funding, classroom management, ethics, and relation to system-level policies. Assignments will emphasize linking goals - instruction assessment. A term project will consist of an in-depth study of one central unit in a discipline or grade level. This course will meet in TQ 1308

85-442 Health Psychology
Intermittent: 9 units
This course is concerned with how behavior and psychological states influence the development of and recovery from disease. The class provides an overview of existing psychological and epidemiological data on the relationship between behavior and disease and addresses the issue of how behavior, emotion and cognition can influence the disease processes. Topics include: measures and concepts, stress and disease, stress and coping, personal control, helplessness and disease, social support and health, reactivity to stress, behavior and hypertension, coronary heart disease, infectious diseases and immune function, and the effectiveness of behavioral interventions in health. Only Juniors and Seniors will be admitted into the course and instructor permission is required.

85-443 Social Factors and Well-Being
Intermittent: 9 units
This course will focus on the role that our social environment plays in our feelings of well-being and in the maintenance of our mental and physical health. Topics to be discussed include marriage, widowhood, loneliness, social support, social participation, social aspects of personality (e.g., social anxiety, extraversion, agreeableness, and hostility), social stressors (betrayal and conflict), discrimination, and socioeconomic status. We will consider how each social factor develops, the extent to which we can alter it or its effects on our lives, and how it influences our overall well-being. Only Juniors and Seniors will be admitted into the course and instructor permission is required.

85-444 Relationships
Fall: 9 units
The primary goal of this course is to introduce you to social psychological theory and research on the topic of relationships. Although a variety of relationship phenomena will be discussed, a heavy emphasis will be placed on research that addresses fundamental processes in close relationships. The coverage of material will include a review of historical roots and classic approaches to the scientific study of relationships, as well as exciting new research and theory on particular subtopics. The majority of class time is spent discussing and evaluating recent research. Special emphasis also is given to learning and critically evaluating the methodological tools that are used to study close relationships. This is an advanced seminar in which students will be expected to read original research articles and chapters on assigned topics and come to class prepared to discuss the material. Readings will consist of theoretical and empirical articles from psychology journals and related sources. Additional course requirements will involve short, weekly writing assignments, student presentations of research articles, and a written research proposal. Over the course of the semester, students will design and carry out a small-scale, original investigation on a relationships topic of interest.

85-446 Psychology of Gender
Spring: 9 units
This course is devoted to the investigation of psychological gender rather than biological sex. That is, sex differences will be explored from a social psychological (e.g., socialization) perspective. Implications of both male gender role and female gender role in the areas of relationships and health will be the course focus.
Prerequisites: 85-241 or 85-251

85-480 Internship in Clinical Psychology
All Semesters
This course allows students to gain applied clinical experience in a mental health setting. Students will work alongside psychology professionals at designated field placements. This course is designed to help students apply and expand their knowledge of clinical psychology and to develop appropriate professional work standards. Students will spend the majority of their time (8 hours per week) in an applied clinical setting, with a one hour per week supervision meeting with Dr. Kasey Creswell. Students must be currently enrolled in 85-422 (Clinical Psychology: Science and Practice) or have already taken this course. Instructor permission is required. Please contact Dr. Kasey Creswell if you are interested in enrolling at kasey@andrew.cmu.edu.

85-481 Seminar in Intervention
Intermittent: 9 units
This course is an introduction to the therapeutic process. Students will be introduced to a variety of therapeutic approaches and techniques (e.g. Solution-Focused, Cognitive, Client Centered, etc.) and will have the opportunity to learn the basic skills associated with each (e.g. Cognitive Restructuring, Mirroring, Empathic Highlighting, etc.). Instruction will entail a mix of discussion and demonstration, and there will be a heavy emphasis on in-class practice of these skills.
Prerequisites: (85-261 and 85-251) or (85-281 and 85-261) or (85-281 and 85-251)

85-482 Internship in Psychology
Fall and Spring
The Internship in Psychology is designed to enable students to gain experience in professional settings related to their studies in Psychology and earn credit for the intellectual work involved. It is the students responsibility to locate an internship site and on-site supervisor, as well as to identify a CMU faculty sponsor.

85-484 Practicum in Child Development
Fall and Spring
This guided field experience is designed to help students deepen their understanding of developmental psychology by assisting in a preschool or kindergarten classroom and discussing the ways that their experiences relate to the theories they have learned previously and to new readings. Each student will individually schedule a consistent 6 hours per week helping in a Children's School classroom (preferably 2 or 3 chunks of time). Classroom duties will include working one-on-one and with small groups of students as they do puzzles, art projects, dramatic play, etc., as well as helping with snack, playground supervision, classroom cleanup, and storytime. Each student will be expected to keep a journal 1) relating general experiences to developmental theories and 2) documenting the development of a particular child during the semester. All students will meet for a 1 hour weekly discussion with the director. Discussion topics and related readings will be selected collaboratively, based on issues/questions raised by the group's observations and discussions. This course is typically 9 units, but may be negotiable between 3 and 9.
Prerequisite: 85-221

85-501 Stress, Coping and Well-Being
Intermittent: 9 units
This course will examine basic processes and theory about stress and coping from a psychological perspective. The first part of the course will explore topics related to the psychobiology of stress, stress measurement, and links between stress and health. The second part of the course will explore topics on mechanisms and theoretical perspectives on coping with stress. This will include a consideration of topics such as emotion regulation, self-regulation, coping with traumatic events, alternative medicine approaches, and resilience factors. This class is a small, upper level seminar that will consist of some lecture and extensive class discussion. Active class participation is required.
Prerequisites: 85-310 or 85-320 or 85-340

85-505 Readings In Psychology
All Semesters
As the name implies, the emphasis in the Reading course is on reading articles and books in some specified area. The students work in the course must lead to the production of a written paper which will be read by the instructor directing the readings. Often the reading is related to a research project which the student may wish to conduct. Readings courses have also been used to give students an opportunity to receive instruction in areas which are not included elsewhere in our course listing. The course may be taken for any number of units up to 9, depending upon the amount of work to be done.

85-506 Readings in Psychology
Fall and Spring
As the name implies, the emphasis in the reading course is on reading articles and books in some specified area. The students work in the course must lead to the production of a written paper which will be read by a psychology faculty instructor directing the readings. Often the reading is related to a research project which the student may wish to conduct. Reading courses have also been used to give students an opportunity to receive instruction in areas which are not included elsewhere in our course listing. The course may be taken for any number of units up to 9, depending upon the amount of work to be done. This course is special permission and can only be added in consultation with a psychology faculty member and registered by the Undergraduate administrator, Emilie O'Leary emilier@andrew.cmu.edu.

85-507 Research in Psychology
Fall
This course may include field study, applied work, or laboratory research. The student should have previous training in the basic research skills that will be used in his/her project, especially statistical methods and experimental design. Independent Research Projects will be supervised by a faculty member and must result in a written paper. It is the students responsibility to make arrangements for independent study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 12, depending upon the amount of work to be done. Please contact the CMU psychology faculty member you wish to work with to get approval to enroll then email Emilie Rendulic at emilier@andrew.cmu.edu in order to be registered for the course.

85-508 Research in Psychology
Spring
This course may include field study, applied work, or laboratory research. The student should have previous training in the basic research skills that will be used in his/her project, especially statistical methods and experimental design. Independent Research Projects will be supervised by a faculty member and must result in a written paper. It is the students responsibility to make arrangements for independent study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 12, depending upon the amount of work to be done.

85-601 Senior Thesis
Fall: 9 units
This course is intended for senior Psychology or Cognitive Science majors who wish to conduct a research project under the direction of a faculty advisor. The project topic is to be selected jointly by the student and the advisor. The project will culminate in a senior paper which will be presented to the Department Head at the end of Fall Semester. Prerequisite: Grade of B or better in a previous research course required to enter, grade of B or better in first semester of senior thesis course required to complete, and permission of instructor. A formal proposal is required in the first semester. This course differs from the Honors Thesis sequence (66-501,502) in that it does not require Honors standing in HSS (i.e., there are no QPA requirements). This course differs from Research in Psychology (85-507,508) in that the student's original contribution to the research is expected to be more substantial, and in that a final written report of the project is to be presented to the Department.

85-602 Senior Thesis
Spring: 9 units
This course is intended for senior Psychology or Cognitive Science majors who wish to conduct a research project under the direction of a faculty advisor. The project topic is to be selected jointly by the student and the advisor. The project will culminate in a senior paper which will be presented to the Department Head at the end of Fall Semester. Prerequisite: Grade of B or better in a previous research course required to enter, grade of B or better in first semester of senior thesis course required to complete, and permission of instructor. A formal proposal is required in the first semester. This course differs from the Honors Thesis sequence (66-501,602) in that it does not require Honors standing in HSS (i.e., there are no QPA requirements). This course differs from Research in Psychology (85-507,508) in that the student's original contribution to the research is expected to be more substantial, and in that a final written report of the project is to be presented to the Department.

85-730 Analytic Research Methods
Intermittent: 12 units
This class will teach students how to apply six major non-experimental research methods used in analytic behavioral analysis. Protocol Analysis. This method is used to study patterns and changes in problem-solving and their matches to theoretical models, including computational models. Corpus Analysis. This method is used to isolate patterns of behavioral and communication usage and change, as revealed through the study of the world-wide web and large computerized databases such as CHILDES, TalkBank, or the British National Corpus. Tools here include text searches and data-mining. Conversation Analysis. This is a microanalytic method used to examine sequencing, repair, and orientation in closely transcribed recordings of spoken interactions, as made available through systems such as the CABank database, as well as recorded programs on YouTube and elsewhere. Coding Systems. This approach seeks to capture interactional and behavioral structures in writing, teaching, interview, and other interactions. Here, there will be a special emphasis on the coding of instructional interactions. Gesture Analysis. This microanalytic method seeks to track patterns in gestural and nonverbal communication, often in association with spoken messages. Profile Analysis. This approach studies differences across learners at various ages and ability levels and group differences involving aphasia, autism, stuttering, dementia, and other individual differences. Students will work with data already available from previous studies, and will also learn to collect their own new datasets. Although the data being examined have been generated through naturalistic processes, they can be analyzed quantitatively using time-series analyses, non-parametric statistics, error matrices, and neural network simulations. In these various analyses, we will also consider how behavioral patterns are shape

85-753 Mindfulness: Science and Practice
Intermittent
This course will focus on blending first-person experience with mindfulness practices (including mindfulness meditation) and learning about the scientific research on mindfulness. Students will engage in guided mindfulness exercises, develop a daily mindfulness practice, and try out different mindfulness training traditions. In addition, much of this course will be focused on applying a critical eye to the theory, measures, mechanisms, and effects of mindfulness (and mindfulness training interventions) across multiple domains cognition, social processes, behavior, biological mechanisms, and health. As such, this will be a small seminar course focused developing first-person experiences of mindfulness and on discussing the debates and opportunities related to the emerging science of mindfulness.

85-762 Seminar on Addiction
Fall: 9 units
This seminar will explore various topics central to the study of drug addiction, with a primary emphasis on psychological and neurobiological theories of drug addiction. We will also discuss research and clinical techniques related to the assessment, diagnosis, and treatment of substance use disorders and related problems. Emphasis will be on alcohol and tobacco, but other drugs will be discussed as well. The main course objective is to provide a unifying model for understanding the fundamental aspects of addiction.

85-765 Cognitive Neuroscience
Intermittent
This course will cover fundamental findings and approaches in cognitive neuroscience, with the goal of providing an overview of the field at an advanced level. Topics will include high-level vison, spatial cognition, working memory, long-term memory, learning, language, executive control, and emotion. Each topic will be approached from a variety of methodological directions, for example, computational modeling, cognitive assessment in brain-damaged humans, non-invasive brain monitoring in humans, and single-neuron recording in animals. Lectures will alternate with sessions in seminar format. Prerequisites: Graduate standing or two upper-level psychology courses from the areas of developmental psychology, cognitive psychology, computational modeling of intelligence, neuropsychology or neuroscience.

85-851 Personality and Health
Intermittent
The general purpose of this course is to examine possible connections between personality and physical well-being. Material will be presented at the outset of the semester that is designed to enable students to understand more fully how psychologists think about the concept of personality (what it is and what it does for us), how it is assessed, and how personality and health psychologists do research on the topic. As the semester progresses, we will explore and discuss research that links certain aspects of personality to health, illness, and mortality. The list of personality characteristics to be considered includes (but is not necessarily limited to) optimism/pessimism, conscientiousness, hostility, trait positive and negative affect, life purpose, and chronic goal adjustment strategies. As time permits, select person variables will also be considered, e.g., the impact of depressive mood on health. Class time will be largely taken by discussion of original research papers. Different sets of students will be responsible for leading these discussions. Grades will be based on a combination of class participation, quality of paper presentations, and performance on a final research paper.

Department of Social and Decision Sciences

Location: Porter Hall 208
www.cmu.edu/dietrich/sds

The Department of Social and Decision Sciences is a multidisciplinary department that offers undergraduate programs that seamlessly combine frontier knowledge in the social sciences with the practical skills needed to excel in key decision making roles in the public, private, and non-profit sectors and in advanced graduate studies. Our students learn how to combine intellectual ideals with the realities of human and organizational behavior and to apply these lessons across a wide variety of endeavors, ranging from government service to leadership positions in the information economy.

The department offers undergraduate majors in Behavioral Economics, Policy and Organizations, in Decision Science, and in Policy and Management. The core courses leverage our strength in decision analysis, decision making, empirical research, and policy analysis. In addition to completing this core, students also specialize in their major area through a set of required and elective courses.

Our faculty is committed to the academic success and growth of our students and many of our undergraduates work with faculty on research projects and internships. The directors of the majors are easily accessible and encourage students to talk with them about their curriculum, progress, and available opportunities. Our academic advisors are committed to working with each individual student to help them create, clarify, and meet their goals.

The Department of Social and Decision Sciences has a long history of creating innovative and prescient undergraduate programs that combine key ideas from across the social sciences into cohesive majors that allow our graduates to excel in their chosen professions or in the pursuit of advanced studies. Our emphasis on the theory and practice of individual and social decision making linked with our high-quality, multidisciplinary social science faculty, provides a solid foundation from which graduates can embrace a variety of future paths.

The Major in Behavioral Economics, Policy and Organizations

Saurabh Bhargava, *Faculty Director*
Location: Porter Hall 319F
DS-advisor@andrew.cmu.edu

Lizzy Stoyle, *Academic Advisor*
Location: Porter Hall 208G
estoyle@andrew.cmu.edu

The field of Behavioral Economics (BE) integrates perspectives from Economics and Psychology to better understand how people make consequential decisions and to leverage this understanding to improve the design of the policies, programs, and institutions that govern such behavior. The last several years has witnessed an explosion of interest in BE among governments and organizations, around the world, including here in the United States. On the policy front, this has led to the formation of government "nudge" units charged with applying BE principles to policy areas such as education, criminal justice, taxation, social benefit programs, consumer protection, and unemployment. Organizations have also aggressively sought to apply BE to encourage employee productivity, improve employee health and financial wellness, reshape managerial and hiring decisions, and to better understand and engage consumers.

The faculty in the Department of Social and Decision Sciences (SDS) has long stood at the forefront of research and teaching in BE. Our faculty has developed a reputation for working closely with governments and firms to help apply BE to address a range of issues such as predatory lending and consumer protection, bias among institutional investors, employee reward and incentive programs, behavioral barriers to retirement savings, participation in social service programs, medical adherence, pre-trial detainment of defendants, and gender and racial inequality in the workplace.

The new major of BEPO-- the first of its kind among US undergraduate institutions--was designed to uniquely train students to study the behavior of individuals and organizations from the perspective of both Economics and Psychology. The major emphasizes the practical promise of BE to solve problems of importance to policymakers and organizations by directly exposing students to the expertise and experiences of SDS faculty and through the largest selection of BE courses of any university in the world. Towards this end, students will learn to collect original data, design field and laboratory experiments, analyze data and draw causal inferences, and develop interventions to improve economic outcomes and decisions. The core requirements include courses in economics, psychology, BE, and quantitative methods including experimental design and econometrics. Students who complete the major will be well positioned to enter the private sector in a role involving data or people analytics, marketing, corporate strategy, or human resources, or to enter a wide range of graduate degree programs.

Prerequisites

All Behavioral Economics, Policy and Organizations majors must complete mathematics and statistics prerequisites (see below), by the end of the sophomore year.

Mathematics Prerequisite		Units
21-111-21-112	Differential Calculus - Integral Calculus	10-20
or 21-120	Differential and Integral Calculus	

Statistics Prerequisite		Units
36-200	Reasoning with Data	9

Curriculum

The core curriculum in Behavioral Economics, Policy and Organizations consists of three quantitative courses, two Economic courses, two Psychology courses, two Behavioral Economics courses, and one project course.

Quantitative Method Courses		Units
36-202	Statistics & Data Science Methods	9
88-251	Empirical Research Methods	9
88-252	Causal Inference in the Field	9
		27

Economics Courses		Units
73-102	Principles of Microeconomics	9
73-160	Foundations of Microeconomics: Applications and Theory	9
or 73-230	Intermediate Microeconomics	
		18

Psychology Courses		Units
88-120	Reason, Passion and Cognition *	9
88-302	Behavioral Decision Making	9
		18

* 88-120 Should be taken in the freshman or sophomore year.

Behavioral Economics Courses		Units
88-360	Behavioral Economics	9
88-367	Behavioral Economics in the Wild	9
		18

Senior Project Course		Units
88-453	Behavioral Economics, Policy, and Organizations Capstone	9
		9

ELECTIVES **36 units**

Complete at least 36 units from the following categories. Students MUST take one elective from each of the three categories. The fourth elective may be chosen from any of the categories. Note that not all elective courses are offered every year.

Economics**		Units
73-328	Health Economics	12
73-348	Behavioral Economics ***	9

73-408	Law and Economics	9
73-476	American Economic History	9

** Students can petition that any 73-3XX or 73-4XX courses be counted as an economic elective course. Consult the Academic Advisor for more information.

*** Can ONLY count as either an Economics OR Behavioral Economics elective course. It cannot be counted in both categories.

Behavioral Economics		Units
73-348	Behavioral Economics ***	9
88-255	Strategic Decision Making: Cooperation and Competition in Social Interactions	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-406	Behavioral Economics in Organizations	9
88-409	Behavioral Economics Perspectives on Ethical Issues	9

*** Can ONLY count as either an Economics OR Behavioral Economics elective course. It cannot be counted in both categories.

Psychology		Units
70-311	Organizational Behavior	9
70-385	Consumer Behavior	9
85-350	Psychology of Prejudice	9
85-352	Evolutionary Psychology	9
85-358	Pro-Social Behavior	9
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-442	Health Psychology	9
85-446	Psychology of Gender	9
88-230	Human Intelligence and Human Stupidity	9
88-342	The Neuroscience of Decision Making	9
88-372	Social and Emotional Brain	9
88-380	Dynamic Decisions	9
88-388	Psychological Models of Decision Making	9
88-418	Domestic Negotiation	9
88-419	International Negotiation	9
88-435	Decision Science and Policy	9

Note: Some courses have additional prerequisites.

Free Elective		Units
Counts IN PLACE OF the fourth elective from any category		
88-275	Bubbles: Data Science for Human Minds	9
88-300	Programming and Data Analysis for Social Scientists	9

Behavioral Economics, Policy and Organizations, B.A. Sample Curriculum

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
88-120 Reason, Passion and Cognition *	36-202 Statistics & Data Science Methods	88-251 Empirical Research Methods	88-252 Causal Inference in the Field
21-120 Differential and Integral Calculus (Or 21-111, depending on placement)	73-160 Foundations of Microeconomics: Applications and Theory***	88-360 Behavioral Economics	88-302 Behavioral Decision Making
36-200 Reasoning with Data Or 36-201	Pick One (Freshman Seminar, 76-101, 79-104)	Psychology Elective	88-367 Behavioral Economics in the Wild
73-102 Principles of Microeconomics	Pick One (Freshman Seminar, 76-101, 79-104)	Gen Ed or Elective	Behavioral Economics Elective
Pick One (Freshman Seminar, 76-101, 79-104)	Gen Ed or Elective	Gen Ed or Elective	Gen Ed or Elective

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
Economics Elective	One Additional Elective From Any Category	88-453 Behavioral Economics, Policy, and Organizations Capstone***	Elective or Senior Honors Thesis***
Gen Ed or Elective	Gen Ed or Elective	Elective	Elective
Gen Ed or Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

* Should be taken as the first course in Behavioral Economics, Policy and Organizations sequence. It is intended for students in their first or second year and is offered in Fall semesters. It may be taken as late as the junior year.

** 73-160 is intended for students in their first or second year; it is offered in Spring semesters. It may be taken as late as the junior year. Additionally, 73-230 Intermediate Microeconomics can serve as a substitute for 73-160 Foundations of Microeconomics: Applications and Theory.

*** Senior Honors Thesis may be substituted in the Spring term for 88-453 Behavioral Economics, Policy, and Organizations Capstone, which is only offered in the Fall term.

This is presented as a recommended plan for completing major requirements. The major can be completed in as few as two years (not that it must be), but students may not have time for other opportunities such as additional majors or study abroad. Students may declare their major as early as the third week of the spring semester in the freshman year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early – and often – with the Behavioral Economics, Policy and Organizations Academic Advisor.

Additional Major

Students who elect Behavioral Economics, Policy and Organizations as an additional major must fulfill all of the requirements of the Behavioral Economics, Policy and Organizations major.

Students pursuing Decision Science with an additional major in Behavioral Economics, Policy and Organizations may only count 36-202 , 73-102, 88-120, 88-251 and 88-302 toward the completion of both majors.

Students pursuing Policy and Management with an additional major in Behavioral Economics. Policy and Organizations may only count 36-202, 73-102 and 88-251 toward the completion of both majors.

Additional majors cannot count menu electives toward simultaneously fulfilling more than one major or minor. Students who are interested in an additional major in Behavioral Economics, Policy and Organizations should see the Academic Advisor of the Behavioral Economics, Policy and Organizations program.

The Major in Decision Science

Gretchen Chapman, *Faculty Director*
Location: Porter Hall 219F
DS-advisor@andrew.cmu.edu

Connie Angermeier and Lizzy Stoyle, *Academic Advisors*
Location: Porter Hall 208A and 208G
cla2@andrew.cmu.edu, estoyle@andrew.cmu.edu

The interdisciplinary field of Decision Science seeks to understand and improve the judgment and decision making of individuals, groups, and organizations. Qualified graduates can continue to PhD programs in Decision Science or related fields (e.g., psychology, business), pursue professional degrees (e.g., MBA, MD, JD, MPH), or take professional positions in business, government, consulting, or the non-profit sector. Students work with faculty and the Academic Advisor to tailor their education to their personal needs and interest.

Carnegie Mellon is one of the leading centers for the study of Decision Science - and offers the only undergraduate major that integrates analytical and behavioral approaches to decision making. Our faculty are involved in applying Decision Science in a wide variety of areas, allowing them to share practical experiences with students. These applications include medical decision making (e.g., conveying the costs and benefits of treatment options), legal decision making (e.g., reducing the effects of hindsight bias on attributions of responsibility for accidents), risk management (e.g., assessing and communicating the risks of climate change), marketing (e.g., understanding the effects of inter-temporal choice on purchasing decisions), and business (e.g., identifying unrecognized conflicts of interest).

Decision Science is grounded in theories and methods drawn from psychology, economics, philosophy, statistics, and management science. Courses in the major cover the three aspects of decision science: (a) normative analysis, creating formal models of choice; (b) descriptive research, studying how cognitive, emotional, social, and institutional factors affect judgment and choice, and (c) prescriptive interventions, seeking to improve judgment and decision making. In addition to gaining a broad education in the principles of judgment and decision making, Decision Science majors gain broadly applicable skills in research design and analysis. They also have the chance to think about and discuss decision making in many different areas.

The core courses present fundamental theories and results from the study of decision making, along with their application to real-world problems. They introduce students to methods for collecting and analyzing behavioral data. For example, students learn to conduct surveys (e.g., uncovering consumer or managerial preferences), design experiments (e.g., evaluating theories, comparing ways of presenting information), and evaluate the effectiveness of interventions.

The elective courses provide students with additional knowledge in areas of decision making that meet their personal, intellectual, and career goals. These courses are organized into six clusters: biological and behavioral aspects of decision making, managerial and organizational aspects, philosophical and ethical perspectives, economic and statistical methods, public policy, and research methods. Students can concentrate in one area or spread their studies across them. In addition to coursework, the department offers research opportunities for interested and qualified students. Participating in research helps students to extend their mastery of decision science, discover whether a research career is right for them, and get to know faculty and graduate students better.

Prerequisites

All Decision Science majors must complete mathematics, statistics, and analytic methods prerequisites (see below), by the end of the sophomore year.

Mathematics Prerequisite		Units
21-111-21-112	Differential Calculus - Integral Calculus	10-20
or 21-120	Differential and Integral Calculus	

Statistics Prerequisite		Units
36-200	Reasoning with Data	9

Students must take one course from the following set (or an approved alternative). Students may not count a course used to fulfill the Mathematics Prerequisite as also filling the Analytic Methods Prerequisite.

Analytic Methods Prerequisite		Units
21-122	Integration and Approximation	10
21-256	Multivariate Analysis	9
21-257	Models and Methods for Optimization	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-401	Modern Regression	9
36-410	Introduction to Probability Modeling	9
80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-223	Causality and Probability	9
80-315	Modal Logic	9
88-252	Causal Inference in the Field	9

Curriculum

The core curriculum in Decision Science consists of two courses in empirical research methods and five courses providing the theoretical perspectives of Decision Science**.**

Theoretical Perspectives		Units
73-102	Principles of Microeconomics	9
85-102	Introduction to Psychology	9
88-120	Reason, Passion and Cognition *	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9
		48

* 88-120 should be taken in the freshman or sophomore year.

Research Methods		Units
36-202	Statistics & Data Science Methods	9
88-251	Empirical Research Methods	9
		18

Electives 45 units

Complete at least 45 units of courses from the following categories. The selected courses may be from one category or from any combination. Note that not all elective courses are offered every year.

At least three of these courses (27 units) must be Department of Social and Decision Sciences courses (88-xxx).

1. Biological and Behavioral Aspects of Decision Making		Units
85-350	Psychology of Prejudice	9
85-352	Evolutionary Psychology	9
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-444	Relationships	9
85-442	Health Psychology	9
85-446	Psychology of Gender	9
88-230	Human Intelligence and Human Stupidity	9
88-342	The Neuroscience of Decision Making	9
88-355	Social Brains: Neural Bases of Social Perception and Cognition	9
88-360	Behavioral Economics	9
88-365	Behavioral Economics and Public Policy	9
88-380	Dynamic Decisions	9

2. Managerial and Organization Aspects of Decision Making		
70-311	Organizational Behavior	9
70-381	Marketing I	9
70-460	Mathematical Models for Consulting	9
88-150	Managing Decisions	9
88-221	Analytical Foundations of Public Policy	9
88-406	Behavioral Economics in Organizations	9
88-418	Domestic Negotiation	9
88-419	International Negotiation	9
88-444	Public Policy and Regulation	9
88-451	Policy Analysis Senior Project	12
or 88-452	Policy Analysis Senior Project	

3. Philosophical and Ethical Perspectives on Decision Making		Units
70-332	Business, Society and Ethics	9
80-208	Critical Thinking	9
80-221	Philosophy of Social Science	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-249	AI, Society, and Humanity	9
80-271	Philosophy and Psychology	9
80-305	Choices, Decisions, and Games	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9
88-275	Bubbles: Data Science for Human Minds	9
88-409	Behavioral Economics Perspectives on Ethical Issues	9

4. Economic and Statistical Methods for Decision Science		Units
70-374	Data Mining & Business Analytics	9
70-455	Modern Data Management	9
70-460	Mathematical Models for Consulting	9
73-265	Economics and Data Science	9
73-347	Game Theory for Economists	9
80-405	Game Theory	9
88-255	Strategic Decision Making: Cooperation and Competition in Social Interactions	9
88-300	Programming and Data Analysis for Social Scientists	9

88-360	Behavioral Economics	9
88-367	Behavioral Economics in the Wild	9

5. Decision Science and Public Policy

84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-369	Decision Science for International Relations	9
88-221	Analytical Foundations of Public Policy	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-405	Risk Perception and Communication	9
88-444	Public Policy and Regulation	9
88-451	Policy Analysis Senior Project	12
or 88-452	Policy Analysis Senior Project	

6. Research Methods for Decision Science		Units
36-303	Sampling, Survey and Society	9
70-460	Mathematical Models for Consulting	9
85-310	Research Methods in Cognitive Psychology	9
88-252	Causal Inference in the Field	9
88-402	Modeling Complex Social Systems	9
88-435	Decision Science and Policy	9

Note: Some courses have additional prerequisites.

Decision Science, B.S. Sample Curriculum

Freshman		**Sophomore**	
Fall	**Spring**	**Fall**	**Spring**
88-120 Reason, Passion and Cognition*	36-202 Statistics & Data Science Methods	85-102 Introduction to Psychology	88-302 Behavioral Decision Making
36-200 Reasoning with Data	Pick One (Freshman Seminar, 76-101, 79-104)	88-251 Empirical Research Methods	88-252 Causal Inference in the Field (or other Analytic Methods course)
21-120 Differential and Integral Calculus (or 21-111, depending on placement)	Pick One (Freshman Seminar, 76-101, 79-104)	Decision Science Elective	Decision Science Elective
73-102 Principles of Microeconomics	Decision Science Elective	Gen Ed or Elective	Gen Ed or Elective
Pick One (Freshman Seminar, 76-101, 79-104)	Gen Ed or Elective	Gen Ed or Elective	Gen Ed or Elective

Junior		**Senior**	
Fall	**Spring**	**Fall**	**Spring**
Decision Science Elective	88-223 Decision Analysis	Senior Honors Thesis or Elective	Senior Honors Thesis or Elective
Gen Ed or Elective	Decision Science Elective	Elective	Elective
Elective	Gen Ed or Elective	Elective	Elective
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

* 88-120 should be taken as the first course in the Decision Science sequence. It is intended for students in their first or second year; it is offered in Fall and Spring semesters. It may be taken as late as the junior year.

This is presented as a recommended plan for completing major requirements. The major can be completed in as few as two years (not that it must be), but students may not have time for other opportunities such as additional majors or study abroad. Students may declare their major as early as the third week of the spring semester in the freshman year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early – and often – with the Decision Science Academic Advisor.

Students are encouraged to consider the Washington Semester Program as part of their education. Suitable courses will be considered as fulfilling requirements of electives in the major. Please send the course syllabus, along with a note explaining how the course addresses fundamental aspects of decision science in one of the six elective categories.

Additional Major in Decision Science

Students who elect Decision Science as an additional major must fulfill all of the requirements of the Decision Science major.

Students pursuing Behavioral Economics, Policy and Organizations with an additional major in Decision Science may only count 36-202, 73-102, 88-120, 88-251 and 88-302 toward the completion of both majors.

Students pursuing Policy and Management with an additional major in Decision Science and may only count 36-202, 73-102, 88-223, and 88-251 toward the completion of both majors.

Additional majors cannot count menu electives toward simultaneously fulfilling more than one major or minor. Students who are interested in an additional major in Decision Science should see the Academic Advisor of the Decision Science program.

The Major in Policy and Management

Christina Fong, *Faculty Director*
Location: Porter Hall 223I
P-and-M-advisor@andrew.cmu.edu

Connie Angermeier, *Senior Academic Advisor*
Location: Porter Hall 208A
cla2@andrew.cmu.edu

The Policy and Management major prepares students for key decision-making and management roles in government, non-profit organizations, and business. The major emphasizes analytical approaches to decision making, practical management skills, and empirical techniques necessary for graduates to excel in the public and private sectors. The multidisciplinary curriculum merges frontier knowledge on the ideals of decision making, policy, and data analysis, as well as the realities of individual behavior within various institutional settings that must be confronted if high-quality outcomes are to be attained.

The major is comprised of three required core areas taken by all Policy and Management majors, a capstone course, plus one of four concentration areas to be chosen by the student.

The three core areas are as follows:

The *Policy Core* gives students applied economic training and policy analysis experience. Students will gain an analytical understanding of some of the biggest domestic and global economic policy challenges, and gain an appreciation of the economic analysis of complex decisions, as well as the trade-off between economic and political-based decision making.

The *Management Core* focuses on real-world applications of decision making. Students will develop an understanding of effective negotiation strategies and tactics, and identify the barriers and the psychological factors that may prevent decision-makers from reaching wise agreements. The courses provide systematic methods for dealing with the complexities that make decisions difficult, ranging from incorporating issues of risk and uncertainty in decision making to dealing with choices that have mutually conflicting objectives. For example, a business or government agency may need to decide on a policy for mitigating the uncertain impacts of air pollution while simultaneously trying to minimize the costs of such a policy on manufacturing. A firm might want to consider the uncertain reductions in security dangers from alternative policies to protect against terrorism.

The *Empirical Core* focuses on key methods for collecting and analyzing data that are needed to make informed decisions. Students learn to use interviews, surveys, experiments, and econometric methods to enhance their ability to test existing, and design new, policies. Students will create statistical models to address questions asked in conceptual, computational, and data-driven investigations.

The required *Capstone* course gives students hands-on experience in a policy-related area. Students work in teams to apply the research and analytical methods learned in their other courses to a real-world problem.

Finally, the *four concentration areas* consist of four courses chosen by the student, in coordination with the Academic Advisor. The concentrations emphasize different aspects of decision making within the major:
(1) Analytics, (2) Policy, (3) Management, and (4) Law. Each of the concentration areas draws upon the research and teaching strength of the Department of Social and Decision Sciences. Additionally, select courses from other areas in the University have been identified and approved as fulfilling elective requirements within the concentrations. More detail will be found in the concentration areas below.

The Policy and Management major provides an excellent combination of theoretical and practical skills for students who intend to seek managerial positions. Because of its strong analytic orientation, it is also an excellent major for those who intend to go on to professional school programs in law, business, or public policy. It is also an appropriate choice for students pursuing graduate degrees in economics, political science, or decision science. One such graduate option is the accelerated master's program offered by the H. J. Heinz III School of Public Policy and Management, in which a student earns both a B.S. in Policy and Management and a M.S. in Public Policy and Management in five years.

Prerequisites

All Policy and Management majors must complete mathematics and statistics prerequisites (see below), by the end of the sophomore year.

Mathematics Prerequisite		Units
21-111-21-112	Differential Calculus - Integral Calculus	10-20
or 21-120	Differential and Integral Calculus	

Statistics Prerequisite		Units
36-200	Reasoning with Data	9

Curriculum

Policy Core		Units
73-102	Principles of Microeconomics	9
88-221	Analytical Foundations of Public Policy	9
		18

Management Core		Units
88-150	Managing Decisions	9
88-223	Decision Analysis	12
88-418	Domestic Negotiation	9
or 88-419	International Negotiation	
		30

Empirical Core		Units
36-202	Statistics & Data Science Methods	9
88-251	Empirical Research Methods	9
88-252	Causal Inference in the Field	9
or 88-275	Bubbles: Data Science for Human Minds	
		27

Capstone		
88-451	Policy Analysis Senior Project	12
or 88-452	Policy Analysis Senior Project	

Concentration 36 units

Complete at least 36 units (a minimum of four courses) from the following concentrations of courses. Students are required to declare a concentration before their graduating semester, but are not required to choose a concentration when they initially declare (typically in the freshman or sophomore year). In fact, students are encouraged to take many of the core classes before making their concentration selection so that they can make a well-informed decision.

1. Analytics Concentration (minimum four total courses)		Units
Programming (one course)		9
88-300	Programming and Data Analysis for Social Scientists	9
Analytics/Empirical electives (select any two courses)		18
88-252	Causal Inference in the Field (if not taken in Empirical Core)	9
88-275	Bubbles: Data Science for Human Minds (if not taken in Empirical Core)	9
88-402	Modeling Complex Social Systems	9
21-257	Models and Methods for Optimization	9
36-303	Sampling, Survey and Society	9
36-315	Statistical Graphics and Visualization	9
70-374	Data Mining & Business Analytics	9
70-455	Modern Data Management	9
70-460	Mathematical Models for Consulting	9
80-321	Causation, Law, and Social Policy	9
90-834	Health Care Geographical Information Systems *	12
Analytics concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx)		9

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

2. Policy Concentration (minimum four total courses)		Units
Students select four courses; two of the four must be 88xxx)		
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics in the Wild	9
88-411	Rise of the Asian Economies	9
88-435	Decision Science and Policy	9
88-444	Public Policy and Regulation	9
36-303	Sampling, Survey and Society	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-421	Emerging Energy Policies	9
19-443	Climate Change Science and Adaptation	9
19-639	Policies of the Internet	12
73-328	Health Economics	12
79-342	Introduction to Science and Technology Studies	9
80-244	Environmental Ethics	9
80-324	Philosophy of Economics	9
80-341	Computers, Society and Ethics	9
84-310	International Political Economy	9
84-362	Diplomacy and Statecraft	9
84-389	Terrorism and Insurgency	9
90-798	Systems Thinking for Environmental Policy & Planning *	12

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

3. Management Concentration (minimum four total courses)		Units
Students select four courses; two of the four must be 88xxx)		
88-341	Team Dynamics and Leadership	9
88-406	Behavioral Economics in Organizations	9
88-411	Rise of the Asian Economies	9
88-418	Domestic Negotiation (if not taken in Management Core)	9
88-419	International Negotiation (if not taken in Management Core)	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-342	Managing Across Cultures	9
70-371	Operations Management	9
70-381	Marketing I	9
70-430	International Management	9
80-344	Management, Environment, and Ethics	9

4. Law Concentration (minimum four total courses)		Units
Students select four courses; one of the four must be 88xxx)		
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9
70-364	Business Law	9
70-365	International Trade and International Law	9
73-408	Law and Economics	9
80-321	Causation, Law, and Social Policy	9
80-447	Global Justice	9
84-313	International Organizations and Law	9
84-373	Emerging Technologies and the Law	9

NOTE: Some courses have additional prerequisites.

Policy and Management, B.S. Sample Curriculum

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
88-150 Managing Decisions	36-202 Statistics & Data Science Methods	88-251 Empirical Research Methods	88-221 Analytical Foundations of Public Policy
36-200 Reasoning with Data	73-102 Principles of Microeconomics	88-275 Bubbles: Data Science for Human Minds or 88-252 in spring	88-223 Decision Analysis
21-120 Differential and Integral Calculus (or 21-111, depending on placement)	Pick Two (Freshman Seminar, 76-101, 79-104)	88-418 Domestic Negotiation or 88-419	88-252 Causal Inference in the Field or 88-275 in fall
Pick One (Freshman Seminar, 76-101, 79-104)	Gen Ed or Elective	Gen Ed or Elective	Gen Ed or Elective
Gen Ed or Elective		Gen Ed or Elective	Gen Ed or Elective

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
Policy & Management concentration elective	Policy & Management concentration elective	Capstone (either 88-452 in fall or 88-451 in spring)	Capstone (either 88-451 in spring or 88-452 in fall)
Policy & Management concentration elective	Policy & Management concentration elective	Senior Honors Thesis or Elective	Senior Honors Thesis or Elective
Gen Ed	Elective	Complete remaining gen eds/electives	Complete remaining gen eds/electives
Elective	Elective	additional Policy & Management concentration electives	additional Policy & Management concentration electives
Elective	Elective		
Students may consider the CMU Washington Semester Program or study abroad in this semester	Students may consider the CMU Washington Semester Program or study abroad in this semester		

This is presented as a recommended plan for completing major requirements. Students may declare their major as early as the third week of the spring semester in the freshman year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early – and often – with the Policy and Management Academic Advisor.

Students are encouraged to consider the Washington Semester Program as part of their education. Suitable courses may be considered as fulfilling requirements of concentration electives in the major. Please discuss course selections with the Academic Advisor during the application phase to the program.

Additional Major

Students who elect Policy and Management as an additional major must fulfill all of the requirements of the Policy and Management major. For additional majors in Policy and Management, courses taken as concentration electives may not count toward the student's primary major or other program.

Students pursuing Behavioral Economics, Policy, and Organizations with an additional major in Policy and Management may only count 36-202 , 73-102, and 88-251 (and 88-252, if taken in Empirical Core) toward the completion of both majors.

Students pursuing Decision Science with an additional major in Policy and Management may only count 36-202 , 73-102, 88-223 , and 88-251 toward the completion of both majors.

Additional majors cannot count menu electives toward simultaneously fulfilling more than one major or minor. Students who are interested in an additional major in Policy and Management should see the Academic Advisor of the Policy and Management program.

The Minor in Decision Science

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Connie Angermeier and Lizzy Stoyle, *Academic Advisors*
Location: Porter Hall 208A and 208G
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The minor in Decision Science provides students with a selective survey of disciplinary perspectives. The courses present descriptive and normative approaches to judgment and decision making, as well as some application of theories and results to real-world problems. Students who elect Decision Science as a minor must complete the four core courses (below) and two electives from the elective set (below).

Students may double-count one course with another major/minor.

Curriculum — 54 units

Core Courses — 36 units

73-102	Principles of Microeconomics	9
88-120	Reason, Passion and Cognition	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9

Elective Courses — 18 units

Complete two courses from the following categories. At least one of the courses (9 units) must be a Social and Decision Sciences course (88-xxx).

1. Biological and Behavioral Aspects of Decision Making		Units
85-350	Psychology of Prejudice	9
85-352	Evolutionary Psychology	9
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-442	Health Psychology	9
85-444	Relationships	9
85-446	Psychology of Gender	9
88-230	Human Intelligence and Human Stupidity	9
88-342	The Neuroscience of Decision Making	9
88-355	Social Brains: Neural Bases of Social Perception and Cognition	9
88-360	Behavioral Economics	9
88-365	Behavioral Economics and Public Policy	9
88-380	Dynamic Decisions	9

2. Managerial and Organizational Aspects of Decision Making		Units
70-311	Organizational Behavior	9
70-381	Marketing I	9
70-460	Mathematical Models for Consulting	9
88-150	Managing Decisions	9
88-221	Analytical Foundations of Public Policy	9
88-406	Behavioral Economics in Organizations	9
88-418	Domestic Negotiation	9
88-419	International Negotiation	9
88-444	Public Policy and Regulation	9
88-451	Policy Analysis Senior Project	12
or 88-452	Policy Analysis Senior Project	

3. Philosophical and Ethical Perspectives on Decision Making		Units
70-332	Business, Society and Ethics	9
80-208	Critical Thinking	9
80-221	Philosophy of Social Science	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-249	AI, Society, and Humanity	9
80-271	Philosophy and Psychology	9
80-305	Choices, Decisions, and Games	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9
88-275	Bubbles: Data Science for Human Minds	9
88-409	Behavioral Economics Perspectives on Ethical Issues	9

4. Economic and Statistical Methods for Decision Science		Units
70-374	Data Mining & Business Analytics	9
70-455	Modern Data Management	9
70-460	Mathematical Models for Consulting	9
73-265	Economics and Data Science	9
73-347	Game Theory for Economists	9
80-405	Game Theory	9
88-255	Strategic Decision Making: Cooperation and Competition in Social Interactions	9
88-300	Programming and Data Analysis for Social Scientists	9
88-360	Behavioral Economics	9
88-367	Behavioral Economics in the Wild	9

5. Decision Science and Public Policy		Units
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-369	Decision Science for International Relations	9
88-221	Analytical Foundations of Public Policy	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-405	Risk Perception and Communication	9
88-444	Public Policy and Regulation	9
88-451	Policy Analysis Senior Project	12
or 88-452	Policy Analysis Senior Project	

6. Research Methods for Decision Science		Units
36-303	Sampling, Survey and Society	9
70-460	Mathematical Models for Consulting	9
85-310	Research Methods in Cognitive Psychology	9
88-252	Causal Inference in the Field	9
88-402	Modeling Complex Social Systems	9
88-435	Decision Science and Policy	9

Note: Some courses have additional prerequisites

The Minor in Policy and Management

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Regardless of major, many Carnegie Mellon graduates will face analytical and managerial challenges and responsibilities in their professional lives. Whether these are in their area of expertise or in more general settings, these roles will to some degree require assumption of the responsibility for directing the work of others. The Policy and Management minor is intended for students who expect to need these management concepts and skills.

At most, one course may be double-counted with another major or minor.

Curriculum — 54 units

Required Courses — 36 units

73-102	Principles of Microeconomics	9
88-150	Managing Decisions	9
88-221	Analytical Foundations of Public Policy	9
88-223	Decision Analysis	12

18 unitsElectives

Complete two courses (at least 18 units) from any of the concentrations (Analytics, Policy, Management, and Law). **Courses do not need to be taken from the same concentration.** The courses are listed by their concentration categories as a way to guide students. At least one of the courses (9 units) must be a Social and Decision Sciences course (88-xxx).

Analytics Concentration		
88-252	Causal Inference in the Field	9
88-275	Bubbles: Data Science for Human Minds	9
88-300	Programming and Data Analysis for Social Scientists	9
88-402	Modeling Complex Social Systems	9
21-257	Models and Methods for Optimization	9
36-303	Sampling, Survey and Society	9
36-315	Statistical Graphics and Visualization	9
70-374	Data Mining & Business Analytics	9
70-455	Modern Data Management	9
70-460	Mathematical Models for Consulting	9
80-321	Causation, Law, and Social Policy	9
90-834	Health Care Geographical Information Systems *	12

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

Policy Concentration		Units
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics in the Wild	9
88-411	Rise of the Asian Economies	9
88-435	Decision Science and Policy	9
88-444	Public Policy and Regulation	9
36-303	Sampling, Survey and Society	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-421	Emerging Energy Policies	9
19-443	Climate Change Science and Adaptation	9
19-639	Policies of the Internet	12
73-328	Health Economics	12
79-342	Introduction to Science and Technology Studies	9
80-244	Environmental Ethics	9
80-324	Philosophy of Economics	9
80-341	Computers, Society and Ethics	9
84-310	International Political Economy	9
84-362	Diplomacy and Statecraft	9
84-389	Terrorism and Insurgency	9
90-798	Systems Thinking for Environmental Policy & Planning *	12

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

Management Concentration		Units
88-341	Team Dynamics and Leadership	9
88-406	Behavioral Economics in Organizations	9
88-411	Rise of the Asian Economies	9
88-418	Domestic Negotiation	9
88-419	International Negotiation	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-342	Managing Across Cultures	9
70-371	Operations Management	9
70-381	Marketing I	9

70-430	International Management	9
80-344	Management, Environment, and Ethics	9

Law Concentration		Units
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9
70-364	Business Law	9
70-365	International Trade and International Law	9
73-408	Law and Economics	9
80-321	Causation, Law, and Social Policy	9
80-447	Global Justice	9
84-313	International Organizations and Law	9
84-373	Emerging Technologies and the Law	9

Faculty

LINDA BABCOCK, James Mellon Walton Professor of Economics and Department Head – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 1988–

SAURABH BHARGAVA, Associate Professor of Economics – Ph.D., University of California, Berkeley; Carnegie Mellon, 2012–

STEPHEN BROOMELL, Associate Professor of Quantitative Psychology – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2011–

GRETCHEN CHAPMAN , Professor of Psychology – Ph.D., University of Pennsylvania ; Carnegie Mellon, 2017–

SIMON DEDEO, Assistant Professor of Social and Decision Sciences – Ph.D., Princeton University; Carnegie Mellon, 2017–

JULIE DOWNS, Associate Professor of Psychology – Ph.D., Princeton University; Carnegie Mellon, 1995–

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CHRISTINA FONG, Senior Research Scientist – Ph.D., University of Massachusetts, Amherst; Carnegie Mellon, 2001–

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CLEOTILDE GONZALEZ, Research Professor of Information and Decision Sciences – Ph.D., Texas Tech University; Carnegie Mellon, 2000–

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ALEX IMAS, Associate Professor of Economics – Ph.D., University of California, San Diego; Carnegie Mellon, 2014–

MARK S. KAMLET, University Professor of Economics and Public Policy and Provost Emeritus – Ph.D., University of California, Berkeley; Carnegie Mellon, 1978–

GEORGE F. LOEWENSTEIN, Herbert A. Simon University Professor of Economics and Psychology – Ph.D., Yale University; Carnegie Mellon, 1990–

JOHN H. MILLER, Professor of Economics and Social Science – Ph.D., The University of Michigan; Carnegie Mellon, 1989–

DANEIL OPPENHEIMER, Professor of Psychology – Ph.D., Stanford University; Carnegie Mellon, 2017–

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ROSALIND CHOW, Associate Professor of Organizational Behavior and Theory – Ph.D., Stanford University; Carnegie Mellon, 2008–

TAYA COHEN, Associate Professor of Organizational Behavior and Theory and Carnegie Bosch Junior Faculty Chair – Ph.D., University of North Carolina at Chapel Hill; Carnegie Mellon, 2008–

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JOSEPH B. KADANE, Leonard J. Savage University Professor of Statistics and Social Science – Ph.D., Stanford University; Carnegie Mellon, 1969–

SARAH B. KIESLER, Professor – Ph.D., The Ohio State University; Carnegie Mellon, 1979–

DAVID M. KRACKHARDT, Professor of Organizations and Public Policy – Ph.D., University of California, Irvine; Carnegie Mellon, 1991–

ROBERT E. KRAUT, Hebert A. Simon Professor of Human Computer Interaction – Ph.D., Yale University; Carnegie Mellon, 1993–

CHRIS OLIVOLA, Assistant Professor of Marketing – Ph.D., Princeton University; Carnegie Mellon, 2013–

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Emeriti Faculty

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LINDA MOYA, Assistant Teaching Professor in Psychology – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016–

MARK PATTERSON, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–

Department of Social and Decision Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

88-120 Reason, Passion and Cognition
Fall: 9 units
This course will introduce students to major concepts and theories in the social and decision sciences, focusing in particular on how cognition and emotion shape judgment and choice. We will address such questions as: In what ways do emotions influence judgments and choices? What are some common mistakes in judgment and decision making? Can information shape our choices even if we do not consciously recognize the information? Throughout the course, the emphasis will be on understanding: (1) basic theories and research findings of decision science and psychology, and (2) the relevance of research findings to everyday life.

88-125 Freshman Seminar: Forecasting Uncertainty
Intermittent: 9 units
Whenever you make a plan, you have to think about the future. Sometimes you know a lot, sometimes you know very little, and sometimes you know very little but think you know a lot. Amazingly, the same types of errors that you make every day are made by policymakers planning multi-billion dollar options. In this course, we will explore these errors and methods for reducing them. Examples will be drawn from many hot topics including climate change, health care, and government regulation.

88-126 Freshman Seminar: Modeling Complex Systems
Intermittent: 9 units
Most of the major issues confronting humanity—-such as climate change, financial collapse, ecosystem survival, terrorism, and disease epidemics —-are the result of complex systems where the interactions of the pieces of the system create a whole that is rather different than any of its parts. Unfortunately, traditional scientific methods that focus on reducing systems to their parts and then analyzing each part provide little insight into such systems. This seminar explores the behavior of complex systems as well as how to model and understand them using both traditional tools and computer-based approaches.

88-150 Managing Decisions
Fall: 9 units
This course will introduce the major concepts behind "good" decision making. Future employers will pay handsomely for decisions that are well thought out, defendable, and understandable. Being able to organize decision processes in a way that will achieve these goals is not trivial. Biases brought on by emotions and heuristic shortcuts often jeopardize the quality of a decision. Multiple levels of "good" decision making will be investigated ranging from life choices to national climate policies. Techniques that account for uncertainty and time preferences will be introduced.

88-198 Research Training: Social and Decision Sciences
Fall and Spring
This course is part of a set of 100-level courses offered by H&SS departments as independent studies for second-semester freshmen, and first- or second-semester sophomores, in the College. In general, these courses are designed to give students some real research experience through work on a faculty project or lab in ways that might stimulate and nurture subsequent interest in research participation. Faculty and students devise a personal and regular-ized meeting and task schedule. Each Research Training course is worth 9 units, which generally means a minimum for students of about 9 work-hours per week. These courses are offered only as electives; i.e., they cannot be applied toward a college or major requirement, although the units do count toward graduation as elective units. Additional details (including a roster and descriptions of Research Training Courses available in any given semester) are available in the H&SS Academic Advisory Center. Prerequisites/ restrictions: for H&SS students only; only for second-semester freshmen, or first- or second-semester sophomores; minimum cumulative QPA of 3.0 (at the time of registration) required for approved entry; additional prerequisites (e.g., language proficiency) may arise out of the particular demands of the research project in question.

88-200 SDS Colloquium
Spring: 3 units
The SDS Colloquium is an opportunity for students to gather and discuss topics related to the various opportunities available both during the undergraduate career and after graduation. Students will explore various areas such as academic planning, personal and professional values, and professional communication/communication skills. Co-curricular experiences such as; study abroad, research, internship/career planning and goal setting, and graduate school are among the topics to be presented. Students will have the opportunity to talk with SDS advisors, faculty, and alumni as well as with other professionals from around the University. Sophomore or junior standing is required.

88-221 Analytical Foundations of Public Policy
Spring: 9 units
In this course, students will achieve an analytical understanding of some of the most pressing policy challenges of our day. The focus of the course lies in the interaction between markets and government. The course will first introduce analytical foundations of how markets, voting and governments work, and important shortcomings of each. The course will briefly touch on a comparative cross-national perspective on the balance between markets and government pursued in different countries. The second part of the course focuses on a substantive understanding of current policy issues, including health care, inequality, economic conditions of the politically pivotal middle class, resource constraints, globalization, technological change, and the role of all of these topics in political debates, and voter demands. A pre-requisite for this course is 73-102 Principles of Microeconomics.
Prerequisites: 73-100 or 73-102 or 88-220

88-223 Decision Analysis
Spring: 12 units
This course offers practical guidance about how to make better decisions and teaches students how to use modeling to do decision analysis. We analyze decisions involving uncertainty, risk, and time delay. In addition to methods of decision analysis, the course will also emphasize sensitivity analysis and communication of recommendations.
Prerequisites: 36-200 or 36-225 or 36-247 or 36-217 or 36-200 or 70-207 or 36-211 or 36-201 or 36-207

88-230 Human Intelligence and Human Stupidity
Fall: 9 units
By some standards, humans are an incredibly intelligent species. We have set foot on the moon, split the atom, and produced extraordinary works of art and literature (including the complete works of Shakespeare, which, despite theoretical accounts to the contrary, no amount of monkeys on typewriters has ever been able to duplicate). And yet. we are also the species that has brought about the Darwin Awards, spent $125 million sending a probe to Mars which was unable to function because engineers failed to convert inches to centimeters, and produced cringe-worthy works of art and literature (including the 1964 movie "Santa Claus Conquers the Martians" which no amount of monkeys on typewriters would ever want to duplicate.). What is intelligence and how does it vary across individuals and over our lifespans? What are we good at, and what are we bad at, and why? Are there things that that make us dumber? Are there things we can do to make ourselves smarter? How should what we know about the range of human intellectual abilities guide policy, education, law, medicine, and business; what implications does this have regarding the tasks/jobs that humans should be doing and the tasks/jobs that machines ought to do? Using cutting edge research from psychology and decision science, this course will explore the strange contradiction that defines the human experience: How are we simultaneously so smart and so dumb?

88-251 Empirical Research Methods
Fall: 9 units
This course teaches students how to evaluate and conduct original research regarding human behavior, whether it be in economic, social, or political settings. The course gives students practical experience in many of the most commonly used research techniques, including surveys, experiments, and quasi-experimental analysis. Although the course focuses primarily on the relationship between formulating research questions and implementing the appropriate methods to answer them, students can expect regularly to apply the statistical techniques learned in the course prerequisites, including regression.
Prerequisites: 36-200 or 36-247 or 36-207 or 36-201

88-252 Causal Inference in the Field
Spring: 9 units
Causal questions are pervasive in the social and behavioral sciences, and empirical researchers often use regression analysis as a tool for tackling such questions. This course focuses on the scientific problem of analyzing causal hypotheses in real-world settings, not on the mathematical details of regression. After clearly distinguishing prediction from causation, we discuss how to represent causal hypotheses and how to use regressions to analyze both predictive and causal hypotheses. Using in-class data exercises throughout, we will examine how to move from an interesting but somewhat vague question about the world (e.g., do police discriminate based on race and gender, do NFL athletes choke under high pressure, does parenthood improve happiness) to a clear statistical model that, when estimated, meaningfully addresses the question asked. The course emphasizes causal analysis as the main research goal and multivariate linear regression as the main statistical tool. After mastering basic techniques, we will introduce students to more advanced econometric approaches such as panel regressions and instrumental variables to deal with trickier settings in which causal inference is more challenging (e.g., do more guns lead to more violence?). In keeping with the hands-on philosophy of the course, a central focus of the semester will be a group research paper/presentation where students will have the opportunity to formulate and empirically test a research question of their choosing. Students will learn how to find, clean, and analyze a new dataset, and then concisely communicate their findings in the form of a scientific paper (and accompanying presentation). The research project makes this course excellent preparation for any student who hopes to ultimately write an undergraduate thesis.
Prerequisites: 36-201 or 36-207 or 70-207 or 36-200

88-255 Strategic Decision Making: Cooperation and Competition in Social Interactions
Fall: 9 units
When should a person cooperate and when should a person be selfish in an ongoing social interaction? How can a business establish strategic partnerships when it comes to creating a pie and at the same time battle with competitors when it comes to dividing up the pie? Strategic decision making requires a framework to think through the implications of cooperation and of competition. This course gives you a systematic approach to understanding how people, firms, or countries interact with one another to achieve their own goals. In this course students will learn to apply behavioral strategic principles to analyze strategic situations arising in business, politics, international relations, domestic policy, organizational management, and everyday life. Our focus will be on practical applicability rather than abstract theorizing. Readings will focus on real-life stories accompanied by a full analysis of the principles involved. The class will be organized as a seminar, centered around discussion, not lecture. Students will also be placed in the role of strategist in occasional simulations in class.

88-257 Experimental Economics
Intermittent: 9 units
This course will focus on the experimental literature studying decision-making and strategic interactions. We will explore both seminal and ongoing experimental work on risk, time and social preferences, as well as how these preferences are affected by emotions and other visceral factors. The course will focus on laboratory experiments. The last section of the class will focus on the use of experiments to test economic theory (both standard and behavioral). The class is meant to be interactive, and students will have many opportunities to critically discuss existing experimental research, as well as to present their own research ideas.

88-275 Bubbles: Data Science for Human Minds
Fall: 9 units
Open discussions turn into echo chambers; optimistic traders pump good money into bad stocks; we fail to see, or sympathize, beyond the limits our culture, upbringing, or education prescribe. These bubbles — information bubbles, market bubbles, social bubbles — drive us to ask some of the most basic questions in the social sciences: Why do we believe the things we do? Where do our ideas come from, and how can we measure the consequences of their conjecture, spread, and evolution? How can we design systems to make us better thinkers? In this introduction to the "big data" study of human behavior, we'll learn some key concepts and simple computational tools for studying how people gain and share information, with a focus on what they say and write. And we'll apply these tools to social behaviors from the writing of Harry Potter fan fiction to online trolling, to science, markets, and liberal democracy itself. The class will include conceptual, computational, and data-driven investigations; students in social science, humanities, engineering and the sciences are equally welcome. At the end of this course, students will be able to build models for how people think and talk to each other, to see how thinking and talking work in both the past and present, and to imagine, and even design, systems that might help us think, and talk, together more effectively in the future. Pre-requisites: willingness and initiative to work with real-world data.

88-281 Topics in Law: 1st Amendment
Fall: 9 units
In their firm desire to perfect the new Constitution, which defined and limited the powers and roles of their new government, the founding fathers insisted on explicit statements that would protect the rights of the new nation's citizens. Indeed, the protection of these essential rights in many ways drove and defined their successful rebellion from Britain. This impulse resulted in ten amendments to the Constitution, which we have come to know as the Bill of Rights. The very first (and arguably considered at the time as the most essential) of these was the First Amendment, which we sometimes call the "free speech" amendment to the Constitution. This amendment guarantees every U.S. citizen five freedoms: freedom of religion, speech, press, peaceable assembly, and the freedom to petition the government for redress of grievances. This course examines the historical and philosophical roots of this key constitutional amendment, how it has been fleshed out and defined over time through case law, and the bases of some more recent critics of this amendments and current interpretations.

88-284 Topics of Law: The Bill of Rights
Spring: 9 units
This course examines the history and place of the Bill of Rights in our nation's constitutional framework. It focuses on the historical origins of the U.S. Constitution, of each of the first ten amendments to the Constitution (that we refer to as the "Bill of Rights"), how the meanings and interpretations of these have evolved over time, and what they mean to us today. Each article of the Bill of Rights will be examined in terms of its original intentions, and then through cases that have challenged and been interpreted through the Bill's articles.

88-300 Programming and Data Analysis for Social Scientists
Spring: 9 units
This course provides a first introduction to the statistical programming language R, and is designed primarily with social science majors in mind. Students will develop skills in all facets of the data analysis pipeline, from installing and loading packages and reading in files to data cleaning, munging, visualization and modeling. We welcome students who will be coding for the first time!
Prerequisites: 36-200 or 36-201

88-302 Behavioral Decision Making
Fall and Spring: 9 units
Behavioral decision making is the study of how people make decisions, in terms that can eventually help them to make better decisions. It draws together research from psychology, economics, political science, and management, among other fields. It has applications that range from managing potentially hazardous technologies, to involving patients more fully in the choice of medical procedures, to the design of computer-interactive systems. The course covers behavioral theories of probabilistic inference, intuitive prediction, preference, and decision making. Topics include heuristics and biases in inference and prediction, risk perceptions and attitudes, strategies for combining information from different sources and dealing with conflicting objectives, and the roles of group and emotional processes in decision making. The course emphasizes the mutually reinforcing relationship between theory and application.
Prerequisites: (36-225 or 36-201 or 36-211 or 36-207 or 36-200 or 70-207 or 36-217 or 36-220 or 36-247) and 88-120

88-341 Team Dynamics and Leadership
Fall: 9 units
Much of the work in groups and organizations consists of communication. You communicate to get information that will be the basis of decisions, to provide a vision for the people who work for and with you, to coordinate activity, and to sell yourself and your work. The goal of this course is to identify sources of communication problems within an organization and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. This course is not a practicum in public speaking or writing, although you will get some experience writing, speaking and managing impressions. Rather the intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly do when you return to work. Readings come from both the research and the managerial literatures. Among the topics considered are managerial communication, persuasion and conformity, self presentation and person perception, social networks. Cases and group projects give you an opportunity to apply what you've learned.
Prerequisites: 36-207 or 36-200 or 36-217 or 36-225 or 36-220 or 36-201 or 36-247 or 70-207

88-342 The Neuroscience of Decision Making
Intermittent: 9 units
Because we are human, feelings provide the basis for reason and rational decision-making. Consider for example, that brain-damaged patients left devoid of emotion struggle to make the most elementary decisions: while they are able layout the pros and cons of a decision, but they are unable to make the final choice. This course will discuss seminal discoveries in affective neuroscience underlying decision-making.
Prerequisites: 88-120 or 85-211

88-355 Social Brains: Neural Bases of Social Perception and Cognition
Intermittent: 9 units
By some accounts, the large expansion of the human brain evolved due to the complex demands of dealing with social others?competing or cooperating with them, deceiving or empathizing with them, understanding or misjudging them. This discussion-based seminar surveys the emerging field of social cognitive neuroscience and its multi-level approach to understanding the brain in its social context. We will review current theories and methods guiding the field and recent research examining the neural bases of social processes, including: theory of mind, empathy, emotion, morality, among others. We will also discuss broader questions that apply to the specific topics that the course covers, including: What are appropriate levels of description for the target phenomena? How can different disciplines in neuroscience and the social sciences contribute to social neuroscience research? What can we learn from animals? behavior about human social cognition? Do neural systems exist that are specialized for social cognition, or do the systems that participate in social cognition have more general cognitive functions?
Prerequisites: 85-355 or 88-251 or 85-310 or 85-340

88-360 Behavioral Economics
Spring: 9 units
This course introduces students to behavioral economics, an emerging subfield of economics that incorporates insights from psychology and other social sciences into economics. We will examine evidence on how human behavior systematically departs from the standard assumptions of economics, and then investigate attempts by behavioral economists to improve economic analyses.
Prerequisites: (21-112 or 21-120) and (88-220 or 73-102 or 73-100)

88-365 Behavioral Economics and Public Policy
Fall: 9 units
Economics has up to now been the social science that has been most broadly and deeply involved in public policy. With its rational choice perspective, the economic perspective has tended to favor certain types of policies namely those that enhance the efficiency of market mechanisms and lower the cost of information. In this course we will spend the first several classes reviewing the assumptions, implications for public policy and limitations of the rational choice perspective. The remainder of the course will then be devoted to examining different public policy issues, including saving, health care, crime and drug abuse, through the competing lenses of traditional and behavioral economics.
Prerequisites: 73-102 or 88-220 or 73-100

88-366 Behavioral Economics of Poverty and Development
Intermittent: 9 units
This course will introduce students to the study of economic development and poverty alleviation, with a special focus on recent insights from the intersection of psychology and economics. We will primarily focus on the health, microfinance, agriculture, and education sectors in developing countries. The course will have a methodological component largely centered on using experiments to evaluate interventions and policies that apply to households, small firms, and farms. While we will cover standard economic approaches, we will give extra attention to how a behavioral lens can help in both understanding development issues (e.g. barriers to household risk management) and in designing effective interventions (e.g. the timing of fertilizer sales).
Prerequisites: (73-102 or 88-220 or 73-100) and 36-202

88-367 Behavioral Economics in the Wild
Spring: 9 units
Behavioral Economics is a sub-field of economics that, relying on insights from psychology and decision-making, aspires to describe actual behavior with greater empirical accuracy and psychological realism than that implied by the standard neoclassical model. In this course, we will investigate the success of this approach in explaining ostensible anomalies in the "wild" such as under-savings for retirement, over-consumption of unhealthy food, extreme aversion to losses among investors, workers, and home-owners, the over-confidence of corporate CEOs and NFL general managers, and the influence of emotions on domestic violence, stock market activity, and risk-taking. We will first document and review the underlying theory for three conceptual departures from the standard model -non-standard preferences (e.g., present-bias, reference dependence), non-standard beliefs (e.g., overconfidence, gambler''s fallacy), and non-standard decision-making (e.g., heuristics, emotions, framing effects)-and then quickly move to assess the evidence for these claims in field settings. We will additionally explore how markets respond to behavioral biases, and discuss recent research in behavioral policy with an emphasis on policies aimed at increasing savings, improving food choice, and heightening program take-up and compliance. The course will be paper-centric and we will review a variety of popular empirical methods from field experiments to quasi-experimental approaches (e.g., estimation through regression-based panel analyses, difference-in-differences, and instrumental variables). Student evaluation will be based on performance on problem sets, an exam, as well as a short class presentation of an empirical paper of choice.
Prerequisite: 36-202

88-372 Social and Emotional Brain
Intermittent: 9 units
This course provides an introductory survey of the methods and findings in social and affective neuroscience. Half the course is lecture style and covers the basics of neuroanatomy, neurochemistry, and neuroendocrine systems, as well as a survey of relevant neuroscience methods (neuroimaging, neuropsychological, psychophysiological, transcranial magnetic stimulation, etc.). The other half of the course is more like a seminar, where each week we will discuss a couple seminal empirical papers from the scientific literature. Topics include interpersonal relationships, prosocial behavior, aggression, prejudice, emotion regulation, stress, etc.
Prerequisite: 85-211

88-380 Dynamic Decisions
Intermittent: 9 units
Decisions we make every day may range from simple and routine to novel and highly complex. For example, decisions while driving (judging the distance to the front car, the speed, the directions, and making choices accordingly) seem effortless and routine after some experience, while triaging patients in an emergency room under scarce resources may be quite overwhelming for everyone. Both types of decisions however, have something in common: they are made in the presence of change and in the absence of explicit information of probabilities, possible alternatives, and outcomes. Our decisions in such situations are the result from the interaction between the dynamic environmental demands and our cognitive processes. In this course you will learn how decisions are made in different dynamic situations and how our cognitive processes (e.g., attention, experience, risk tendencies, and other factors) influence the way those decisions are made. Students will be introduced to different aspects of decision processes by analyzing the sources of error in complex problems, such as cases of accidents and disasters (natural or man-made), in multiple disciplines (e.g., aviation, management, military strategy, and others). The course will also use simulation-based representations of dynamic decision making situations (e.g., microworlds) to illustrate relevant cognitive processes needed for learning, adaptation and choice. Finally, students will learn how to construct mathematical/computational models of dynamic systems, be able to interpret simulation results and to explore scenarios regarding effects of variables in the models and the predictions that the models can make.
Prerequisites: (88-120 or 88-230 or 85-211 or 85-213 or 85-241 or 85-102) and (36-200 or 36-201)

88-388 Psychological Models of Decision Making
Intermittent: 9 units
This course provides an introduction to several techniques and theories for modeling psychological processes and decision making. The topics covered include: signal detection theory, individual decision modeling, and multidimensional scaling. The course will include an introduction to the theory behind the models as well as "hands on" computational applications of the models with data. The topics covered in this course can be used in a variety of applied settings-ranging from medical and public policy to marketing and psychological research-to produce simplified representations of seemingly complex phenomena.
Prerequisites: (36-200 or 36-201) and (21-120 or 21-112)

88-398 Independent Study
Fall and Spring
Students conduct independent academic study under the supervision of a Social & Decision Sciences faculty member. Students who wish to engage in an independent study should seek out a faculty member whose interests are appropriate to the topic. Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Coordinator of Student Programs in Porter 208A. Prerequisite: Permission of a faculty sponsor.

88-399 Undergraduate Research
Fall and Spring
Students conduct research under the supervision of a Social & Decision Sciences faculty member. Students who wish to engage in research should seek out a faculty member whose interests are appropriate to the research. Prerequisite: Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Coordinator of Student Programs in Porter 208A. Permission of a faculty sponsor.

88-402 Modeling Complex Social Systems
9 units
Many of the biggest challenges facing modern societies—-maintaining global political and financial stability, protecting against terrorist acts, cooperating to solve collective problems such as climate change or corruption—-are complex. They are not simply complicated; they arise as interacting agents create various feedbacks that result in, often unintentional, emergent phenomena. Confronting these challenges requires an understanding of the properties of complex systems. In this course, we will provide an overview of complex systems theory and concepts. You will learn the fundamental properties of complex adaptive systems and how to apply these insights to a variety of key social science problems. We will introduce and analyze computational and mathematical models, as well as qualitative models, so you should have some familiarity with basic probability and algebra. We will explore topics such as inequality, networks, information spread, community formation, the evolution of cooperation, and the stabilization of financial markets. We will cross traditional disciplinary boundaries and venture into economics, political science, sociology, finance, cognitive science, computer science, physics, statistics, and mathematics as needed. Students will be expected to think critically about how to apply modeling insights to the real world, taking account of the social, political, and economic implications of proposed policies. They will express their ideas in class discussions, presentations, and written reports. The course will culminate with students engaging in a research project to model a complex social system of their choice.
Prerequisites: 36-207 or 36-201 or 70-207 or 36-247 or 36-225 or 36-217 or 36-220

88-405 Risk Perception and Communication
9 units
Throughout their lives, people make decisions about risks that may potentially affect their health, safety, finances, use of technology, and effects on the environment. This course will review the risk perception and communication literature, focusing on theoretical and methodological issues as well as practical implications for educators, public health officials, engineers, economists, and other experts who aim to teach people about risks. We will discuss how to design surveys to increase our understanding of the problems people face when making decisions about specific risks, and how to design communication materials that help people to improve their decisions. We will highlight examples and applications taken from multiple disciplines, including health psychology, adolescent decision making, environmental science, and engineering.
Prerequisites: 36-247 or 70-207 or 36-225 or 36-220 or 36-217 or 36-207 or 36-201

88-406 Behavioral Economics in Organizations
Fall: 9 units
Non-profit organizations and businesses are increasingly incorporating insights from behavioral economics and other behavioral sciences into their strategies. This course provides an overview of psychological and economic factors that affect the choices and behavior of individuals within organizations. The course will review empirical research on applications of behavioral insights to a wide range of organizational areas including product pricing, marketing, designing incentives schemes, motivating employees, fundraising, and behavior change. In-class exercises and group projects will supplement the lectures and provide students with hands-on experience in designing solutions to organizations challenges based on behavioral insights. The course emphasizes experimentation as a primary tool for informing organizations decision-making and accurately measuring the effectiveness of behavioral interventions.
Prerequisites: 88-220 or 73-100 or 73-102

88-409 Behavioral Economics Perspectives on Ethical Issues
Intermittent: 9 units
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88-411 Rise of the Asian Economies
Intermittent: 9 units
For most of the past quarter century, no region of the world has been more economically dynamic than Asia. This course is designed to provide students with the essential knowledge necessary to evaluate opportunities and risks in Asia. The course will use analytical tools drawn from economics and finance, business cases, and guest lectures to focus on the key strengths that sustained economic growth in East Asia for decades, the weaknesses that undermined that growth in the late 1990s, and what lies ahead. The course will also examine Indian economic growth since the early 1980s, and compare India's experience with that of the East Asian economies. A special focus will be placed on recent developments in India and China and the prospects for continued growth in those countries over the next decade.
Prerequisites: 88-220 or 73-150 or 73-102 or 73-100

88-415 Global Competitiveness: Firms Nations, and Technological Change
Fall: 9 units
Global Competitiveness introduces students to the fundamental principles surrounding global competitiveness and technological change in the 21st century. The course is broken into three sections. The first section introduces students to competing economic, sociological, and political science theories on the structures supporting technological change. The second section presents the contemporary literature on technological change. The concluding section leverages lessons from the preceding two sections to evaluate national innovation systems, and the factors that lead to national comparative advantage. Students should leave the class able to reflect competently on what the existing literature tells us about the factors influencing global technology competitiveness, and on how modern changes in the structures supporting innovation as well as technology itself may be changing the rules of the game for firms and for nations. The course is open to undergraduate juniors and seniors.

88-418 Domestic Negotiation
Fall: 9 units
Negotiation is the art and science of securing an agreement between two or more interdependent parties. Decision-makers use negotiation to reach agreements with co-workers, bosses, clients, subordinates, firms, family and friends. Hence, the ability to negotiate effectively is a critical skill. In this course, students will develop a systematic and insightful approach to negotiation. Students will learn to analyze the features of the negotiation environment, develop an understanding of effective negotiation strategies and tactics, and identify the barriers and the psychological factors that may prevent decision-makers from reaching wise agreements. Considerable emphasis will be placed on negotiation exercises and role-playing. In-class discussions and lectures will supplement the exercises. This course will focus on negotiations in a wide variety of context: public policy negotiations, business negotiations, salary negotiations, and inter-personal negotiations.

88-419 International Negotiation
Fall: 9 units
Negotiation is a process in which two or more parties undertake a process to resolve conflicting interests. Decision makers use negotiation in a variety of circumstances to reach agreements among countries, among employers and employees, among firms, and among family and friends. International section: The objective of this course is to understand the process of negotiations and how the structure of the negotiation environment affects the outcomes achieved. Students will learn to analyze the features of the negotiation environment, develop an understanding of effective negotiation strategies, and identify the barriers to reaching wise agreements. This course will focus on negotiations in primarily international contexts.

88-435 Decision Science and Policy
Spring: 9 units
Research in the social sciences has extensively investigated how decision makers behave when they encounter many different and difficult decision scenarios. This course serves as an introduction to how relevant research from decision and social sciences can be applied to policy questions encountered by governments (intelligence and policy analysts) and private industry (business strategists and information officers). Topics of operations research, game theory, signal detection theory, and decision theory (heuristics and biases) will be discussed with respect to the application of these theories to improve the performance of individuals and groups within these organizations.

88-444 Public Policy and Regulation
Intermittent: 9 units
Regulations are a significant policy tool of government. How society and the economy will react to new regulations can be hard to predict. Unintended side effects sometimes occur resulting in costs exceeding estimates and/or benefits never being realized. This course will review the basics of regulatory policy and using historical examples, will explore the reasons why past regulations have succeeded and failed. The second half of the course will involve 2-3 detailed case studies. Quantitative methods will be used to evaluate several pending regulations for real-world clients from both government and industry perspectives.

88-451 Policy Analysis Senior Project
Spring: 12 units
Students in this course apply the research and analytical methods learned in their other courses to a real-world problem. Students decide how to structure the problem, divide into teams responsible for its different parts, identify and analyze relevant literature, collect data, synthesize their results, and present their conclusions in oral and written form to a review panel of individuals concerned with the problem. Faculty members help them along the way. Performance is based on students' contribution to the process and substance of the class, as observed by the faculty and by their fellow students. One or two such projects is offered every term. A complete list of previous topics is available from the department. Course is open only to seniors in SDS.

88-452 Policy Analysis Senior Project
Fall: 12 units
Students in this course apply the research and analytical methods learned in their other courses to a real-world problem. Students decide how to structure the problem, divide into teams responsible for its different parts, identify and analyze relevant literature, collect data, synthesize their results, and present their conclusions in oral and written form to a review panel of individuals concerned with the problem. Faculty members help them along the way. Performance is based on students' contribution to the process and substance of the class, as observed by the faculty and by their fellow students. One or two such projects is offered every term. A complete list of previous topics is available from the department. Course is open only to seniors in SDS.

88-453 Behavioral Economics, Policy, and Organizations Capstone
Spring: 9 units
The Capstone in Behavioral Economics, Policy, and Organizations will work to apply the theories, concepts, and statistical techniques mastered in prior courses to an applied project. Students will work closely both in teams and individually with the instructor on a project that will address a problem posed by an organization or government that behavioral economics can help to solve. Students will work to structure the problem, design an intervention or study, collect and analyze the data, and make recommendations for implementation. Students will manage the project and drive interactions with the client organization.

88-499 Advanced Undergraduate Research
Fall and Spring
Students conduct research at an advanced level under the supervision of a Social & Decision Sciences faculty member. Students who wish to engage in advanced research should seek out a faculty member whose interests are appropriate to the research. Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Coordinator of Student Programs in Porter 208A. Prerequisite: Permission of a faculty sponsor.

88-505 Undergraduate Internship
All Semesters
An internship is an approved and monitored work experience than can be related to an academic field of study through active reflection and specific learning goals. Students must work at least 10 hours per week for the semester at the internship. Additionally, students will also keep in regular contact with a faculty member in Social and Decision Sciences, who will assign and evaluate academic work. Internships are available for 1-9 units, depending on the type and amount of academic work produced. Students are responsible for finding their own internships and faculty sponsors, although assistance is available in the department.

Department of Statistics and Data Science

Christopher R. Genovese, Department Head

Rebecca Nugent, Director of Undergraduate Studies

Samantha Nielsen, Lead Academic Advisor

Glenn Clune, Academic Advisor

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Overview

Uncertainty is inescapable: randomness, measurement error, deception, and incomplete or missing information complicate all our lives. Statistics is the science and art of making predictions and decisions in the face of uncertainty. Statistical issues are central to big questions in public policy, law, medicine, industry, computing, technology, finance, and science. Indeed, the tools of Statistics apply to problems in almost every area of human activity where data are collected.

Statisticians must master diverse skills in computing, mathematics, decision making, forecasting, interpretation of complicated data, and design of meaningful comparisons. Moreover, statisticians must learn to collaborate effectively with people in other fields and, in the process, to understand the substance of these other fields. For all these reasons, Statistics students are highly sought-after in the marketplace.

Recent Statistics majors at Carnegie Mellon have taken jobs at leading companies in many fields, including the National Economic Research Association, Boeing, Morgan Stanley, Deloitte, Rosetta Marketing Group, Nielsen, Proctor and Gamble, Accenture, and Goldman Sachs. Other students have taken research positions at the National Security Agency, the U.S. Census Bureau, and the Science and Technology Policy Institute or worked for Teach for America. Many of our students have also gone on to graduate study at some of the top programs in the country including Carnegie Mellon, the Wharton School at the University of Pennsylvania, Johns Hopkins, University of Michigan, Stanford University, Harvard University, Duke University, Emory University, Yale University, Columbia University, and Georgia Tech.

The Department and Faculty

The Department of Statistics and Data Science at Carnegie Mellon University is world-renowned for its contributions to statistical theory and practice. Research in the department runs the gamut from pure mathematics to the hottest frontiers of science. Current research projects are helping make fundamental advances in neuroscience, cosmology, public policy, finance, and genetics.

The faculty members are recognized around the world for their expertise and have garnered many prestigious awards and honors. (For example, three members of the faculty have been awarded the COPSS medal, the highest honor given by professional statistical societies.) At the same time, the faculty is firmly dedicated to undergraduate education. The entire faculty, junior and senior, teach courses at all levels. The faculty are accessible and are committed to involving undergraduates in research.

The Department augments all these strengths with a friendly, energetic working environment and exceptional computing resources. Talented graduate students join the department from around the world, and add a unique dimension to the department's intellectual life. Faculty, graduate students, and undergraduates interact regularly.

How to Take Part

There are many ways to get involved in Statistics at Carnegie Mellon:

- The Bachelor of Science in Statistics in the Dietrich College of Humanities and Social Sciences (DC) is a broad-based, flexible program that helps you master both the theory and practice of Statistics. The program can be tailored to prepare you for later graduate study in Statistics or to complement your interests in almost any field, including Psychology, Physics, Biology, History, Business, Information Systems, and Computer Science.
- The Minor (or Additional Major) in Statistics is a useful complement to a (primary) major in another Department or College. Almost every field of inquiry must grapple with statistical problems, and the tools of statistical theory and data analysis you will develop in the Statistics minor (or Additional Major) will give you a critical edge.
- The Bachelor of Science in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. Jointly administered by the Department of Statistics and Data Science and the Undergraduate Economics Program, the major's curriculum provides students with a solid foundation in the theories and methods of both fields. (See Dietrich College Interdepartmental Majors as well later in this section)
- The Bachelor of Science in Statistics and Machine Learning is a program housed in the Department of Statistics and Data Science and is jointly administered with the Department of Machine Learning. In this major students take courses focused on skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. The program is geared toward students interested in statistical computation, data science, and "big data" problems.
- The Statistics Concentration and the Operations Research and Statistics Concentration in the Mathematical Sciences Major (see Department of Mathematical Sciences) are administered by the Department of Mathematical Sciences with input from the Department of Statistics and Data Science.
- There are several ongoing exciting research projects in the Department of Statistics and Data Science, and the department enthusiastically seeks to involve undergraduates in this work. Both majors and non-majors are welcome.
- Non-majors are eligible to take most of our courses, and indeed, they are required to do so by many programs on campus. Such courses offer one way to learn more about the Department of Statistics and Data Science and the field in general.

Curriculum

Statistics consists of two intertwined threads of inquiry: Statistical Theory and Data Analysis. The former uses probability theory to build and analyze mathematical models of data in order to devise methods for making effective predictions and decisions in the face of uncertainty. The latter involves techniques for extracting insights from complicated data, designs for accurate measurement and comparison, and methods for checking the validity of theoretical assumptions. Statistical Theory informs Data Analysis and vice versa. The Department of Statistics and Data Science curriculum follows both of these threads and helps the student develop the complementary skills required.

Throughout the sections of this catalog, we describe the requirements for the Major in Statistics and the different categories within our basic curriculum, followed by the requirements for the Major in Economics and Statistics, the Major in Statistics and Machine Learning, and the Minor in Statistics.

Note: We recommend that you use the information provided below as a general guideline, and then schedule a meeting with a Statistics Undergraduate Advisor (statadvising@stat.cmu.edu) to discuss the requirements in more detail, and build a program that is tailored to your strengths and interests.

B.S. in Statistics

Glenn Clune, Academic Advisor
Peter Freeman, Faculty Advisor
Location: Baker Hall 132
statadvising@stat.cmu.edu

Students in the Bachelor of Science program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. The requirements for the Major in Statistics are detailed below and are organized by categories #1-#7.

Curriculum

1. Mathematical Foundations (Prerequisites) 29–39 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics.

Calculus*:

Complete one of the following three sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Differential Calculus	10
21-112	Integral Calculus	10
and one of the following		
21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Sequence 2

21-120	Differential and Integral Calculus	10
and one of the following		
21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Notes:

- Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Linear Algebra:**

Complete *one* of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	10
21-242	Matrix Theory	10

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis: 36–45 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the DC College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the College. (Note: A score of 4 or 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement). Other courses emphasize examples in business (36-207), engineering and architecture (36-220), and the laboratory sciences (36-247).

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data	9
36/70-207	Probability and Statistics for Business Applications	9
36-220	Engineering Statistics and Quality Control	9
36-247	Statistics for Lab Sciences	9

Note: Students who enter the program with 36-225 or 36-226 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for a Statistics Major and Minor may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

36-202	Statistics & Data Science Methods **	9
36/70-208	Regression Analysis	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-290	Introduction to Statistical Research Methodology	9
*Or extra data analysis course in Statistics		
** Must take prior to 36-401		

Advanced

Choose *one* of the following courses:

36-303	Sampling, Survey and Society	9
36-315	Statistical Graphics and Visualization	9
36-311	Statistical Analysis of Networks	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9
and take the following two courses:		
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Students can also take a second 36-46x (see section #5).

Sequence 2 (For students beginning later in their college career)

Advanced

Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

3. Probability Theory and Statistical Theory: 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following two courses:

36-225	Introduction to Probability Theory **	9
and one of the following two courses:		
36-226	Introduction to Statistical Inference	9
36-326	Mathematical Statistics (Honors)	9

**It is possible to substitute 36-217, 36-218, or 21-325 for 36-225. (36-225 is the standard introduction to probability, 36-217 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll),and 21-325 is a rigorous probability theory course offered by the Department of Mathematics.)

Comment:

(i) In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-225, 36-226 and 36-401. In particular, a grade of C or higher is required in order to be able to continue in the major.

4. Statistical Computing: 9 units

36-350	Statistical Computing *	9

*In rare circumstances, a higher level *Statistical Computing* course, approved by your Statistics advisor, may be used as a substitute.

5. Special Topics 9 units

The Department of Statistics and Data Science offers advanced courses that focus on specific statistical applications or advanced statistical methods. These courses are numbered 36-46x (36-461, 36-462, etc.). Two of these courses will be offered every year, one per semester. Past topics included Statistical Learning, Data Mining, Statistics and the Law, Bayesian Statistics, Nonparametric Statistics, Statistical Genetics, Multilevel and Hierarchical Models, and Statistical Methods in Epidemiology. The objective of the course is to expose students to important topics in statistics and/or interesting applications which are not part of the standard undergraduate curriculum.

To satisfy the Special Topics requirement choose *one* of the **36-46x** courses (which are 9 units).

Note: All 36-46x courses require 36-401 as a prerequisite or corequisite.

6. Statistical Elective: 9–10 units

Students are required to take one elective which can be within or outside the Department of Statistics and Data Science. **Courses within Statistics** can be any 300 or 400 level course (that is not used to satisfy any other requirement for the statistics major).

The following is a partial list of **courses outside Statistics** that qualify as electives as they provide intellectual infrastructure that will advance the student's understanding of statistics and its applications. Other courses may qualify as well; consult with the Statistics Undergraduate Advisor.

15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-121	Introduction to Data Structures	10
15-122	Principles of Imperative Computation	10
10-301	Introduction to Machine Learning	12
10-315	Introduction to Machine Learning (Undergrad)	12
15-388	Practical Data Science	9
21-127	Concepts of Mathematics	10
21-260	Differential Equations	9
21-292	Operations Research I	9
21-301	Combinatorics	9
21-355	Principles of Real Analysis I	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-310	Formal Logic	9
85-310	Research Methods in Cognitive Psychology	9
85-320	Research Methods in Developmental Psychology	9
85-340	Research Methods in Social Psychology	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9

Note: Additional prerequisites are required for some of these courses. Students should carefully check the course descriptions to determine if additional prerequisites are necessary.

7. Tracks*:

Self-Defined Concentration Area (with advisor's approval) 36 units

The power of Statistics, and much of the fun, is that it can be applied to answer such a wide variety of questions in so many different fields. A critical part of statistical practice is understanding the questions being asked so that appropriate methods of analysis can be used. Hence, a critical part of statistical training is to gain experience applying the abstract tools to real problems.

The Concentration Area is a set of four related courses outside of Statistics that prepares the student to deal with statistical aspects of problems that arise in another field. These courses are usually drawn from a *single* discipline of interest to the student and must be approved by the Statistics Undergraduate Advisor. While these courses are not in Statistics, the concentration area must compliment the overall Statistics degree.

For example, students intending to pursue careers in the health or biomedical sciences could take further courses in Biology or Chemistry, or students intending to pursue graduate work in Statistics could take further courses in advanced Mathematics.

The concentration area can be fulfilled with a minor or additional major, but not *all* minors and additional majors fulfill this requirement. Please make sure to consult the Undergraduate Statistics Advisor *prior* to pursuing courses for the concentration area. Once the concentration area is approved, any changes made to the previously agreed upon coursework requires re-approval by the Undergraduate Advisor.

Concentration Approval Process

- Submit the below materials to the Undergraduate Statistics Advisor
  - List of possible coursework to fulfill the concentration*
  - 150-200 word essay describing how the proposed courses complement the Statistics degree.

* These courses can be amended later, but must be re-approved by the Statistics Undergraduate Advisor if amended.

* Note: The concentration/track requirement is only for students whose *primary* major is statistics and have no other additional major or minor. The requirement does not apply for students who pursue an *additional* major in statistics.

Mathematical Statistics Track 46–52 units

21-127	Concepts of Mathematics	10
21-355	Principles of Real Analysis I	9
36-410	Introduction to Probability Modeling	9

And *two* of the following:

36-700	Probability and Mathematical Statistics	12
or 36-705	Intermediate Statistics	
21-228	Discrete Mathematics	9
21-257	Models and Methods for Optimization	9
21-292	Operations Research I	9
21-301	Combinatorics	9
21-356	Principles of Real Analysis II	9

Statistics and Neuroscience Track 45–54 units

85-211	Cognitive Psychology	9
85-219	Biological Foundations of Behavior	9

And three electives (at least one from Methodology and Analysis and at least one from Neuroscientific Background):

Methodology and Analysis

36-700	Probability and Mathematical Statistics	12
or 36-705	Intermediate Statistics	
10-301	Introduction to Machine Learning	12
18-290	Signals and Systems	12
85-314	Cognitive Neuroscience Research Methods	9
42/86-631	Neural Data Analysis	9

Neuroscience Background

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
15-386	Neural Computation	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9

Total Number of Units for the Major:	**146-185***
Total Number of Units for the Degree:	**360**

* Note: This number can vary depending on the calculus sequence and on the concentration area a student takes. In addition this number includes the 36 units of the “Concentration Area” category which may not be required (see category 7 above for details).

Recommendations

Students in the College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 by the end of their Freshman year.

The linear algebra requirement is a prerequisite for the course 36-401. It is therefore essential to complete this requirement during your junior year at the latest.

Recommendations for Prospective PhD Students

Students interested in pursuing a PhD in Statistics or Biostatistics (or related programs) after completing their undergraduate degree are strongly recommended to pursue the **Mathematical Statistics Track**.

Additional Major in Statistics

Students who elect Statistics as a second or third major must fulfill all Statistics degree requirements except for the Concentration Area requirement. Majors in many other programs would naturally complement a Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least five statistics courses that do not count for their primary major. If students do not have at least five, they typically take additional advanced data analysis electives.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Statistics.

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department Statistics does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Research

One goal of the Statistics program is to give students experience with statistical research. The department gives students research experience through various courses focused on real world experiences and application. There is a variety of research projects in the department as well, and students who would like to pursue working on a project with faculty will need to contact that faculty directly to discuss that possibility.

Before graduation, students are encouraged to participate in a research project under faculty supervision. Students mostly do this through projects in specific courses, such as 36-290, 36-303, 36-490, and/or 36-497. Students can also pursue an independent study, or a summer research position.

Qualified students are also encouraged to participate in an advanced research project through 36-490 Undergraduate Research or 36-497 Corporate Capstone Project. Note that both of these courses require an application. Students who maintain a quality point average of 3.25 overall may also apply to participate in the Dietrich College Senior Honors Program (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/#collegeservicesandprograms).

Sample Programs

The following sample programs illustrate three (of many) ways to satisfy the requirements of the Statistics Major. However, keep in mind that the program is flexible enough to support *many* other possible schedules and to emphasize a wide variety of interests.

The first schedule uses calculus sequence 1.

The second schedule is an example of the case when a student enters the program through 36-225 and 36-226 (and therefore skips the beginning data analysis sequence). This schedule has more emphasis on statistical theory and probability.

The third schedule is an example of the Mathematical Statistics track.

In these schedules, C.A. refers to Concentration Area courses.

Schedule 1

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	36-202 Statistics & Data Science Methods	21-256 Multivariate Analysis	21-240 Matrix Algebra with Applications
21-111 Differential Calculus	21-112 Integral Calculus	C.A.	

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
36-225 Introduction to Probability Theory	36-226 Introduction to Statistical Inference	36-401 Modern Regression	36-402 Advanced Methods for Data Analysis
Stat Elective	36-350 Statistical Computing	C.A.	36-46x - Special Topics
	C.A.		C.A.

Schedule 2

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	36-225 Introduction to Probability Theory	36-226 Introduction to Statistical Inference
36-200 Reasoning with Data			21-240 Matrix Algebra with Applications

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	36-46x Special Topics	Stat Elective
36-401 Modern Regression	Stat Elective	C.A.	C.A.
C.A.	C.A.		

Schedule 3 - Mathematics Track Only

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	36-225 Introduction to Probability Theory	36-226 Introduction to Statistical Inference
	21-260 Differential Equations	21-127 Concepts of Mathematics	21-241 Matrices and Linear Transformations

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	36-46x Special Topics	36-410 Introduction to Probability Modeling
36-401 Modern Regression	Stat Elective	21-355 Principles of Real Analysis I	Stat Elective
21-228 Discrete Mathematics	21-341 Linear Algebra		

B.S. in Economics and Statistics

Samantha Nielsen, *Statistics & Data Science Lead Academic Advisor*
Kathleen Conway, *Economics Senior Academic Advisor*
Rebecca Nugent and Edward Kennedy, *Faculty Advisors*
Carol Goldburg, Executive Director, *Undergraduate Economics Program*

Statistics & Data Science Location: Baker Hall 132
statadvising@stat.cmu.edu

Economics Location: Tepper 2400
econprog@andrew.cmu.edu

The B.S. in Economics and Statistics is jointly advised by the Department of Statistics and Data Science and the Undergraduate Economics Program.

The Major in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. With joint curriculum from the Department of Statistics and Data Science and the Undergraduate Economics Program, the major provides students with a solid foundation in the theories and methods of both fields. Students in this major are trained to advance the understanding of economic issues through the analysis, synthesis and reporting of data using the advanced empirical research methods of statistics and econometrics. Graduates are well positioned for admission to competitive graduate programs, including those in statistics, economics and management, as well as for employment in positions requiring strong analytic and conceptual skills - especially those in economics, finance, education, and public policy.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

The requirements for the B.S. in Economics and Statistics are the following:

I. Prerequisites 38-39 units

1. Mathematical Foundations 38-39 units

Calculus

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Note: Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Note: Taking/having credit for both 21-111 and 21-112 is equivalent to 21-120. The Mathematical Foundations total is then 48-49 units. The Economics and Statistics major would then total 201-211 units.

Linear Algebra

One of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	10
21-242	Matrix Theory	10

Note: 21-241 and 21-242 are intended only for students with a very strong mathematical background.

II. Foundations 18-36 units

2. Economics Foundations 18 units

73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9

3. Statistical Foundations 9-18 units

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data	9
36/70-207	Probability and Statistics for Business Applications	9
36-220	Engineering Statistics and Quality Control	9
36-247	Statistics for Lab Sciences	9

Note: Students who enter the program with 36-225 or 36-226 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for the Economics and Statistics Major may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

36-202	Statistics & Data Science Methods **	9
36-208	Regression Analysis	9
36-290	Introduction to Statistical Research Methodology	9
36-309	Experimental Design for Behavioral & Social Sciences	9

* Or extra data analysis course in Statistics
** Must take prior to 36-401 Modern Regression.

Advanced
Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Sequence 2 (For students beginning later in their college career)

Advanced
Choose *three* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

III. Disciplinary Core 126 units

1. Economics Core 45 units

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-270	Professional Communication for Economists	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9

2. Statistics Core 36 units

36-225	Introduction to Probability Theory *#	9

and *one* of the following two courses:

36-226	Introduction to Statistical Inference *	9
36-326	Mathematical Statistics (Honors) *	9

and *both* of the following two courses:

36-401	Modern Regression *	9
36-402	Advanced Methods for Data Analysis	9

*In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-225 (or equivalents), 36-226 or 36-326 and 36-401.

#It is possible to substitute 36-217, 36-218, or 21-325 for 36-225 36-225 36-22536-225. (36-225 36-225 36-22536-225 is the standard introduction to probability, 36-217 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 21-325 21-32521-325 is a rigorous Probability Theory course offered by the Department of Mathematics.)

3. Computing 9 units

36-350	Statistical Computing *	9

*In rare circumstances, a higher level *Statistical* Computing course, approved by your Statistics advisor, may be used as a substitute.

4. Advanced Electives 36 units

Students must take two advanced Economics elective courses (numbered 73-300 through 73-495, excluding 73-374) and two (or three - depending on previous coursework, see Section 3) advanced Statistics elective courses (numbered 36-303, 36-311, 36-315, 36-46x, 36-490, or 36-497).

Students pursuing a degree in Economics and Statistics also have the option of earning a concentration area (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Total number of units for the major	**191-201 units**
Total number of units for the degree	**360 units**

Professional Development

Students are strongly encouraged to take advantage of professional development opportunities and/or coursework. One option is 73-210 Economics Colloquium I, a fall-only course that provides information about careers in Economics, job search strategies, and research opportunities. The Department of Statistics and Data Science also offers a series of workshops pertaining to resume preparation, graduate school applications, careers in the field, among other topics. Students should also take advantage of the Career and Professional Development Center.

Additional Major in Economics and Statistics

Students who elect Economics and Statistics as a second or third major must fulfill all Economics and Statistics degree requirements. Majors in many other programs would naturally complement an Economics and Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least six courses (three Economics and three Statistics) that do not count for their primary major. If students do not have at least six, they typically take additional advanced data analysis or economics electives, depending on where the double counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Economics and Statistics.

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Economics and Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Economics and Statistics.

Sample Program

The following sample program illustrates one way to satisfy the requirements of the Economics and Statistics Major. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule).

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	36-202 Statistics & Data Science Methods	36-225 Introduction to Probability Theory	21-240 Matrix Algebra with Applications
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	36-226 Introduction to Statistical Inference
73-102 Principles of Microeconomics	73-103 Principles of Macroeconomics	73-210 Economics Colloquium I *not required	73-240 Intermediate Macroeconomics
73-060 Economics: BaseCamp *not required	-----		73-274 Econometrics I
-----	-----	73-265 Economics and Data Science	-----

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	Statistics Elective	Economics Elective
36-401 Modern Regression	73-270 Professional Communication for Economists	Economics Elective	Statistics Elective
73-374 Econometrics II	-----	-----	-----
-----	-----	-----	-----
-----		-----	-----

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Prospective PhD students might add 21-127 fall of sophomore year, replace 21-240 with 21-241, add 21-260 in spring of junior year and 21-355 in fall of senior year.

B.S. in Statistics and Machine Learning

Samantha Nielsen, *Academic Advisor*
Ryan Tibshirani and Ann Lee, *Faculty Advisors*
Location: Baker Hall 132
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Students in the Statistics and Machine Learning program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics and Machine Learning majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. This program is geared towards students interested in statistical computation, data science, or “Big Data” problems. The requirements for the Major in Statistics and Machine Learning are detailed below and are organized by categories.

Curriculum

1. Mathematical Foundations (Prerequisites) 49–59 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics and Machine Learning.

Calculus*:

Complete one of the following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Differential Calculus	10
21-112	Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Sequence 2

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Notes:

- Passing the Mathematical Sciences 21-120 assessment test is an acceptable alternative to completing 21-120

Integration and Approximation

21-122	Integration and Approximation	10

Linear Algebra**:

Complete *one* of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	10
21-242	Matrix Theory	10

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

Mathematical Theory:

21-127	Concepts of Mathematics	10

2. Data Analysis 45–54 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the Dietrich College Core Requirement in Statistical Reasoning. One of these courses is therefore recommended for students in the College. (Note: A score of 4 or 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement). Other courses emphasize examples in business (36-207), engineering and architecture (36-220), and the laboratory sciences (36-247).

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1

Beginning*

Choose one of the following courses:

36-200	Reasoning with Data	9
36/70-207	Probability and Statistics for Business Applications	9
36-220	Engineering Statistics and Quality Control	9
36-247	Statistics for Lab Sciences	9

Note: Students who enter the program with 36-225 or 36-226 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for a Statistics Major and Minor may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

36-202	Statistics & Data Science Methods **	9
36/70-208	Regression Analysis	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-290	Introduction to Statistical Research Methodology	9
*Or extra data analysis course in Statistics		
**Must take prior to 36-401		

Advanced

Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Special Topics rotate and new ones are regularly added.

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Sequence 2

Advanced

Choose *three* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

All Special Topics are not offered every semester, and new special topics are regularly added.

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following *two* courses**:

36-225	Introduction to Probability Theory	9
36-226	Introduction to Statistical Inference	9
or 36-326	Mathematical Statistics (Honors)	

**It is possible to substitute 36-217 , 36-218, or 21-325 for 36-225 . (36-225 is the standard introduction to probability, 36-217 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.) 36-326 Mathematical Statistics (Honors) can be substituted for 36-226 Introduction to Statistical Inference and is considered an honors course.

Comments:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-225 , 36-226 and 36-401.

4. Statistical Computing 9 units

36-350	Statistical Computing *	9

*In rare circumstances, a higher level *Statistical* Computing course, approved by your Statistics advisor, may be used as a substitute.

5. Machine Learning/Computer Science 46-48 units

Statistical modeling in practice nearly always requires computation in one way or another. Computational algorithms are sometimes treated as “black-boxes”, whose innards the statistician need not pay attention to. But this attitude is becoming less and less prevalent, and today there is much to be gained from a strong working knowledge of computational tools. Understanding the strengths and weaknesses of various methods allows the data analyst to select the right tool for the job; understanding how they can be adapted to work in new settings greatly extends the realm of problems that he/she can solve. While all Majors in Statistics are given solid grounding in computation, extensive computational training is really what sets the Major in Statistics and Machine Learning apart.

15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	10
15-351	Algorithms and Advanced Data Structures	12
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (Undergrad)	

and take *one* of the following Machine Learning Advanced Electives:

10-405	Machine Learning with Large Datasets (Undergraduate)	12
10-605	Machine Learning with Large Datasets	12
10-703	Deep Reinforcement Learning & Control	12
10-707	Topics in Deep Learning	12
11-411	Natural Language Processing	12
11-441	Machine Learning for Text Mining	9
11-661	Language and Statistics	12
15-381	Artificial Intelligence: Representation and Problem Solving	9
15-386	Neural Computation	9
15-387	Computational Perception	9
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
16-720	Computer Vision	12
11-761	Language and Statistics	12
*PhD level ML course as approved by Statistics advisor		
** Independent research with an ML faculty member		

Total number of units for the major	**176–198 units**
Total number of units for the degree	**360 units**

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 Reasoning with Data by the end of their Freshman year.

The linear algebra requirement is a prerequisite for the course 36-401 . It is therefore essential to complete this requirement during your junior year at the latest!

Recommendations for Prospective PhD Students

Students interested in pursuing a PhD in Statistics or Machine Learning (or related programs) after completing their undergraduate degree are strongly recommended to take additional Mathematics courses. They should see a faculty advisor as soon as possible. Students should consider 36-326 Mathematical Statistics (Honors) as an alternative to 36-226 . Although 21-240 Matrix Algebra with Applications is recommended for Statistics majors, students interested in PhD programs should consider taking 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory instead. Additional courses to consider are 21-228 Discrete Mathematics, 21-260 Differential Equations, 21-341 Linear Algebra, 21-355 Principles of Real Analysis I, and 21-356 Principles of Real Analysis II.

Additional experience in programming and computational modeling is also recommended. Students should consider taking more than one course from the list of Machine Learning electives provided under the Computing section.

Additional Major in Statistics and Machine Learning

Students who elect Statistics and Machine Learning as a second or third major must fulfill *all* degree requirements.

With respect to double-counting courses, it is departmental policy that students must have at least six courses (three Computer Science/Machine Learning and three Statistics) that do not count for their primary major. If students do not have at least six, they typically take additional advanced data analysis or ML electives, depending on where the double counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Statistics and Machine Learning.

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Statistics and Machine Learning major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics and Machine Learning.

Sample Programs

The following sample program illustrates one way to satisfy the requirements of the Statistics and Machine Learning program. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule). Sample program 1 is for students who have not satisfied the basic calculus requirements. Sample program 2 is for students who have satisfied the basic calculus requirements and choose option 2 for their data analysis courses (see section #2)

Schedule 1

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	36-202 Statistics & Data Science Methods	36-225 Introduction to Probability Theory	36-226 Introduction to Statistical Inference
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	21-122 Integration and Approximation	21-241 Matrices and Linear Transformations
15-112 Fundamentals of Programming and Computer Science	15-112 Fundamentals of Programming and Computer Science	21-127 Concepts of Mathematics	15-122 Principles of Imperative Computation
-----*	-----	-----	-----
-----	-----	-----	-----

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
36-401 Modern Regression	36-402 Advanced Methods for Data Analysis	10-301 Introduction to Machine Learning	ML Elective
36-350 Statistical Computing	15-351 Algorithms and Advanced Data Structures	Stat Elective	Stat Elective
-----	-----	-----	-----
-----	-----	-----	-----
-----	-----	-----	-----

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Schedule 2

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-256 Multivariate Analysis	21-127 Concepts of Mathematics	36-225 Introduction to Probability Theory	36-226 Introduction to Statistical Inference
15-112 Fundamentals of Programming and Computer Science	-----	15-122 Principles of Imperative Computation	21-241 Matrices and Linear Transformations
-----*	-----	-----	Stat Elective
-----	-----	-----	-----
-----		-----	-----

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	10-301 Introduction to Machine Learning	ML Elective
36-401 Modern Regression	15-351 Algorithms and Advanced Data Structures	Stat Elective	Stat Elective
-----	-----	-----	-----
-----	-----	-----	-----
-----	-----	-----	-----

*In each semester, "-----" represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

The Minor in Statistics

Glenn Clune, *Academic Advisor*
Peter Freeman, *Faculty Advisor*
Location: Baker Hall 132M
statadvising@stat.cmu.edu

The Minor in Statistics develops skills that complement major study in other disciplines. The program helps the student master the basics of statistical theory and advanced techniques in data analysis. This is a good choice for deepening understanding of statistical ideas and for strengthening research skills.

In order to get a minor in Statistics a student must satisfy all of the following requirements:

1. Mathematical Foundations (Prerequisites) 29–39 units

Calculus:*:

Complete *one* of the following two sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Differential Calculus	10
21-112	Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Sequence 2

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Note: Other sequences are possible, and require approval from the undergraduate advisor.

Note: Passing the Mathematical Sciences 21-120 assessment test if an acceptable alternative to completing 21-120.

Linear Algebra:

Complete *one* of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	10
21-242	Matrix Theory	10

*It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be complete before taking 36-401 Modern Regression or 36-46X Special Topics.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis 36 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the DC College Core Requirement in Statistical Reasoning. One of these courses is therefore recommended for students in the College. (Note: A score of 4 or 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement). Other courses emphasize examples in business (36-207), engineering and architecture (36-220), and the laboratory sciences (36-247).

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning Data Analysis*

Choose *one* of the following courses:

36-200	Reasoning with Data	9
36/70-207	Probability and Statistics for Business Applications	9

36-220	Engineering Statistics and Quality Control	9
36-247	Statistics for Lab Sciences	9

*Or extra data analysis course in Statistics

Note: Students who enter the program with 36-225 or 36-226 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for a Statistics Major and Minor may be counted as a Statistical Elective.

Intermediate Data Analysis*

Choose *one* of the following courses:

36-202	Statistics & Data Science Methods **	9
36/70-208	Regression Analysis	9
36-290	Introduction to Statistical Research Methodology	9
36-309	Experimental Design for Behavioral & Social Sciences	9

*Or extra data analysis course in Statistics

**Must take prior to 36-401

Advanced Data Analysis and Methodology

Take the following course:

36-401	Modern Regression	9

and *one* of the following courses:

36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-465	Special Topics: An Introduction to Bayesian Inference	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Special Topics rotate and new ones are regularly added.

Sequence 2 (For students beginning later in their college career)

Advanced Data Analysis and Methodology

Take the following course:

36-401	Modern Regression	9

and take *two* of the following courses (one of which must be 400-level):

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-465	Special Topics: An Introduction to Bayesian Inference	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Special Topics rotate and new ones are regularly added.

3. Probability Theory and Statistical Theory 18 units

To satisfy the theory requirement take the following *two* courses:

36-225	Introduction to Probability Theory	9
36-226	Introduction to Statistical Inference	9
or 36-326	Mathematical Statistics (Honors)	

**It is possible to substitute 36-217 , 36-218 or 21-325 for 36-225 . (36-225 is the standard introduction to probability, 36-217 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.) 36-326 Mathematical Statistics (Honors) can be substituted for 36-226 Introduction to Statistical Inference and is considered an honors course.

Comments:

(i) In order to be a Major or a Minor in good standing, a grade of at least a C is required in 36-225 , 36-226 and 36-401. In particular, a grade of C or higher is required in order to be able to continue in the major.

Total number of units required for the minor	**83 Units**

Double Counting

With respect to double-counting courses, it is departmental policy that students must have at least three statistics courses (36-xxx) that do not count for their primary major. If students do not have at least three, they need to take additional advanced electives.

Sample Programs for the Minor

The following two sample programs illustrates two (of many) ways to satisfy the requirements of the Statistics Minor. Keep in mind that the program is flexible and can support many other possible schedules.

The first schedule uses calculus sequence 1, and 36-202to satisfy the intermediate data analysis requirement. The second schedule is an example of the case when a student enters the Minor through 36-225 and 36-226 (and therefore skips the beginning data analysis course). The schedule uses calculus sequence 2, and an advanced data analysis elective (to replace the beginning data analysis course).

Schedule 1

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-111 Differential Calculus	21-112 Integral Calculus	36-202 Statistics & Data Science Methods	21-240 Matrix Algebra with Applications
36-200 Reasoning with Data		21-256 Multivariate Analysis	

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
36-225 Introduction to Probability Theory	36-226 Introduction to Statistical Inference	36-401 Modern Regression	36-402 Advanced Methods for Data Analysis

Schedule 2

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	36-225 Introduction to Probability Theory	36-226 Introduction to Statistical Inference

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
21-240 Matrix Algebra with Applications	Advanced Data Analysis Elective	36-401 Modern Regression	36-462 Special Topics: Data Mining

Substitutions and Waivers

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and

Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

However, the Statistics Director of Undergraduate Studies will provide advice and information to the student's advisor about the viability of a proposed substitution. Students should make available as much information as possible concerning proposed substitutions. Students seeking waivers may be asked to demonstrate mastery of the material.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Statistics Majors and Minors seeking substitutions or waivers should speak to the Academic Advisor in Statistics.

Faculty

ZACHARY BRANSON, Assistant Teaching Professor – M.S. in Statistics, Harvard University; Carnegie Mellon, 2019–

DAVID CHOI, Assistant Professor of Statistics and Information Systems – Ph.D., Stanford University; Carnegie Mellon, 2004–

ALEXANDRA CHOULDECHOVA, Assistant Professor of Statistics and Public Policy – Ph.D. , Stanford University; Carnegie Mellon, 2014–

PETER FREEMAN, Assistant Teaching Faculty – Ph.D. , University of Chicago; Carnegie Mellon, 2004–

MAX G'SELL, Assistant Professor – Ph.D., Stanford University ; Carnegie Mellon, 2014–

CHRISTOPHER R. GENOVESE, Department Head and Professor of Statistics – Ph.D., University of California, Berkeley; Carnegie Mellon, 1994–

JOEL B. GREENHOUSE, Professor of Statistics – Ph.D., University of Michigan; Carnegie Mellon, 1982–

AMELIA HAVILAND, Anna Loomis McCandless Professorship of Statistics and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2003–

JIASHUN JIN, Professor of Statistics – Ph.D., Stanford University; Carnegie Mellon, 2007–

BRIAN JUNKER, Associate Dean and Professor of Statistics – Ph.D., University of Illinois; Carnegie Mellon, 1990–

ROBERT E. KASS, Professor of Statistics – Ph.D., University of Chicago; Carnegie Mellon, 1981–

EDWARD KENNEDY, Assistant Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 2016–

ANN LEE, Associate Professor – Ph.D., Brown University; Carnegie Mellon, 2005–

JOHN P. LEHOCZKY, Thomas Lord Professor of Statistics – Ph.D., Stanford University; Carnegie Mellon, 1969–

JING LEI, Associate Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2011–

ANJALI MAZUMDER, Assistant Research Professor

DANIEL NAGIN, Teresa and H. John Heinz III Professor of Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1976–

MATEY NEYKOV, Assistant Professor – Ph.D., Harvard University; Carnegie Mellon, 2017–

NYNKE NIEZINK, Assistant Professor – Ph.D., University of Groningen; Carnegie Mellon, 2017–

REBECCA NUGENT, Associate Department Head, Teaching Professor – Ph.D., University of Washington; Carnegie Mellon, 2006–

ALEX REINHART, Assistant Teaching Faculty – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–

ALESSANDRO RINALDO, Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2005–

KATHRYN ROEDER, Professor of Statistics – Ph.D., Pennsylvania State University; Carnegie Mellon, 1994–

CHAD M. SCHAFER, Associate Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

TEDDY SEIDENFELD, Herbert A. Simon Professor of Philosophy and Statistics – Ph.D., Columbia University; Carnegie Mellon, 1985–

COSMA SHALIZI, Associate Professor – Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 2005–

RYAN TIBSHIRANI, Associate Professor – Ph.D., Stanford University; Carnegie Mellon, 2011–

VALERIE VENTURA, Associate Professor – Ph.D., University of Oxford; Carnegie Mellon, 1997–

ISABELLA VERDINELLI, Professor in Residence – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1991–

LARRY WASSERMAN, Professor of Statistics – Ph.D., University of Toronto; Carnegie Mellon, 1988–

YUTING WEI, Assistant Professor – Ph.D. , University of California; Carnegie Mellon, 2019–

Emeriti Faculty

GEORGE T. DUNCAN, Professor of Statistics and Public Policy – Ph.D., University of Minnesota; Carnegie Mellon, 1974–

WILLIAM F. EDDY, John C. Warner Professor of Statistics – Ph.D, Yale University; Carnegie Mellon, 1976–

JOSEPH B. KADANE, Leonard J. Savage Professor of Statistics and Social Sciences – Ph.D., Stanford University; Carnegie Mellon, 1969–

MARK J. SCHERVISH, Professor of Statistics – Ph.D., University of Illinois; Carnegie Mellon, 1979–

DALENE STANGL, Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

Adjunct Faculty

OLGA CHILINA, Lecturer – MS, University of Toronto; Carnegie Mellon, 2016–

APRIL GALYARDT – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

CHRISTOPHER PETER MAKRIS, Adjunct Lecturer – MSP, Carnegie Mellon University; Carnegie Mellon, 2018–

ROSS O'CONNELL – Ph.D., University of Michigan; Carnegie Mellon, 2016–

GORDON WEINBERG, Senior Lecturer – M.A. Mathematics, University of Pittsburgh; Carnegie Mellon, 2004–

Special Faculty

ROBIN MEJIA

Affiliated Faculty

ANTHONY BROCKWELL – Ph.D., Melbourne University; Carnegie Mellon, 1999–

BERNIE DEVLIN – Ph.D., Pennsylvania State University; Carnegie Mellon, 1994–

SAM VENTURA – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2015–

Department of Statistics and Data Science Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

36-200 Reasoning with Data
Fall and Spring: 9 units
This course is an introduction to learning how to make statistical decisions and "reason with data". The approach will emphasize thinking through an empirical problem from beginning to end and using statistical tools to look for evidence for/against an explicit argument/hypothesis. Types of data will include continuous and categorical variables, images, text, networks, and repeated measures over time. Applications will largely drawn from interdisciplinary case studies spanning the humanities, social sciences, and related fields. Methodological topics will include basic exploratory data analysis, elementary probability, hypothesis tests, and empirical research methods. There is no calculus or programming requirement. There will be one weekly computer lab for additional hands-on practice using an interactive software platform that allows student-driven inquiry. Not open to students who have received credit for 36-201, 36-207/70-207, 36-220, 36-247, 36-225, or any upper level course in Statistics This course is the credit-equivalent to 36-201 and will be honored appropriately as a pre-requisite for downstream Statistics courses. As such, this course is not currently open to students who have received credit for 36-201, 36/70-207, 36-220, 36-247, or any 300- or 400-level Statistics course.

36-201 Statistical Reasoning and Practice
Intermittent: 9 units
This course will introduce students to the basic concepts, logic, and issues involved in statistical reasoning, as well as basic statistical methods used to analyze data and evaluate studies. The major topics to be covered include methods for exploratory data analysis, an introduction to research methods, elementary probability, and methods for statistical inference. The objectives of this course are to help students develop a critical approach to the evaluation of study designs, data and results, and to develop skills in the application of basic statistical methods in empirical research. An important feature of the course will be the use of the computer to facilitate the understanding of important statistical ideas and for the implementation of data analysis. In addition to three lectures a week, students will attend a computer lab once a week. Examples will be drawn from areas of applications of particular interest to H&SS students. Not open to students who have received credit for 36-207/70-207, 36-220, 36-225, 36-625, or 36-247.

Course Website: http://www.stat.cmu.edu/academics/courselist

36-202 Statistics & Data Science Methods
Spring: 9 units
This course builds on the principles and methods of statistical reasoning developed in 36-200 (or its equivalents). The course covers simple and multiple regression, analysis of variance methods and logistic regression. Other topics may include non-parametric methods and probability models, as time permits. The objectives of this course is to develop the skills of applying the basic principles and methods that underlie statistical practice and empirical research. In addition to three lectures a week, students attend a computer lab once week for "hands-on" practice of the material covered in lecture. Not open to students who have received credit for: 36-208/70-208, 36-309. Students who have completed 36-401 prior to or concurrent with 36-202 will not receive credit for 36-202.
Prerequisites: 36-201 or 36-200 or 36-247 or 70-207 or 36-220 or 36-207

Course Website: http://www.stat.cmu.edu/academics/courselist

36-207 Probability and Statistics for Business Applications
Spring: 9 units
This is the first half of a year long sequence in basic statistical methods that are used in business and management. Topics include exploratory and descriptive techniques, probability theory, statistical inference in simple settings, basic categorical analysis, and statistical methods for quality control. Not open to students who have received credit for 36-201, 36-220, 36-625, or 36-247. Cross-listed as 70-207.
Prerequisites: 21-121 or 21-120 or 21-112

Course Website: http://www.stat.cmu.edu/academics/courselist

36-208 Regression Analysis
Spring: 9 units
This is the second half of a year long sequence in basic statistical methods that are used in business and management. Topics include time series, regression and forecasting. In addition to two lectures a week, students will attend a computer lab once a week. Not open to students who have received credit for 36-202, 36-626. Cross-listed as 70-208. Students who have completed 36-401 prior to 36-208 will not receive credit for 36-208.
Prerequisites: (21-112 or 21-120) and (36-201 or 70-207 or 36-247 or 36-207 or 36-220) and (73-102 or 73-100)

Course Website: http://www.stat.cmu.edu/academics/courselist

36-217 Probability Theory and Random Processes
All Semesters: 9 units
This course provides an introduction to probability theory. It is designed for students in electrical and computer engineering. Topics include elementary probability theory, conditional probability and independence, random variables, distribution functions, joint and conditional distributions, limit theorems, and an introduction to random processes. Some elementary ideas in spectral analysis and information theory will be given. A grade of C or better is required in order to use this course as a pre-requisite for 36-226 and 36-410. Not open to students who have received credit for 36-225, or 36-625.
Prerequisites: 21-259 or 21-256 or 21-123 or 21-122 or 21-112

Course Website: http://www.stat.cmu.edu/academics/courselist

36-218 Probability Theory for Computer Scientists
All Semesters: 9 units
Probability theory is the mathematical foundation for the study of both statistics and of random systems. This course is an intensive introduction to probability,from the foundations and mechanics to its application in statistical methods and modeling of random processes. Special topics and many examples are drawn from areas and problems that are of interest to computer scientists and that should prepare computer science students for the probabilistic and statistical ideas they encounter in downstream courses and research. A grade of C or better is required in order to use this course as a pre-requisite for 36-226, 36-326, and 36-410. Not open to students who have received credit for 36-225, 21-325, or 36-700. If you hold a Statistics primary/additional major or minor you will be required to complete 36-226. For those who do not have a major or minor in Statistics, and receive at least a B in 36-218, you will be eligible to move directly onto 36-401.
Prerequisites: 21-259 or 21-112 or 21-122 or 21-123 or 21-256

Course Website: http://www.stat.cmu.edu/academics/courselist

36-220 Engineering Statistics and Quality Control
All Semesters: 9 units
This is a course in introductory statistics for engineers with emphasis on modern product improvement techniques. Besides exploratory data analysis, basic probability, distribution theory and statistical inference, special topics include experimental design, regression, control charts and acceptance sampling. Not open to students who have received credit for 36-201, 36-207/70-207, 36-226, 36-626, or 36-247, except when AP credit is awarded for 36-201.
Prerequisites: 21-112 or 21-120 or 21-121

Course Website: http://www.stat.cmu.edu/academics/courselist

36-225 Introduction to Probability Theory
Fall: 9 units
This course is the first half of a year long course which provides an introduction to probability and mathematical statistics for students in economics, mathematics and statistics. The use of probability theory is illustrated with examples drawn from engineering, the sciences, and management. Topics include elementary probability theory, conditional probability and independence, random variables, distribution functions, joint and conditional distributions, law of large numbers, and the central limit theorem. A grade of C or better is required in order to advance to 36-226, 36-326, and 36-410. Not open to students who have received credit for 36-217, 36-218, 21-325, 36-700.

Course Website: http://www.stat.cmu.edu/academics/courselist

36-226 Introduction to Statistical Inference
Spring: 9 units
This course is the second half of a year long course in probability and mathematical statistics. Topics include maximum likelihood estimation, confidence intervals, and hypothesis testing. If time permits there will also be a discussion of linear regression and the analysis of variance. A grade of C or better is required in order to advance to 36-401, 36-402 or any 36-46x course. Not open to students who have received credit for 36-626.
Prerequisites: 15-359 Min. grade C or 36-225 Min. grade C or 36-217 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist

36-247 Statistics for Lab Sciences
Spring: 9 units
This course is a single-semester comprehensive introduction to statistical analysis of data for students in biology and chemistry. Topics include exploratory data analysis, elements of computer programming for statistics, basic concepts of probability, statistical inference, and curve fitting. In addition to two lectures, students attend a computer lab each week. Not open to students who have received credit for 36-201, 36-207/70-207, 36-220, or 36-226.
Prerequisites: 21-112 or 21-120 or 21-121

36-290 Introduction to Statistical Research Methodology
Intermittent: 9 units
This course is designed to introduce statistical research methodology—the procedures by which statisticians go about approaching and analyzing data —to early undergraduates. Students will learn basic concepts of statistical learning—inference vs. prediction, supervised vs. unsupervised learning, regression vs. classification, etc.—and will reinforce this knowledge by applying, e.g., linear regression, random forest, principal components analysis, and/or hierarchical clustering and more to datasets provided by the instructor. Students will also practice disseminating the results of their analyses via oral presentations and posters. Analyses will primarily be carried out using the R programming language, but with attention paid to how one would perform similar analyses using Python. Previous knowledge of R is not required for this course. Space is very limited; there will be an application process. The course is currently open to sophomore statistics students only.

36-300 Statistics & Data Science Internship
Summer: 3 units
The Department of Statistics & Data Science considers experiential learning as an integral part of our program. One such option is through an internship. If a student has an internship, they dont have to register for this class unless they want it listed on their official transcripts. This process should be used by international students interested in Curricular Practical Training (CPT) and should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website. This course will be taken as Pass/Fail, and students will be charged tuition for 3 units. There is an approval process in order to register for this course. Please contact the Department of Statistics & Data Science for more details.

36-303 Sampling, Survey and Society
Spring: 9 units
This course will revolve around the role of sampling and sample surveys in the context of U.S. society and its institutions. We will examine the evolution of survey taking in the United States in the context of its economic, social and political uses. This will eventually lead to discussions about the accuracy and relevance of survey responses, especially in light of various kinds of nonsampling error. Students will be required to design, implement and analyze a survey sample.
Prerequisites: 88-250 or 36-208 or 36-218 or 36-226 or 36-202 or 36-625 or 36-225 or 73-261 or 36-309 or 70-208

Course Website: http://www.stat.cmu.edu/academics/courselist

36-304 Biostatistics
Fall: 9 units
TBD

36-309 Experimental Design for Behavioral & Social Sciences
Fall: 9 units
Statistical aspects of the design and analysis of planned experiments are studied in this course. A clear statement of the experimental factors will be emphasized. The design aspect will concentrate on choice of models, sample size and order of experimentation. The analysis phase will cover data collection and computation, especially analysis of variance and will stress the interpretation of results. In addition to a weekly lecture, students will attend a computer lab once a week.
Prerequisites: 36-207 or 36-220 or 36-217 or 36-200 or 36-201 or 36-247

Course Website: http://www.stat.cmu.edu/academics/courselist

36-311 Statistical Analysis of Networks
Intermittent: 9 units
Networks are omnipresent. In this course, students will get an introduction to network science, mainly focusing on social network analysis. The course will start with some empirical background, and an overview of concepts used when measuring and describing networks. We will also discuss network visualization. Most traditional models cannot be applied straightforwardly to social network data, because of their complex dependence structure. We will discuss random graph models and statistical network models, that have been developed for the study of network structure and growth. We will also cover models of how networks impact individual behavior.
Prerequisite: 36-226

36-314 Biostatistics
Fall: 9 units
This course is an introduction to methods used frequently in biostatistics and public health applications.
Prerequisites: 36-226 or 88-250 or 36-225 or 70-208 or 36-303 or 36-309 or 36-202 or 36-208 or 36-625

36-315 Statistical Graphics and Visualization
Spring: 9 units
Graphical displays of quantitative information take on many forms as they help us understand both data and models. This course will serve to introduce the student to the most common forms of graphical displays and their uses and misuses. Students will learn both how to create these displays and how to understand them. As time permits the course will consider some more advanced graphical methods such as computer-generated animations. Each student will be required to engage in a project using graphical methods to understand data collected from a real scientific or engineering experiment. In addition to two weekly lectures there will be lab sessions where the students learn to use software to aid in the production of appropriate graphical displays.
Prerequisites: 21-325 or 36-625 or 36-225 or 36-309 or 36-303 or 70-208 or 36-218 or 36-217 or 88-250 or 36-226 or 36-208 or 36-202

Course Website: http://www.stat.cmu.edu/academics/courselist

36-326 Mathematical Statistics (Honors)
Spring: 9 units
This course is a rigorous introduction to the mathematical theory of statistics. A good working knowledge of calculus and probability theory is required. Topics include maximum likelihood estimation, confidence intervals, hypothesis testing, Bayesian methods, and regression. A grade of C or better is required in order to advance to 36-401, 36-402 or any 36-46x course. Not open to students who have received credit for 36-625. Prerequisites: 15-359 or 21-325 or 36-217 or 36-225 with a grade of A AND advisor approval. Students interested in the course should add themselves to the waitlist pending review.
Prerequisites: 36-225 Min. grade A or 15-359 Min. grade A or 36-218 Min. grade A or 21-325 Min. grade A or 36-217 Min. grade A

36-350 Statistical Computing
Fall and Spring: 9 units
Statistical Computing: An introduction to computing targeted at statistics majors with minimal programming knowledge. The main topics are core ideas of programming (functions, objects, data structures, flow control, input and output, debugging, logical design and abstraction), illustrated through key statistical topics (exploratory data analysis, basic optimization, linear models, graphics, and simulation). The class will be taught in the R language. No previous programming experience required. 36-225 is a pre-req.
Prerequisites: 21-325 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist

36-375 Data Ethics & Responsible Conduct of Research
Intermittent: 3 units
TBD

36-401 Modern Regression
Fall: 9 units
This course is an introduction to the real world of statistics and data analysis. We will explore real data sets, examine various models for the data, assess the validity of their assumptions, and determine which conclusions we can make (if any). Data analysis is a bit of an art; there may be several valid approaches. We will strongly emphasize the importance of critical thinking about the data and the question of interest. Our overall goal is to use a basic set of modeling tools to explore and analyze data and to present the results in a scientific report. A grade of C is required to move on to 36-402 or any 36-46x course.
Prerequisites: (36-226 Min. grade C or 36-218 Min. grade B or 36-625 Min. grade C or 36-326 Min. grade C) and (21-240 or 21-241)

Course Website: http://www.stat.cmu.edu/academics/courselist

36-402 Advanced Methods for Data Analysis
Spring: 9 units
This course introduces modern methods of data analysis, building on the theory and application of linear models from 36-401. Topics include nonlinear regression, nonparametric smoothing, density estimation, generalized linear and generalized additive models, simulation and predictive model-checking, cross-validation, bootstrap uncertainty estimation, multivariate methods including factor analysis and mixture models, and graphical models and causal inference. Students will analyze real-world data from a range of fields, coding small programs and writing reports. Prerequisites: 36-401
Prerequisite: 36-401 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist

36-410 Introduction to Probability Modeling
Spring: 9 units
An introductory-level course in stochastic processes. Topics typically include Poisson processes, Markov chains, birth and death processes, random walks, recurrent events, and renewal theory. Examples are drawn from reliability theory, queuing theory, inventory theory, and various applications in the social and physical sciences.
Prerequisites: 36-225 or 36-217 or 21-325 or 36-625

Course Website: http://www.stat.cmu.edu/academics/courselist

36-428 Time Series
Spring: 6 units
The course is designed for graduate students and advanced undergraduate students. It will introduce the analysis and some of the theory of sequences of serially-dependent random variables (known as time series). Students should already have learned mathematical probability and statistics, including multivariate and conditional distributions, linear regression, calculus, matrix algebra, and the fundamentals of complex variables and functions. The focus will be on popular models for time series and the analysis of data that arise in applications.
Prerequisite: 36-401 Min. grade C

36-431 Foundations of Causal Inference
Intermittent: 6 units
This course will provide an introduction to the fundamentals of causal inference. Causal inference is concerned with whether and how one can go beyond statistical associations to draw causal conclusions from observational data. Topics will include: counterfactuals (potential outcomes and graphs), identification and estimation of average treatment effects in experiments and observational studies, nonparametric bounds, sensitivity analysis, instrumental variables, effect modification, and longitudinal studies. Special permission is required for undergraduate students.

36-432 Modern Causal Inference
Intermittent: 6 units
This course will provide an in-depth look at modern causal inference. Topics will include: optimal treatment regimes, mediation, principal stratification, stochastic interventions, accounting for complex confounding and exposures, and methods for efficient nonparametric estimation. Some background in mathematical statistics is advised. Special permission is required for undergraduate students.

36-459 Statistical Models of the Brain
Spring: 12 units
This new course is intended for CNBC students, as an additional option for fulfilling the computational core course requirement, but it will also be open to Statistics and Machine Learning students. It should be of interest to anyone wishing to see the way statistical ideas play out within the brain sciences, and it will provide a series of case studies on the role of stochastic models in scientific investigation. Statistical ideas have been part of neurophysiology and the brainsciences since the first stochastic description of spike trains, and the quantal hypothesis of neurotransmitter release, more than 50 years ago. Many contemporary theories of neural system behavior are built with statistical models. For example, integrate-and-fire neurons are usually assumed to be driven in part by stochastic noise; the role of spike timing involves the distinction between Poisson and non-Poisson neurons; and oscillations are characterized by decomposing variation into frequency-based components. In the visual system, V1 simple cells are often described using linear-nonlinear Poisson models; in the motor system, neural response may involve direction tuning; and CA1 hippocampal receptive field plasticity has been characterized using dynamic place models. It has also been proposed that perceptions, decisions, and actions result from optimal (Bayesian) combination of sensory input with previously-learned regularities; and some investigators report new insights from viewing whole-brain pattern responses as analogous to statistical classifiers. Throughout the field of statistics, models incorporating random ``noise'' components are used as an effective vehicle for data analysis. In neuroscience, however, the models also help form a conceptual framework for understanding neural function. This course will examine some of the most important methods and claims that have come from applying statistical thinking
Prerequisite: 36-401 Min. grade C

36-461 Special Topics: Statistical Methods in Epidemiology
Intermittent: 9 units
Epidemiology is concerned with understanding factors that cause, prevent, and reduce diseases by studying associations between disease outcomes and their suspected determinants in human populations. Epidemiologic research requires an understanding of statistical methods and design. Epidemiologic data is typically discrete, i.e., data that arise whenever counts are made instead of measurements. In this course, methods for the analysis of categorical data are discussed with the purpose of learning how to apply them to data. The central statistical themes are building models, assessing fit and interpreting results. There is a special emphasis on generating and evaluating evidence from observational studies. Case studies and examples will be primarily from the public health sciences.
Prerequisite: 36-401 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist

36-462 Special Topics: Data Mining
Intermittent: 9 units
Data mining is the science of discovering patterns and learning structure in large data sets. Covered topics include information retrieval, clustering, dimension reduction, regression, classification, and decision trees.
Prerequisites: 36-401 (C or better).
Prerequisite: 36-401 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist

36-463 Special Topics: Multilevel and Hierarchical Models
Intermittent: 9 units
Multilevel and hierarchical models are among the most broadly applied "sophisticated" statistical models, especially in the social and biological sciences. They apply to situations in which the data "cluster" naturally into groups of units that are more related to each other than they are the rest of the data. In the first part of the course we will review linear and generalized linear models. In the second part we will see how to generalize these to multilevel and hierarchical models and relate them to other areas of statistics, and in the third part of the course we will learn how Bayesian statistical methods can help us to build, estimate and diagnose problems with these models using a variety of data sets and examples.
Prerequisite: 36-401 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist

36-464 Special Topics: Applied Multivariate Methods
Intermittent: 9 units
This course is an introduction to applied multivariate methods. Topics include a discussion of the multivariate normal distribution, the multivariate linear model, repeated measures designs and analysis, principle component and factor analysis. Emphasis is on the application and interpretation of these methods in practice. Students will use at least one statistical package.
Prerequisites: 36-401 (C or better).
Prerequisite: 36-401 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist

36-465 Special Topics: An Introduction to Bayesian Inference
Intermittent: 9 units
The aim of this course is to introduce students to theory and application of Bayesian statistical modeling and inference. The course starts with epistemological differences between the Bayesian and Frequentist paradigms and the treatment of simple models, such as those based on well-known distributions. Concepts of conjugate and non informative priors are illustrated, for single- and multi-parameters models. Basic treatment of hierarchical models and linear regression models are also covered. Bayesian computational methods such as the Gibbs sampler and Metropolis-Hastings algorithms, are briefly presented with an emphasis on their implementation and use on simple cases.
Prerequisite: 36-401 Min. grade C

36-466 Special Topics: Statistical Methods in Finance
Intermittent: 9 units
Financial econometrics is the interdisciplinary area where we use statistical methods and economic theory to address a wide variety of quantitative problems in finance. These include building financial models, testing financial economics theory, simulating financial systems, volatility estimation, risk management, capital asset pricing, derivative pricing, portfolio allocation, proprietary trading, portfolio and derivative hedging, and so on and so forth. Financial econometrics is an active field of integration of finance, economics, probability, statistics, and applied mathematics. Financial activities generate many new problems and products, economics provides useful theoretical foundation and guidance, and quantitative methods such as statistics, probability and applied mathematics are essential tools to solve quantitative problems in finance. Professionals in finance now routinely use sophisticated statistical techniques and modern computation power in portfolio management, proprietary trading, derivative pricing, financial consulting, securities regulation, and risk management.

36-467 Special Topics: Data over Space & Time
Intermittent: 9 units
This course is an introduction to the opportunities and challenges of analyzing data from processes unfolding over space and time. It will cover basic descriptive statistics for spatial and temporal patterns; linear methods for interpolating, extrapolating, and smoothing spatio-temporal data; basic nonlinear modeling; and statistical inference with dependent observations. Class work will combine practical exercises in R, a little mathematics on the underlying theory, and case studies analyzing real problems from various fields (economics, history, meteorology, ecology, etc.). Depending on available time and class interest, additional topics may include: statistics of Markov and hidden-Markov (state-space) models; statistics of point processes; simulation and simulation-based inference; agent-based modeling; dynamical systems theory. Co-requisite: For undergraduates taking the course as 36-467, 36-401. For graduate students taking the course as 36-667, consent of the professor.

36-468 Special Topics: Text Analysis
Intermittent: 9 units
The analysis of language is concerned with how variables relate to people (their gender, age, and location, for example), how variables relate to use (such as writing in different academic disciplines), and how variables change over time. While we are surrounded by data that might potentially shed light on many of these questions, working with real-world linguistic data can present some unique challenges in sampling, in the distribution of features, and in their high dimensionality. In this course, we work through some of these issues, paying particular attention to the aligning of the statistical questions we want to investigate with the choice of statistical models, as well as focusing on the interpretation of results. Analysis will be carried out in R and students will develop a suite of tools as they work through their course projects.

36-490 Undergraduate Research
Intermittent: 9 units
This course is designed to give undergraduate students experience using statistics in real research problems. Small groups of students will be matched with clients and do supervised research for a semester. Students will gain skills in approaching a research problem, critical thinking, statistical analysis, scientific writing, and conveying and defending their results to an audience.
Prerequisite: 36-401

Course Website: http://www.stat.cmu.edu/academics/courselist

36-492 Topic Detection and Document Clustering
Intermittent: 6 units
Imagine if someone read all your email. Everything you sent, everything you received. What would they find? Do you have repeating topics? How do the topics change over time? The Enron Corporation was an energy, commodities, and services company in Houston, Texas that went spectacularly bankrupt in 2001 after it was revealed that it was engaging in systematic, planned accounting fraud. At its peak, it employed over 20,000 people with revenues over $100 billion. Its downfall was related to deregulation of California's energy commodity trading and a series of rolling power blackouts over months. For example, Enron traders encouraged the removal of power during the energy crisis by suggesting plant shutdowns. The resulting increase in the price for power made them a fortune. After Enron's collapse, journalists used the Freedom of Information Act to release the emails sent/received by the employees of Enron. Subsequently, the emails were analyzed to see who knew what and when. Every news article, email, letter, blog, tweet, etc can be thought of as an observation. We characterize these documents by their length, what words they use and how often, and possibly extra information like the time, the recipient, etc. Topic detection and document clustering methods are statistical and machine learning tools that extract and identify related documents, possibly over time. These methods need to be flexible enough to handle both very small and very large clusters of documents, topics that change in importance, and topics that appear and disappear. This class will emphasize application of methods and real-world data analysis. Class time will be split into lecture and "lab". (Bring your laptop.) Occasional homeworks and final project, but mostly we'll focus on the downfall of Enron as our overarching case study.
Prerequisite: 36-401

36-494 Astrostatistics
Intermittent: 6 units
Since a young age, many of us have pondered the vastness and beauty of the Universe as we gazed up at the night sky. Planets, moons, stars, galaxies, and beyond have fascinated humanity for centuries. It turns out it also provides a plethora of interesting and complex statistical problems. In this course, problems in astronomy, cosmology, and astrophysics are going provide motivation for learning about some advanced statistical methodology. Possible topics include computational statistics, topological data analysis, nonparametric regression, spatial statistics, and statistical learning. While exploring newer statistical methodology, we will get to sample a variety of problems that appeal to astrostatisticians Statistical problems related to exoplanets (planets orbiting stars outside our Solar System), the large-scale structure of the Universe (the "Cosmic Web''), dark matter (over 80% of the matter in the Universe is thought to be invisible), Type Ia supernova (a dying star eats its companion star until explodes), cosmic microwave background (a.k.a. "baby pictures of the Universe'') are some possibilities. This course will be suitable for advanced undergraduate statistics majors through Ph.D. level statistics students, and astronomy Ph.D. students with some background in statistics.
Prerequisite: 36-401 Min. grade C

36-497 Corporate Capstone Project
Fall and Spring: 9 units
This course is designed to give undergraduate students experience applying statistics & data science methodology to real industry projects. Small groups of students will be matched with industry clients and do supervised projects for a semester. Students will gain skills in approaching a real world problem, critical thinking, advanced statistical analysis, scientific writing, collaborating in an industry setting, communicating results, and meeting expectations with respect to deliverables and timelines. The industry clients will change and rotate each semester; available projects will be advertised prior to registration. The course size is limited, and students will submit an application including their project preferences. Students with skill sets matching project needs will be given priority. We will also take into consideration whether or not a student has had a recent prior corporate capstone experience with the goal of providing experiences to a broad group of qualified students.

36-601 Perspectives in Data Science I
Fall: 6 units
This course covers the principles and practice of Data Science including data input and cleaning, exploratory data analysis, intermediate R programming, beginning SAS programming, beginning to intermediate python programming, and SQL. For Master's in Statistical Practice students only.

36-602 Perspectives in Data Science II
Spring: 9 units
This course is a continuation of 36-601 and covers interactive data visualization with Shiny, advanced R programming techniques, intermediate SAS (macros), web scraping, Hadoop, and Spark. For Master's in Statistical Practice students only.
Prerequisite: 36-601 Min. grade C

36-611 Professional Skills for Statisticians I
Fall: 6 units
This course covers a variety of professional skills including resumes and cover letters, writing reports, oral presentations, teamwork, and project planning. Consulting skills are developed in the form of a whole-class consulting project. For Master's in Statistical Practice students only.

36-612 Professional Skills for Statisticians II
Spring: 6 units
This course is a continuation of 36-611 and covers additional writing and presentation skills, as well as interview skills. For Master's in Statistical Practice students only.
Prerequisite: 36-611 Min. grade C

36-617 Applied Linear Models
Fall: 12 units
This course covers the theory and practice of linear models in matrix form with emphasis on practical skills for working with real data and communicating results to technical and non-technical audiences. For Master's in Statistical Practice students only.

36-618 Experimental Design & Time Series
Spring: 12 units
This course covers fundamentals of experimental design including various ANOVA models, Latin squares and factorial and fractional factorial designs. The time series components covers exponential smoothing models and ARIMA, including seasonal models and transfer function models. Special topics are intermittent. For Master's in Statistical Practice students only.
Prerequisites: 36-601 Min. grade C and 36-617 Min. grade C

36-625 Probability and Mathematical Statistics I
Fall: 12 units
This course is a rigorous introduction to the mathematical theory of probability, and it provides the necessary background for the study of mathematical statistics and probability modeling. A good working knowledge of calculus is required. Topics include combinatorial analysis, conditional probability, generating functions, sampling distributions, law of large numbers, and the central limit theorem. Undergraduate students studying Computer Science, or considering graduate work in Statistics or Operations Research, must receive permission from their advisor and from the instructor. Prerequisite: 21-122 and 21-241 and (21-256 or 21-259).
Prerequisites: 21-123 or 21-256 or 21-118 or 21-122

36-626 Probability and Mathematical Statistics II
Intermittent: 12 units
An introduction to the mathematical theory of statistical inference. Topics include likelihood functions, estimation, confidence intervals, hypothesis testing, Bayesian inference, regression, and the analysis of variance. Not open to students who have received credit for 36-226. Students studying Computer Science should carefully consider taking this course instead of 36-220 or 36-226 after consultation with their advisor. Prerequisite: 36-625.
Prerequisite: 36-625

36-635 Applied Survival Analysis
Intermittent: 6 units
TBD

36-636 Methods for Clinical Trials
Intermittent: 6 units
TBD

36-650 Statistical Computing
Spring: 9 units
A detailed introduction to elements of computing relating to statistical modeling, targeted to advanced undergraduates, masters students, and doctoral students in Statistics. Topics include important data structures and algorithms; numerical methods; databases; parallelism and concurrency; and coding practices, program design, and testing. Multiple programming languages will be supported (e.g., C, R, Python, etc.). Those with no previous programming experience are welcome but will be required to learn the basics of at least one language via self-study. There are very limited spots for undergraduates; special permission from both advisor and instructor required.

36-651 Advanced Statistical Computing
Intermittent: 6 units
A project-based course in statistical computing. Students will choose individual projects on computing topics related to statistical modeling and practice, including databases, parallel and cluster programming, big data frameworks (e.g. Spark or Hadoop), algorithms and data structures, numerical methods, and other topics based on student interest. The course will include introductions to each topic as well as student presentations on the results of their projects. Multiple programming languages will be supported. Recommended prerequisite: 36-650 or 36-750
Prerequisite: 36-650 Min. grade B

36-661 Special Topics: Statistical Methods in Epidemiology
Intermittent: 9 units
Epidemiology is concerned with understanding factors that cause, prevent, and reduce diseases by studying associations between disease outcomes and their suspected determinants in human populations. Epidemiologic research requires an understanding of statistical methods and design. Epidemiologic data is typically discrete, i.e., data that arise whenever counts are made instead of measurements. In this course, methods for the analysis of categorical data are discussed with the purpose of learning how to apply them to data. The central statistical themes are building models, assessing fit and interpreting results. There is a special emphasis on generating and evaluating evidence from observational studies. Case studies and examples will be primarily from the public health sciences.

36-663 Multilevel and Hierarchical Models
Intermittent: 9 units
Multilevel and hierarchical models are among the most broadly applied "sophisticated" statistical models, especially in the social and biological sciences. They apply to situations in which the data "cluster" naturally into groups of units that are more related to each other than they are the rest of the data. In the first part of the course we will see how to generalize linear models to multilevel and hierarchical models and relate them to other areas of statistics, and in the last part of the course we will learn how Bayesian statistical methods can help us to build, estimate and diagnose problems with these models using a variety of data sets and examples.

36-665 Special Topics: Bayesian Methods
Intermittent: 9 units
TBD

36-666 Special Topics: Statistical Methods in Finance
Intermittent: 9 units
Financial econometrics is the interdisciplinary area where we use statistical methods and economic theory to address a wide variety of quantitative problems in finance. These include building financial models, testing financial economics theory, simulating financial systems, volatility estimation, risk management, capital asset pricing, derivative pricing, portfolio allocation, proprietary trading, portfolio and derivative hedging, and so on and so forth. Financial econometrics is an active field of integration of finance, economics, probability, statistics, and applied mathematics. Financial activities generate many new problems and products, economics provides useful theoretical foundation and guidance, and quantitative methods such as statistics, probability and applied mathematics are essential tools to solve quantitative problems in finance. Professionals in finance now routinely use sophisticated statistical techniques and modern computation power in portfolio management, proprietary trading, derivative pricing, financial consulting, securities regulation, and risk management.

36-667 Special Topics: Data over Space & Time
Intermittent: 9 units
This course is an introduction to the opportunities and challenges of analyzing data from processes unfolding over space and time. It will cover basic descriptive statistics for spatial and temporal patterns; linear methods for interpolating, extrapolating, and smoothing spatio-temporal data; basic nonlinear modeling; and statistical inference with dependent observations. Class work will combine practical exercises in R, a little mathematics on the underlying theory, and case studies analyzing real problems from various fields (economics, history, meteorology, ecology, etc.). Depending on available time and class interest, additional topics may include: statistics of Markov and hidden-Markov (state-space) models; statistics of point processes; simulation and simulation-based inference; agent-based modeling; dynamical systems theory.

36-668 Special Topics: Text Analysis
Intermittent: 9 units
TBD

36-675 Data Ethics & Responsible Conduct of Research
Intermittent: 3 units
TBD

36-692 Topic Detection and Document Clustering
Intermittent: 6 units
Imagine if someone read all your email. Everything you sent, everything you received. What would they find? Do you have repeating topics? How do the topics change over time? The Enron Corporation was an energy, commodities, and services company in Houston, Texas that went spectacularly bankrupt in 2001 after it was revealed that it was engaging in systematic, planned accounting fraud. At its peak, it employed over 20,000 people with revenues over $100 billion. Its downfall was related to deregulation of California's energy commodity trading and a series of rolling power blackouts over months. For example, Enron traders encouraged the removal of power during the energy crisis by suggesting plant shutdowns. The resulting increase in the price for power made them a fortune. After Enron's collapse, journalists used the Freedom of Information Act to release the emails sent/received by the employees of Enron. Subsequently, the emails were analyzed to see who knew what and when. Every news article, email, letter, blog, tweet, etc can be thought of as an observation. We characterize these documents by their length, what words they use and how often, and possibly extra information like the time, the recipient, etc. Topic detection and document clustering methods are statistical and machine learning tools that extract and identify related documents, possibly over time. These methods need to be flexible enough to handle both very small and very large clusters of documents, topics that change in importance, and topics that appear and disappear. This class will emphasize application of methods and real-world data analysis. Class time will be split into lecture and "lab". (Bring your laptop.) Occasional homeworks and final project, but mostly we'll focus on the downfall of Enron as our overarching case study.

36-699 Statistical Immigration
Fall: 3 units
Students are introduced to the faculty and their interests, the field of statistics, and the facilities at Carnegie Mellon. Each faculty member gives at least one elementary lecture on some topic of his or her choice. In the past, topics have included: the field of statistics and its history, large-scale sample surveys, survival analysis, subjective probability, time series, robustness, multivariate analysis, psychiatric statistics, experimental design, consulting, decision-making, probability models, statistics and the law, and comparative inference. Students are also given information about the libraries at Carnegie Mellon and current bibliographic tools. In addition, students are instructed in the use of the Departmental and University computational facilities and available statistical program packages. THIS COURSE IS FOR PHD STUDENTS IN THE DEPT OF STATISTICS ONLY.

36-700 Probability and Mathematical Statistics
Fall: 12 units
This is a one-semester course covering the basics of statistics. We will first provide a quick introduction to probability theory, and then cover fundamental topics in mathematical statistics such as point estimation, hypothesis testing, asymptotic theory, and Bayesian inference. If time permits, we will also cover more advanced and useful topics including nonparametric inference, regression and classification. Prerequisites: one- and two-variable calculus and matrix algebra.

36-705 Intermediate Statistics
Fall: 12 units
This course covers the fundamentals of theoretical statistics. Topics include: probability inequalities, point and interval estimation, minimax theory, hypothesis testing, data reduction, convergence concepts, Bayesian inference, nonparametric statistics, bootstrap resampling, VC dimension, prediction and model selection.

36-707 Regression Analysis
All Semesters: 12 units
This is a course in data analysis. Topics covered include: Simple and multiple linear regression, causation, weighted least-squares, global and case diagnostics, robust regression, exponential families, logistic regression and generalized linear models; Model selection: prediction risk, bias-variance tradeoff, risk estimation, model search, ridge regression and lasso, stepwise regression, maybe boosting; Smoothing and nonparametric regression: linear smoothers, kernels, local regression, penalized regression, regularization and splines, wavelets, variance estimation, confidence bands, local likelihood, additive models; Classification: parametric and nonparametric regression, LDA, QDA, trees. Practice in data analysis is obtained through course projects. This course is primarily for first year PhD students in Statistics & Data Science; it requires an appropriate background for entering that program.

36-708 Statistical Methods in Machine Learning
All Semesters: 12 units
TBD
Prerequisite: 36-705 Min. grade A

36-709 Advanced Statistical Theory I
All Semesters: 12 units
This is a core Ph.D. course in theoretical statistics. The class will cover a selection of modern topics in mathematical statistics, focussing on high-dimensional parametric models and non-parametric models. The main goal of the course is to provide the students with adequate theoretical background and mathematical tools to read and understand the current statistical literature on high-dimensional models. Topics will include: concentration inequalities, covariance estimation, principal component analysis, penalized linear regression, maximal inequalities for empirical processes, Rademacher and Gaussian complexities, non-parametric regression and minimax theory. This will be the first part of a two semester sequence.
Prerequisite: 36-705 Min. grade A

36-710 Advanced Statistical Theory
All Semesters: 12 units
This is a core Ph.D. course in theoretical statistics. The class will cover a selection of modern topics in mathematical statistics, focussing on high-dimensional parametric models and non-parametric models. The main goal of the course is to provide the students with adequate theoretical background and mathematical tools to read and understand the current statistical literature on high-dimensional models. Topics will include: concentration inequalities, covariance estimation, principal component analysis, penalized linear regression, maximal inequalities for empirical processes, Rademacher and Gaussian complexities, non-parametric regression and minimax theory.

36-721 Statistical Graphics and Visualization
Intermittent: 6 units
An effective statistical graphic is a powerful tool for analyzing data and communicating insights. This course will introduce students to creating, understanding, and critiquing such graphical displays, choosing the right visual tool for the task at hand. Students will learn how to produce legible, self-contained, informative graphics using statistical software, as well as how to plan effective statistical graphics by following the principles of human visual perception. Beyond the most commonly used graphs for univariate and bivariate data, we will cover useful visualizations for statistical model diagnostics; cartographic maps; network- and tree-structured data; and interactive exploration of high-dimensional datasets. Through project assignments, students will practice applying the principles of graphic design and interaction design. Course materials will primarily use R (including ggplot2 and Shiny), but we will also introduce Illustrator/Inkscape and Tableau, and students may complete assignments using other software if they wish (Python, MATLAB, etc.).

36-725 Convex Optimization
Intermittent: 12 units
Nearly every problem in machine learning can be formulated as the optimization of some function, possibly under some set of constraints. This universal reduction may seem to suggest that such optimization tasks are intractable. Fortunately, many real world problems have special structure, such as convexity, smoothness, separability, etc., which allow us to formulate optimization problems that can often be solved efficiently. This course is designed to give a graduate-level student a thorough grounding in the formulation of optimization problems that exploit such structure, and in efficient solution methods for these problems. The main focus is on the formulation and solution of convex optimization problems. These general concepts will also be illustrated through applications in machine learning and statistics. Students entering the class should have a pre-existing working knowledge of algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. Though not required, having taken 10-701 or an equivalent machine learning or statistics class is strongly encouraged, since we will use applications in machine learning and statistics to demonstrate the concepts we cover in class. Students will work on an extensive optimization-based project throughout the semester; those wanting to take the class without the project can register under the 9 unit option.

Course Website: http://www.stat.cmu.edu/~ryantibs/convexopt/

36-726 Statistical Practice
Spring: 12 units
Students are taught how to structure a consulting session, elicit and diagnose a problem, manage a project, and report an analysis. The class will participate in meetings with industrial and academic clients. For Master's in Statistical Practice students only.

36-727 Modern Experimental Design
Intermittent: 6 units
Designed experiments are crucial to draw causal conclusions with minimum expense and maximum precision. This course introduces the basic principles and theory of experimental design, including randomized designs, blocking, analysis of covariance, factorial designs, and power analysis, along with a selection of more advanced topics, which may include sequential and adaptive designs, A/B testing, the design of observational studies, or other topics depending on time and class interest. Students will learn to design appropriate experiments for a variety of research scenarios, and practice these skills through a course project. Coursework will primarily use R for analysis of experimental data. Students will be expected to have taken a graduate course in regression or being taking a graduate course in regression concurrently.

36-730 Graphical Models and its Applications
Intermittent: 6 units
Probabilistic graphical models (PGMs) lie at the intersection of probability and graph theory. Its application to real world problems has served useful in the process of understanding, formulating and solving problems, and in particular as tools for making decisions and calculating the probability of a particular based on (often incomplete) collections of prior knowledge. This course will introduce the fundamentals of graphical models and probability propagation algorithms; demonstrate how to build and model (PGMs) using R, focusing on DAGs. The aim will be to learn and demonstrate the versatility of PGMs, through applications and methodology, including its use in decision support, causal and temporal problems. Applications will focus on areas of public policy including criminal justice/ forensic science, health/ medical, environment, etc.

36-731 Foundations of Causal Inference
Intermittent: 6 units
This course will provide an introduction to the fundamentals of causal inference. Causal inference is concerned with whether and how one can go beyond statistical associations to draw causal conclusions from observational data. Topics will include: counterfactuals (potential outcomes and graphs), identification and estimation of average treatment effects in experiments and observational studies, nonparametric bounds, sensitivity analysis, instrumental variables, effect modification, and longitudinal studies.

36-732 Modern Causal Inference
Intermittent: 6 units
This course will provide an in-depth look at modern causal inference. Topics will include: optimal treatment regimes, mediation, principal stratification, stochastic interventions, accounting for complex confounding and exposures, and methods for efficient nonparametric estimation. Some background in mathematical statistics is advised.

36-733 Probability Models and Stochastic Processes
Intermittent: 6 units
By the end of this course you will be able to handle basic discrete and continuous time stochastic processes, including random walks, branching processes, Markov chains, Markov chain Monte Carlo (MCMC), Poisson processes, birth and death processes, renewal processes, and queuing processes. This class is not overly mathematical, but techniques such as generating functions, difference and differential equations, linear systems of equations, are needed at a basic level. Students will be expected to have taken a graduate course in regression or being taking a graduate course in regression concurrently. Knowledge of R or similar statistical packages is needed.

36-736 Methods for Clinical Trials
Intermittent: 6 units
TBD

36-741 Statistics meets Optimization: Randomized Sketching Methods
All Semesters: 6 units
In this mini, we will discuss some aspects of the interface between statistics and optimization. The goal of these lectures is to touch on various evolving areas at this interface. The objectives of optimization can be influenced by underlying statistical objectives in many ways, for example, the statistics precision caused by not having enough sample size is often of higher order than the machine precision; worst-case instance can be too conservative compared to the random ensembles; polynomial-time complexity may still be too large to be tractable. To further discuss these issues, we will start with a dimension reduction technique based on random projections and analyze how this technique helps us achieve faster optimization convergence without hurting statistical precision.

36-742 Statistics meets Optimization: Approximate Message Passing Algorithm
All Semesters: 6 units
In this mini, we focus our attention on the recent development of the approximate message passing algorithm. We follow a rigorous approach that builds upon ideas from statistical physics, information theory and graphical models, and is based on the analysis of an highly efficient reconstruction algorithm. We start with some basics for the probability graphical model, introduce the message passing algorithm and motivate the AMP algorithm along the way. Then we will discuss the exact asymptotic characterization in terms of the so-called state evolution and talk about the applications in LASSO and more generally, high-dimensional robust M-estimation.

36-743 Statistical Methods for Reproduciblity and Replicability: Static Settings
Intermittent: 6 units
See http://www.stat.cmu.edu/~aramdas/reproducibility19/

36-744 Statistical Methods for Reproducibility and Replicability: Dynamic Settings
All Semesters: 6 units
See http://www.stat.cmu.edu/~aramdas/reproducibility19/

36-746 Statistical Methods for Neuroscience and Psychology
Intermittent: 12 units
This course provides a survey of basic statistical methods, emphasizing motivation from underlying principles and interpretation in the context of neuroscience and psychology. Though 36-746 assumes only passing familiarity with school-level statistics, it moves faster than typical university-level first courses. Vectors and matrices will be used frequently, as will basic calculus. Topics include Probability, Random Variables, and Important Distributions (binomial, Poisson, and normal distributions; the Law of Large Numbers and the Central Limit Theorem); Estimation and Uncertainty (standard errors and confidence intervals; the bootstrap); Principles of Estimation (mean squared error; maximum likelihood); Models, Hypotheses, and Statistical Significance (goodness-of-fit, p-values; power); General methods for testing hypotheses (permutation, bootstrap, and likelihood ratio tests); Linear Regression (simple linear regression and multiple linear regression); Analysis of Variance (one-way and two-way designs; multiple comparisons); Generalized Linear and Nonlinear Regression (logistic and Poisson regression; generalized linear models); and Nonparametric regression (smoothing scatterplots; smoothing histograms).

36-750 Statistical Computing
Fall: 9 units
A detailed introduction to elements of computing relating to statistical modeling, targeted to advanced undergraduates, masters students, and doctoral students in Statistics. Topics include important data structures and algorithms; numerical methods; databases; parallelism and concurrency; and coding practices, program design, and testing. Multiple programming languages will be supported (e.g., C, R, Python, etc.). Those with no previous programming experience are welcome but will be required to learn the basics of at least one language via self-study.

36-751 Advanced Statistical Computing
Intermittent: 6 units
A project-based course in statistical computing. Students will choose individual projects on computing topics related to statistical modeling and practice, including databases, parallel and cluster programming, big data frameworks (e.g. Spark or Hadoop), algorithms and data structures, numerical methods, and other topics based on student interest. The course will include introductions to each topic as well as student presentations on the results of their projects. Multiple programming languages will be supported. Recommended prerequisite: 36-650 or 36-750
Prerequisite: 36-750 Min. grade B

36-759 Statistical Models of the Brain
Intermittent: 12 units
This new course is intended for CNBC students, as an additional option for fulfilling the computational core course requirement, but it will also be open to Statistics and Machine Learning students. It should be of interest to anyone wishing to see the way statistical ideas play out within the brain sciences, and it will provide a series of case studies on the role of stochastic models in scientific investigation. Statistical ideas have been part of neurophysiology and the brainsciences since the first stochastic description of spike trains, and the quantal hypothesis of neurotransmitter release, more than 50 years ago. Many contemporary theories of neural system behavior are built with statistical models. For example, integrate-and-fire neurons are usually assumed to be driven in part by stochastic noise; the role of spike timing involves the distinction between Poisson and non-Poisson neurons; and oscillations are characterized by decomposing variation into frequency-based components. In the visual system, V1 simple cells are often described using linear-nonlinear Poisson models; in the motor system, neural response may involve direction tuning; and CA1 hippocampal receptive field plasticity has been characterized using dynamic place models. It has also been proposed that perceptions, decisions, and actions result from optimal (Bayesian) combination of sensory input with previously-learned regularities; and some investigators report new insights from viewing whole-brain pattern responses as analogous to statistical classifiers. Throughout the field of statistics, models incorporating random ``noise'' components are used as an effective vehicle for data analysis. In neuroscience, however, the models also help form a conceptual framework for understanding neural function. This course will examine some of the most important methods and claims that have come from applying statistical thinking

36-762 Data Privacy
Fall: 6 units
Protection of individual data is a growing problem due to the large amount of sensitive and personal data being collected, stored, analyzed, and shared across multiple domains and stakeholders. Researchers are facing new policies and technical requirements imposed by funding agencies on accessing and sharing of the research data. This course will introduce students to (1) key principles associated with the concepts of confidentiality and privacy protection, and (2) techniques for data sharing that support useful statistical inference while minimizing the disclosure of sensitive personal information. Methodologies to be considered will include tools for disclosure limitation used by government statistical agencies and those associated with the approach known as differential privacy which provides a formal privacy guaranteed. Students will explore specific techniques using special tools in R.

36-763 Multilevel and Hierarchical Models
Fall: 6 units
Multilevel and hierarchical models are among the most broadly applied "sophisticated" statistical models, especially in the social and biological sciences. They apply to situations in which the data "cluster" naturally into groups of units that are more related to each other than they are the rest of the data. In the first part of the course we will review linear and generalized linear models. In the second part we will see how to generalize these to multilevel and hierarchical models and relate them to other areas of statistics, and in the third part of the course we will learn how Bayesian statistical methods can help us to build, estimate and diagnose problems with these these models using a variety of data sets and examples.

36-765 Writing in Statistics
Intermittent: 6 units
There is no one correct way to write. But there are things you can do that tend to make it difficult for a reader to absorb the ideas you are writing about, or make it easier for the reader. Thus, it is important to focus on the reader, and the constraints and habits of mind that most readers (even in the rarefied population of academics who can understand the technical details of your work) bring to the task of reading what you have written. The goals for students in this course are: to understand that writing requires an intellectual investment similar to the investment that you put into other areas of your research, from developing research questions, data collection, and data analysis, to writing and testing algorithms, and formulating and proving theorems; to understand ways of organizing your writing that make it more likely that the reader will interpret and understand your ideas in the way that you intend; and to gain experience writing with these ideas in mind. The course is most suitable for graduate students in statistics who are engaged in a writing project (ADA paper, journal article, thesis work, etc.).

36-771 Martingales 1: Concentration Inequalities, The Basics
Intermittent: 6 units
Martingales are a central topic in statistics, but are even more relevant today due to modern applications to sequential learning and decision making problems. This course will present a unified derivation of a wide-variety of new and old concentration inequalities for martingales. We will prove inequalities for scalars and matrices, that hold under a wide variety of nonparametric assumptions. For example, we will encounter exponential concentration inequalities for martingales whose increments have heavy-tails, for continuous-time martingales, and for martingales in general Banach spaces. This course will be a pre-requisite for the second mini, which focuses more on applications.

36-772 Martingales 2: Concentration Inequalities, Applications to Sequential Analysis
Intermittent: 6 units
This second mini will focus on deriving guarantees for a variety of important problems in sequential analysis using the tools developed in the first mini, as well as new tools such as uniform nonasymptotic versions of the law of the iterated logarithm for scalars and matrices. Applications include sequential analogs of the t-test, that are valid without a Gaussian assumption, best-arm identification in multi-armed bandits, average treatment effect estimation in sequential clinical trials, sequential covariance matrix estimation, and other such problems.

36-775 Data Ethics & Responsible Conduct of Research
Intermittent: 3 units
TBD

36-777 Multivariate Analysis I
Intermittent: 6 units
This is the first part of a semester long course on multivariate analysis. The aim of the class is to provide fundamental tools in understanding multivariate (including high dimensional) data. In this MINI we will study in detail the multivariate Gaussian distribution, the Wishart and Hotelling distributions. Time permitting we will cover principal component analysis (PCA) as well as discriminant analysis.

36-778 Multivariate Analysis II
All Semesters: 6 units
This is the second part of the multivariate analysis class. This MINI will discuss asymptotic inequalities for eigenvalues of Gaussian matrices, quadratic form concentration inequalities, and matrix estimation (including multivariate regression, covariance matrix estimation, PCA). Time permitting the class might also cover dimension reduction and graphical models.

36-779 Topics in Modern Multivariate Analysis II
Intermittent: 6 units
This is the second part of a semester-long course on modern multivariate analysis. In this MINI we will introduce recent research results focusing on high dimensional multivariate analysis. Topics include high dimensional mean and covariance testing, kernel based methods, structured high dimensional subspace estimation (sparse PCA, functional data), and network data.

36-791 Central Limit Theorem in High-Dimensions
Intermittent: 6 units
TBD

36-792 Topic Detection and Document Clustering
Intermittent: 6 units
Imagine if someone read all your email. Everything you sent, everything you received. What would they find? Do you have repeating topics? How do the topics change over time? The Enron Corporation was an energy, commodities, and services company in Houston, Texas that went spectacularly bankrupt in 2001 after it was revealed that it was engaging in systematic, planned accounting fraud. At its peak, it employed over 20,000 people with revenues over $100 billion. Its downfall was related to deregulation of California's energy commodity trading and a series of rolling power blackouts over months. For example, Enron traders encouraged the removal of power during the energy crisis by suggesting plant shutdowns. The resulting increase in the price for power made them a fortune. After Enron's collapse, journalists used the Freedom of Information Act to release the emails sent/received by the employees of Enron. Subsequently, the emails were analyzed to see who knew what and when. Every news article, email, letter, blog, tweet, etc can be thought of as an observation. We characterize these documents by their length, what words they use and how often, and possibly extra information like the time, the recipient, etc. Topic detection and document clustering methods are statistical and machine learning tools that extract and identify related documents, possibly over time. These methods need to be flexible enough to handle both very small and very large clusters of documents, topics that change in importance, and topics that appear and disappear. This class will emphasize application of methods and real-world data analysis. Class time will be split into lecture and "lab". (Bring your laptop.) Occasional homeworks and final project, but mostly we'll focus on the downfall of Enron as our overarching case study.

Dietrich College Interdisciplinary Majors

When addressing complex issues, we often rely on approaches that take advantage of a variety of relevant disciplines. The college houses the special category of "interdepartmental majors" for programs where this interdisciplinary approach is most pronounced and in which the varied disciplinary perspectives are most fully integrated. These majors are presented here separately, rather than as departmentally-based options, to reflect and underscore their sponsorship by more than one academic department and the unique features that follow from this structure.

Interdepartmental majors are administered by the academic department of the major's faculty advisor.

The Major in Economics and Mathematical Sciences

Kathleen Conway, Academic Advisor
Location: Tepper Quad 2407
kconway@andrew.cmu.edu

The B.S. in Economics and Mathematical Sciences (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/undergraduateeconomicsprogram/#bsineconomicsandmathematicalsciencescurriculum) is a collaborative effort between the Department of Mathematical Sciences and the Undergraduate Economics Program. Combining advanced mathematics with advanced economic theory is the hallmark of this curriculum. The curriculum provides students with courses that complement and develop depth of understanding of economic theory, applied economics, and applied mathematics. This major offers an integrated curriculum, guiding students through a program of coursework that exploits and builds upon the synergies between mathematics and economics. This degree program equips students with the mathematical tools that are essential for success in Ph.D. programs in economics; mathematics; and key functional areas of business including finance, accounting, marketing, and information systems. Students pursuing this degree will be well prepared for the beginning of their research careers in academia, government, and industry. There are a limited number of student slots in this program; interested students may apply as early as their sophomore year.

The Major in Economics and Politics

Kathleen Conway, *Senior Academic Advisor, Economics*
Location: Tepper Quad 2407
kconway@andrew.cmu.edu

Emily Half, *Deputy Director, Institute for Politics and Strategy Advising*
Location: Baker Hall A55B
ehalf@andrew.cmu.edu

Politics and economics are deeply interconnected. Political institutions and decision-making impact economic growth, income distribution, and many other aspects of economic life. Both fiscal and monetary policies affect the economy, but these policies are often employed with political considerations in mind and can influence political activity. Conversely, economic outcomes shape political preferences and policy choices. The overlap between these two disciplines is endless. For example, while the United Nations is often thought of in purely political terms, the Security Council can and does impose sanctions on countries- an example of an economic policy used for political change.

The Economics and Politics major (p. 305) is offered jointly between the Undergraduate Economics Program (https://www.cmu.edu/tepper/programs/undergraduate-economics) (UEP) and the Institute for Politics and Strategy (https://www.cmu.edu/ips) (IPS). Students are equal members of both academic units and receive advising from both units. The major will appeal to any student interested in the design, evaluation, and political implementation of policy. It will be especially attractive to students considering careers in politics, government agencies, political and business consulting, lobbying, or the law.

The B.S. in Economics and Politics is an interdisciplinary major. The major will develop the political context and underpinnings of economic policy making. It will explore how political institutions resolve the tradeoffs and disagreements associated with policymaking and how they can facilitate or impede desirable economic outcomes.

IPS strengths lie in topics like national security, grand strategy, and globalization. Economic policy is just one facet of grand strategy, through which an administration pursues domestic and international goals. This major will also address key issues such as the complementarity between the multilateral economic institutions such as the IMF and World Bank and the use of economic coercion, and enable students to understand economic statecraft more broadly. Whether coercion is successful depends not just on the levers of power but on also on variations in authoritarian regime structure, and complex linkages in the international economy. This is also important for our understanding of the relationship between international economics on human rights practices, extending even to how treaty commitments can facilitate compliance with a global initiative to combat climate change. And, not least important, there is broad recognition that the viability of the "Euro Zone" depends on whether the political-economic agreements necessary to mitigate institutional weaknesses are politically feasible or destined to failure.

Economics and Politics is available as both a primary and additional major.

The Major in Economics and Statistics

Samantha Nielsen, *Statistics & Data Science Lead Academic Advisor*
Kathleen Conway, *Economics Senior Academic Advisor*
Rebecca Nugent and Edward Kennedy, *Faculty Advisors*
Carol Goldburg, Executive Director, *Undergraduate Economics Program*

Statistics & Data Science Location: Baker Hall 132
statadvising@stat.cmu.edu

Economics Location: Tepper 2400
econprog@andrew.cmu.edu

The B.S. in Economics and Statistics is jointly advised by the Department of Statistics and Data Science and the Undergraduate Economics Program.

The Major in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. With joint curriculum from the Department of Statistics and Data Science and the Undergraduate Economics Program, the major provides students with a solid foundation in the theories and methods of both fields. Students in this major are trained to advance the understanding of economic issues through the analysis, synthesis and reporting of data using the advanced empirical research methods of statistics and econometrics. Graduates are well positioned for admission to competitive graduate programs, including those in statistics, economics and management, as well as for employment in positions requiring strong analytic and conceptual skills - especially those in economics, finance, education, and public policy.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

The requirements for the B.S. in Economics and Statistics are the following:

I. Prerequisites 38-39 units

1. Mathematical Foundations 38-39 units

Calculus

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Note: Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Note: Taking/having credit for both 21-111 and 21-112 is equivalent to 21-120. The Mathematical Foundations total is then 48-49 units. The Economics and Statistics major would then total 201-211 units.

Linear Algebra

One of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	10
21-242	Matrix Theory	10

Note: 21-241 and 21-242 are intended only for students with a very strong mathematical background.

II. Foundations 18-36 units

2. Economics Foundations 18 units

73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9

3. Statistical Foundations 9-18 units

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data	9
36/70-207	Probability and Statistics for Business Applications	9
36-220	Engineering Statistics and Quality Control	9
36-247	Statistics for Lab Sciences	9

Note: Students who enter the program with 36-225 or 36-226 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for the Economics and Statistics Major may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

36-202	Statistics & Data Science Methods **	9
36-208	Regression Analysis	9
36-290	Introduction to Statistical Research Methodology	9
36-309	Experimental Design for Behavioral & Social Sciences	9

* Or extra data analysis course in Statistics

** Must take prior to 36-401 Modern Regression.

Advanced
Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Sequence 2 (For students beginning later in their college career)

Advanced
Choose *three* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

III. Disciplinary Core 126 units

1. Economics Core 45 units

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-270	Professional Communication for Economists	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9

2. Statistics Core 36 units

36-225	Introduction to Probability Theory *#	9

and *one* of the following two courses:

36-226	Introduction to Statistical Inference *	9
36-326	Mathematical Statistics (Honors) *	9

and *both* of the following two courses:

36-401	Modern Regression *	9
36-402	Advanced Methods for Data Analysis	9

*In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-225 (or equivalents), 36-226 or 36-326 and 36-401.

#It is possible to substitute 36-217, 36-218, or 21-325 for 36-225 36-225 36-22536-225. (36-225 36-225 36-22536-225 is the standard introduction to probability, 36-217 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 21-325 21-32521-325 is a rigorous Probability Theory course offered by the Department of Mathematics.)

3. Computing 9 units

36-350	Statistical Computing *	9

*In rare circumstances, a higher level *Statistical* Computing course, approved by your Statistics advisor, may be used as a substitute.

4. Advanced Electives 36 units

Students must take two advanced Economics elective courses (numbered 73-300 through 73-495, excluding 73-374) and two (or three - depending on previous coursework, see Section 3) advanced Statistics elective courses (numbered 36-303, 36-311, 36-315, 36-46x, 36-490, or 36-497).

Students pursuing a degree in Economics and Statistics also have the option of earning a concentration area (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Total number of units for the major	**191-201 units**
Total number of units for the degree	**360 units**

Professional Development

Students are strongly encouraged to take advantage of professional development opportunities and/or coursework. One option is 73-210 Economics Colloquium I, a fall-only course that provides information about careers in Economics, job search strategies, and research opportunities. The Department of Statistics and Data Science also offers a series of workshops pertaining to resume preparation, graduate school applications, careers in the field, among other topics. Students should also take advantage of the Career and Professional Development Center.

Additional Major in Economics and Statistics

Students who elect Economics and Statistics as a second or third major must fulfill all Economics and Statistics degree requirements. Majors in many other programs would naturally complement an Economics and Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least six courses (three Economics and three Statistics) that do not count for their primary major. If students do not have at least six, they typically take additional advanced data analysis or economics electives, depending on where the double counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Economics and Statistics.

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Economics and Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Economics and Statistics.

Sample Program

The following sample program illustrates one way to satisfy the requirements of the Economics and Statistics Major. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule).

Freshman		**Sophomore**	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	36-202 Statistics & Data Science Methods	36-225 Introduction to Probability Theory	21-240 Matrix Algebra with Applications
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	36-226 Introduction to Statistical Inference
73-102 Principles of Microeconomics	73-103 Principles of Macroeconomics	73-210 Economics Colloquium I *not required	73-240 Intermediate Macroeconomics
73-060 Economics: BaseCamp *not required	-----		73-274 Econometrics I
-----	-----	73-265 Economics and Data Science	-----

Junior		**Senior**	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	Statistics Elective	Economics Elective
36-401 Modern Regression	73-270 Professional Communication for Economists	Economics Elective	Statistics Elective
73-374 Econometrics II	-----	-----	-----
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*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Prospective PhD students might add 21-127 fall of sophomore year, replace 21-240 with 21-241, add 21-260 in spring of junior year and 21-355 in fall of senior year.

Additional Major in Environmental Policy

Professor Abigail E. Owen, *Faculty Advisor*
aeowen@cmu.edu, Wean Hall 3709, 412-268-2953

Dr. Andrew Ramey, *Academic Advisor*
aramey@andrew.cmu.edu, Baker Hall 240, 412-268-7906

The additional major in Environmental Policy focuses on human - environment interactions from a multitude of disciplinary perspectives. The curriculum draws on the expertise of faculty across several Carnegie Mellon colleges in order to provide students with the interdisciplinary background and skills necessary to understand environmental problems and the means to mitigate them. It emphasizes three general areas: (1) natural science and technology; (2) social sciences; and (3) the humanities. The flexible curriculum features training in research methods; a set of core courses on fundamental environmental issues including energy, pollution, and biological diversity; and a project course experience geared toward policy formulation. The total units required are 121.

Note that some courses carry prerequisites and/or reserve seats for primary majors. Students interested in pursuing the additional major must meet beforehand with the Faculty Advisor and their home unit academic advisor in order to evaluate the feasibility of completing the additional major and to map out a course of study. Double counting follows guidelines set by the Dietrich College. Students are encouraged to be alert to new course offerings; every effort will be made to find equivalent courses that meet student interest when done in consultation with the Faculty Advisor.

Prerequisites (55-57 units)

Complete ALL of the following courses:

		Units
21-111	Differential Calculus-(or equivalent)	10
36-200	Reasoning with Data Students entering CMU prior to 2018 may substitute 36-201 for 36-200.	9
36-202	Statistics & Data Science Methods	9

Complete THREE of the following courses:

03-121	Modern Biology	9
03-124	Modern Biology Laboratory (03-121 is corequisite)	9
03-125	Evolution	9
03-128	Biology for Life Special Topics Biology for Life: Environmental Science (Fall 2019, Section A only)	9
09-103	Atoms, Molecules and Chemical Change	9
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-225	Climate Change: Chemistry, Physics and Planetary Science	9

Disciplinary Perspectives: Complete TWO of the following courses (18 units)

09-510	Chemistry and Sustainability	9
73-427	Sustainability, Energy, and Environmental Economcs	9
76-319	Environmental Rhetoric	9
99-236	Introduction to Environmental Ideas	9

Thematic Electives: Complete TWO of the following courses (18 units)

12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
19-101	Introduction to Engineering and Public Policy	12
19-424	Energy and the Environment	9
76-395	Science Writing	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-336	Oil & Water: Middle East Perspectives	6
79-372/90-765	Cities, Technology, and the Environment	6
79-394	Exploring History through Geography	6
80-348	Health, Human Rights, and International Development	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9
90-765/79-372	Cities, Technology and the Environment	6
90-798	Systems Thinking for Environmental Policy & Planning	12
90-808	Energy Policy	6

(90-xxx Heinz College courses open only to seniors)

Research and Analytical Methods: Complete TWO of the following courses (18 units)

		Units
36-309	Experimental Design for Behavioral & Social Sciences	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
88-251	Empirical Research Methods	9
88-252	Causal Inference in the Field	9

Project Course: Complete ONE of the following courses (12 units)

19-451	EPP Projects (pre-approved topics)	12
19-452	EPP Projects (pre-approved topics)	12

The Major in Ethics, History, and Public Policy

Alex John London, *Director*
Location: Baker Hall 150A
ajlondon@andrew.cmu.edu
www.cmu.edu/dietrich/ehpp

The B.A./B.S. in Ethics, History, and Public Policy is an interdepartmental major offered jointly by the Departments of History and Philosophy. It prepares students for leadership positions by providing them with a rigorous, interdisciplinary humanistic and social-scientific education. It also serves as an excellent springboard for graduate study in a wide variety of disciplines such as law, public policy, ethics, and advocacy. The program focuses equally on the historical understanding of how modern-day problems have evolved, and the importance of developing clear criteria for ethical decision-making. The capstone project course provides students with the opportunity to engage with real-world public policy challenges using the methods, theories, and knowledge that they have gained through the major. Offered jointly by the departments of History and Philosophy, the B.A./B.S. in EHPP encourages specialization, internship experiences, and research in a wide range of policy areas.

Curriculum

Students graduating with a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science Degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 9 units in Economics, 36 units in History, 36 units in Philosophy, 27 units of elective courses, and a 12-unit senior capstone course. This program may also be taken as an additional (e.g., second) major. All courses toward the major must be taken for a letter grade, and 79-300 must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundations of Public Policy — 9 units

Choose one 9-unit course from the list below.

73-102	Principles of Microeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-110	Foundations of Political Economy	9

II. History Core — 36 units

Choose one 9-unit course from each category below:

Policy History (9 units)

79-300	Guns in American History: Culture, Violence, and Politics	9

U.S. History (9 units)

79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-249	20th & 21st Century U.S. History	9
79-320	Women, Politics, and Protest	9

Non-U.S. History (9 units)

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-237	Comparative Slavery	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-307	Religion and Politics in the Middle East	9

History Elective (9 units)

Take at least 9 additional units in the History Department with course number 79-200 or above. The following courses may not count: 79-400, 79-420, 79-449, 79-491, 79-505, 79-506.

III. Philosophy Core — 36 units

Choose one 9-unit course from each category below. No more than 9 units at the 100 level may be counted toward the Philosophy Core.

Ethics (9 units)

80-130	Introduction to Ethics	9
80-330	Ethical Theory	9

Political Philosophy (9 units)

80-135	Introduction to Political Philosophy	9
80-335	Social and Political Philosophy	9

Foundations of Social Science (9 units)

80-221	Philosophy of Social Science	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9

Applied Philosophy (9 units)

80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

IV. Senior Capstone Project Course — 12 units

79-449	EHPP Project Course [cross-listed]	12
80-449	EHPP Project Course	12

The Ethics, History and Public Policy Project Course is required for the Ethics, History and Public Policy major and is taken in the fall semester of the senior year. In this capstone course, Ethics, History and Public Policy majors carry out a collaborative research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis. The students develop an original research report based on both archival and contemporary policy analysis and they present their results to a client organization in the community.

V. Elective Courses — 27 units

Choose any three courses (at least 27 units) from any category or categories shown below. Substitution of elective courses that cohere with a student's interest or concentration may be allowed after consultation with and approval from the Director.

Engineering and Public Policy (some courses have prerequisites; see EPP catalog listing)

19-424	Energy and the Environment	9

Business

70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-332	Business, Society and Ethics	9
70-364	Business Law	9
70-365	International Trade and International Law	9
70-430	International Management	9

Economics (some courses have prerequisities; see Economics catalog listing)

73-352	Public Economics	9
73-359	Benefit-Cost Analysis	9
73-365	Firms, Market Structures, and Strategy	9
73-372	International Money and Finance	9
73-408	Law and Economics	9
73-476	American Economic History	9

English

76-492	Rhetoric of Public Policy	9

History

Courses from the EHPP History Core (above) may be taken as electives only if they are not being used to fulfill the core requirement. Double counting is not permitted.

79-206	Crime and Punishment in Early Modern Europe	9
79-228	The Civil Rights Movement and the World	9
79-233	The United States and the Middle East since 1945	9
79-234	Technology and Society	9
79-242	African American History: Reconstruction to the Present	9
79-247	African Americans, Imprisonment, and the Carceral State	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-298	Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal	6
79-299	From Newton to the Nuclear Bomb: History of Science, 1750-1950	9
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-305	Moneyball Nation: Data in American Life	9
79-310	Modern U. S. Business History: 1870 to the Present	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-320	Women, Politics, and Protest	9
79-322	Stalin and the Great Terror	9
79-325	U.S. Gay and Lesbian History	6
79-330	Medicine and Society	9
79-331	Body Politics: Women and Health in America	9
79-336	Oil & Water: Middle East Perspectives	6
79-338	History of Education in America	9
79-339	Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)	6
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6
79-342	Introduction to Science and Technology Studies	9
79-343	Education, Democracy, and Civil Rights	9
79-349	United States and the Holocaust	6
79-370	Disasters in American History (2):Epidemics & Fires	6
79-371	African American Urban History	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-397	Environmental Crises and the City	6

Philosophy

Courses from the EHPP Philosophy Core (above) may be taken as electives only if they are not being used to fulfill the core requirement. Double counting is not permitted.

80-256	Modern Moral Philosophy	9
80-305	Choices, Decisions, and Games	9
80-405	Game Theory	9

Institute for Politics and Strategy

84-310	International Political Economy	9
84-380	Grand Strategy in the United States	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6

Social and Decision Sciences

88-223	Decision Analysis	12
88-281	Topics in Law: 1st Amendment	9
88-444	Public Policy and Regulation	9

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

21-257	Models and Methods for Optimization	9
36-202	Statistics & Data Science Methods	9
or 36-208	Regression Analysis	
or 70-208	Regression Analysis	
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
70-257	Optimization for Business	9
80-305	Choices, Decisions, and Games	9
80-405	Game Theory	9
84-265	Political Science Research Methods	9
88-251	Empirical Research Methods	9
88-221	Analytical Foundations of Public Policy	9
88-223	Decision Analysis	12
88-300	Programming and Data Analysis for Social Scientists	9

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy, Professor Alex John London, ajlondon@andrew.cmu.edu.

Ethics, History, and Public Policy Sample Curriculum

Junior Year		Senior Year	
Fall	**Spring**	**Fall**	**Spring**
Core requirement in Economics	Core requirement in History or Philosophy	Capstone Course	EHPP Elective Course
Core requirement in History or Philosophy	Core requirement in History or Philosophy	EHPP Elective Course	Second Course (open)
Core requirement in History or Philosophy	Core requirement in History or Philosophy	EHPP Elective Course	Third Course (open)
Core requirement in History or Philosophy	Core requirement in History or Philosophy	Fourth Course (open)	Fourth Course (open)
Core requirement in History or Philosophy	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be. Students may enter the EHPP major, and begin major course requirements, as early as the start of the sophomore year, or even in the first year. Students should consult their advisor when planning their program.

The Major in Information Systems

Randy S. Weinberg, *Faculty Program Director*

Location: Porter Hall 224C, rweinberg@cmu.edu

Carol Young, *Program Advisor*
Location: Porter Hall 222F, caroly@cmu.edu

Faculty: C.F. Larry Heimann, Jeria Quesenberry, Raja Sooriamrthi

Information Systems (IS) is a unique and innovative undergraduate interdisciplinary program, drawing on a wide range of exciting college and university strengths. IS is an internationally recognized undergraduate major for students who want to design and implement effective solutions to meet organizational and management needs for information and decision support. IS majors learn how elements of organizations, technology, economics, social aspects and human interaction work together to create effective computer-based information systems to affect real outcomes. Graduates of the Program are ideally situated to take a leading role in managing and shaping our information-based future.

For full program information, go to The Major in Information Systems (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/informationsystems).

The Major in Linguistics

Tom Werner, *Director*
Location: Baker Hall 155F
twerner@andrew.cmu.edu
www.cmu.edu/dietrich/linguistics

Linguistics is the study of human language, and it encompasses a broad spectrum of research questions, approaches and methodologies. Some linguists are concerned with the cognitive aspects of language learning, production and comprehension; some are concerned with language as a social and cultural phenomenon; others engage in the analysis of linguistic form and meaning, some from a functional and others from a formal perspective. There are also computational approaches to linguistics with both applied and theoretical goals.

The major in Linguistics reflects the multidisciplinary character of the field and of the Linguistics faculty here at Carnegie Mellon, offering a program which provides students with the fundamental tools of linguistic analysis while maintaining a focus on the human context in which language is learned and used. The major is available as either a primary major or an additional major. It is an ideal choice for students with a general interest in their own or other languages, and combines well thematically with studies in any of the departments represented in the major.

Curriculum

The Linguistics primary major requires a total of 12 courses plus a senior thesis. The Linguistics additional major requires at total of 13 courses. This includes 2 semesters of language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor.

Linguistics Core (36 units)

Complete the following requirements.

80-180	Nature of Language	9
80-282	Phonetics and Phonology I	9
80-280	Linguistic Analysis	9
or 80-285	Natural Language Syntax	
80-381	Meaning in Language	9
or 80-383	Language in Use	

Extended Core (27 units)

Choose three courses (27 units) from Extended Core and/or additional courses from Linguistics Core.

80-283	It Matters How You Say It	9
80-284	Invented Languages	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: Transcription and Analysis	9
80-382	Phonetics and Phonology II	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9

Electives

Primary majors choose **three** additional electives (27 or more units).
Additional majors choose **four** additional electives (36 or more units).
Primary majors see thesis requirement below.

These can be **additional courses from the Core or Extended Core courses listed above**, **the electives list below**, or any other course which is approved by the Director as a linguistics elective. Listed below are the additional electives taught on a regular basis. **Additional appropriate courses** are offered irregularly or on a one-off basis. The Director will provide students with a list of possible electives each semester, and will assist students in selecting electives which are consistent with their goals and interests.

Philosophy

80-380	Philosophy of Language	9
80-484	Language and Thought	9

English

76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-385	Introduction to Discourse Analysis	9
76-386	Language & Culture	9
76-389	Rhetorical Grammar	9

Modern Languages

82-283	Language Diversity & Cultural Identity	9
82-305	French in its Social Contexts	9
82-373	Structure of the Japanese Language	9
82-383	Second Language Acquisition: Theories and Research	9
82-585	Topics in Second Language Acquisition	9

Psychology

85-354	Infant Language Development	9
85-421	Language and Thought	9

Language Technologies Institute

11-411	Natural Language Processing	12
11-423	ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.	12
11-492	Speech Processing	12
11-661	Language and Statistics	12
11-722	Grammar Formalisms	12

Language Requirement

Students must successfully complete two semesters of consecutive language courses. (Note that students may not 'test out' of this requirement. However, language courses taken at other institutions or as part of a study abroad program will typically substitute for a semester of language study.)

Senior Thesis [primary majors only]

Primary majors must complete a senior thesis (a workload equivalent to a 12-unit course) during their senior year. Topics must be approved by an advisor, who will work with the student and guide the thesis project. Students are responsible for identifying their topic and securing their thesis advisor. Students should work with the director of the major to begin the process of identifying their thesis topic and advisor during the fall of their senior year at the latest. Students will be required to submit a written proposal of their thesis project, signed by their thesis faculty advisor, before the end of the second week of classes in which the thesis is being completed.

Note

- All 11-xxx courses have significant Computer Science prerequisites. Interested students should check with the course instructor before registering.

The Major in Psychology and Biological Sciences

This unified major is intended to reflect the interdisciplinary nature of our current research in the fields of psychology and biology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences. Students entering from the Dietrich

College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students entering from the Mellon College of Sciences receive a Bachelor of Science in Biological Sciences and Psychology.

Pre-Major Requirements

The unified major specifies particular pre-major requirements in the areas of mathematical sciences and statistics, natural science, and computational reasoning. Particular courses are specified in these areas because they are prerequisites for courses required in the major and therefore they are the most efficient way to complete the general education requirements for either Dietrich College or SHS. All other general education categories can be filled in any way that satisfies the requirements of the student's college or of the SHS program.

The major in Psychology and Biological Sciences is offered only as a B.S. degree. Full curriculum requirements can be viewed under the Department of Psychology (p. 471) section of the Catalog.

Student-Defined Major Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*
Location: Baker Hall 154F
jd0x@andrew.cmu.edu
www.cmu.edu/dietrich/academics/degrees-majors-minors/student-defined-majors.html

For Dietrich College students whose educational goals cannot be as adequately served by the curricula of existing majors, the college offers the opportunity to self-define a major. The procedure for establishing such a major centers on a written proposal, submitted to the Dietrich College Dean's Office. This proposal consists of two parts:

Major Description and Rationale

A description of the components of the proposed program of study; a presentation of the objectives of the program of study, how it represents a coherent and (given available faculty, courses, and other resources) viable course of study, and the reason(s) why these objectives cannot be accomplished within one or more of the college's existing majors.

Curriculum

Presentation of a complete outline of all courses that will comprise the requirements for the major. These courses should be categorized in two ways: first, according to that component of the major program to which each belongs (e.g., mathematical prerequisites; research methods; theoretical perspectives; etc.); and second, a semester-by-semester outline that indicates when each course is to be taken (or, for any already taken, when taken and grade received). In addition to courses taken at Carnegie Mellon, the major's curriculum may include courses taken (or to be taken) at other schools, related projects or internships, or programs of study abroad. The minimum requirements for graduation is, as with all majors in the college, 360 units of credit and completion of the Dietrich College general education program.

Proposals and curricula are evaluated for clarity of focus, coherence and depth in related areas, and viability. Proposals should generally be developed no later than the sophomore year, and approved majors begin their program generally no later than the junior year.

The student-defined option is also possible to propose as an additional major or minor. These options extend to undergraduates from all Carnegie Mellon colleges.

Dietrich College Interdisciplinary Minors

Dietrich College interdepartmental minors are programs whose content and components span two or more academic departments to form coherent patterns of study.

A number of interdepartmental minors are offered by Dietrich College and are, in general, available to all Carnegie Mellon undergraduate students. As well, there are numerous other minors offered by other colleges in the university that are generally available to Dietrich College students. The full list of minors available to Carnegie Mellon students is located in the catalog index under “Minors.”

Completion of the requirements for any of these minors is noted on the final transcript.

To declare a Dietrich College interdepartmental minor, students should contact the college's Academic Advisory Center (AAC) and the faculty advisor for that minor.

To discuss the possibility of declaring a non-Dietrich College minor, contact the advisor listed for the minor in question.

In general, unless noted, no course taken to fulfill requirements for these interdepartmental minors may apply toward any other program's requirements.

The Minor in African and African American Studies

Professor Edda L. Fields-Black, *Faculty Advisor*
fieldsblack@andrew.cmu.edu, Baker Hall 362, 412-268-8012

Dr. Andrew Ramey, *Academic Advisor*
aramey@andrew.cmu.edu, Baker Hall 240, 412-268-7906

Mission

The African and African American Studies minor introduces students to several large regions of the world: sub-Saharan Africa, the Americas, and the Caribbean. Broad geographic coverage and a comparative framework encourage students to make connections between Africa and the African Diaspora, as well as among different Diasporan communities. The minor offers undergraduates the opportunity to undertake an empirical and theoretical examination of the cultural, political, social, and historical experiences of Africans and people of African descent.

This unique transnational minor brings together several departments and colleges within the university and allows students to develop analytical skills particular to the arts, humanities, social sciences, public policy, and management. The African and African American Studies minor allow students a considerable degree of freedom in their choice of electives and independent research projects, including opportunities to study and conduct research in a relevant foreign language.

Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Requirements

- The minor is composed of 54 units - two core courses and four elective courses.
- The elective courses must include one course that requires a research paper or project.
- Students may take an additional two core courses as electives, but not more than four total courses.
- Students must take courses in at least two of the four regions (African, African American, Latin American, and the Caribbean) between their core and elective courses.

Core Courses 18 units

Choose two from the History and/or English Department courses listed below:

African		
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
African American		
76-232	Introduction to Black Literature	9
76-332	African American Literature: The African American Crime Novel	9
79-241	African American History: Africa to the Civil War	9
79-242	African American History: Reconstruction to the Present	9
Caribbean		
79-235	Caribbean Cultures	9

Elective Courses 36 units

African		
79-225	West African History in Film	9
79-237	Comparative Slavery *	9
79-290	The Slave Passage: From West Africa to the Americas	6
79-291	Globalization in East African History	6
79-385	Out of Africa: The Making of the African Diaspora *	9
79-386	Entrepreneurs in Africa, Past, Present and Future *	9
82-304	The Francophone World **	9
African American		
57-480	History of Black American Music	6
76-238	What Was the Hip-Hop Generation?	9
76-332	African American Literature: The African American Crime Novel	9
76-333	Race and Controversy in the Arts	9
76-432	Advanced Seminar in African American Studies *	9
79-237	Comparative Slavery *	9
79-304	African Americans in Pittsburgh	6
79-371	African American Urban History	9
Caribbean		
79-237	Comparative Slavery *	9
79-385	Out of Africa: The Making of the African Diaspora *	9
82-304	The Francophone World **	9
Latin American		
79-317	Art, Anthropology, and Empire	9
82-343	Latin America Language and Culture	9
82-451	Studies in Latin American Literature and Culture	9

Notes:

* Denotes courses that require a research paper/project.

** Denotes courses taught in a foreign language

The Minor in Film and Media Studies

Laura E. Donaldson, *Academic Advisor*
Jeffrey Hinkelman, *Faculty Advisor*

Location: Department of English, Baker Hall 259

Film and the electronic media are a crucial part of contemporary culture and society; they constitute an important tool for under-standing social arrangements, historical changes, and play an increasingly important role in the development of aesthetic and cultural theory. The Dietrich College minor in Film and Media Studies takes an interdisciplinary approach to the study of film and other electronic media. Courses provide techniques for analyzing and criticizing film and other media, for assessing their value as historical, anthropological and social scientific data, and for understanding the aesthetic and philosophical premises of various media texts.

A maximum of two courses may double count with other programs.

The courses listed below are offered with at least general regularity. Participating departments may subsequently develop and offer other courses that, while not listed here, are deemed appropriate for this minor. A faculty advisor for the minor should be consulted (especially when the schedule of courses to be offered for a given semester becomes available) to identify such additional courses.

Required Introductory Course — 9 units

76-239	Introduction to Film Studies (prerequisite for 76-439)	9

Required Intermediate Course — 9 units

76-310	Advanced Studies in Film and Media	9

Film and Media Electives — 27 units

Complete a minimum of 27 units of course work at the 200-level or above when the primary topic is film and media. Courses may include, but are not limited to, the following:

76-238	What Was the Hip-Hop Generation?	9
76-269	Survey of Forms: Screenwriting	9
76-312	Crime and Justice in American Film	9
76-338	The American Cinema	9
76-339	Topics in Film and Media: Hollywood vs. the World *	9
76-353	Transnational Feminisms: Fiction and Film	9
76-367	Fact Into Film: Translating History into Cinema	9
76-374	IDeATe - Dietrich College Cuban Interactive Documentary Project	9
76-377	Shakespeare and Film	9
76-381	Mad-Men, Television, and the History of Advertising	9
76-419	Media in a Digital Age	9
76-438	The Wire: Crime, Realism, and Long-Form TV	9
76-439	Seminar in Film and Media Studies: Class, Race, & Gender in Film	9
76-448	Shakespeare on Film	9
76-456	Independent Study in Film & Media Studies	Var.
76-469	Screenwriting Workshop: Screenwriting/ Television Writing	9
76-472	Topics in Journalism: Storytelling in a Digital Age	9
79-214	Paris in Revolt: History, Literature, Film	6
79-220	Screening Mexico: Mexican Cinema, 1898 to Present	6
79-306	Fact into Film: Translating History into Cinema	9
79-308	Crime and Justice in American Film	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6
79-341	The Cold War in Documents and Film	9
82-215	Arab Culture Through Film & Literature	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-296	A Century of Russian Film	9
82-362	Italian Language and Culture II	9
82-253	Korean Culture Through Film	9
82-428	History of German Film	9
82-456	Topics in Hispanic Studies	9
82-533	Cultural Topics in Chinese Studies	9

* May be taken up to three times and counted for additional credit toward Film and Media Electives if topics differ.

Students should consult with a faculty advisor for the minor regarding courses not listed above.

400-level Film and Media Course — 9 units

Complete one 400-level course that concentrates on film/media directly or that uses it as a tool of social or cultural analysis.

76-419	Media in a Digital Age	9
76-438	The Wire: Crime, Realism, and Long-Form TV	9
76-439	Seminar in Film and Media Studies: Class, Race, & Gender in Film	9
76-448	Shakespeare on Film	9
76-456	Independent Study in Film & Media Studies	Var.
76-469	Screenwriting Workshop: Screenwriting/ Television Writing	9
76-472	Topics in Journalism: Storytelling in a Digital Age	9

The Minor in Gender Studies

Lisa Tetrault, *Professor of History and Faculty Advisor*
tetrault@andrew.cmu.edu
Location: English Department, Baker Hall 259

Gender studies is an interdisciplinary field that investigates how gender is embedded in social, cultural, and political relationships. It understands gender as a category of power that intersects with other power relations, including race, class, and sexuality.

Courses allow students to develop a deeper understanding of how gender operates, and to transfer the analytical skills they acquire to other courses as well as to their personal and professional lives. The minor combines coursework in some combination of the following fields: English, history, anthropology, psychology, philosophy, economics, and modern languages.

Courses listed are only examples. Course offerings change regularly, so please consult semester offerings and the minor advisor for other courses.

The courses listed below are offered with at least general regularity. Participating departments may develop and offer other courses that, while not listed here, are appropriate for the study of gender. Consult the minor advisor to confirm the relevance of unlisted, gender-focused courses.

Complete 1 of the following required courses. — 9 units

76-241	Introduction to Gender Studies	9
79-320	Women, Politics, and Protest	9
79-331	Body Politics: Women and Health in America	9

Complete 5 or more additional courses totaling at least 45 units. — 45 units

See examples below, but other courses may fulfill this requirement.*

76-205	Jane Austen	9
76-311	Acting Out in the London Theatre	9
76-327	Influential Women Writers	9
76-329	Unruly Women in Early Modern Drama	9
76-341	Gender and Sexuality in Performance	9
76-353	Transnational Feminisms: Fiction and Film	9
76-412	Performance and 18th Century Theatrical Culture	9
76-422	Gender and Sexuality Studies	4.5
76-441	Theorizing Sexuality	9
79-244	Women in American History	9
79-320	Women, Politics, and Protest **	9
79-323	Family, Gender, and Sexuality in European History, 500-1800	9
79-324	#MeToo: Naming and Resisting Gender Violence	6
79-325	U.S. Gay and Lesbian History	6
79-327	Modern Girlhood: Historical and Contemporary Perspectives	6
79-331	Body Politics: Women and Health in America **	9
79-333	Sex, Gender & Anthropology	9
80-224	Race, Gender and Science	9
82-300	Language & Society in the Arab World	9
84-312	Gender and Development in Sub-Saharan Africa	6
85-350	Psychology of Prejudice	9
85-446	Psychology of Gender	9

* Consult with Gender Studies Minor Advisor Professor Lisa Tetrault at tetrault@andrew.cmu.edu.

** If not taken as a requirement.

The Minor in Global Systems and Management

Brandy Wilson, *Faculty Advisor*
Location: HBH 3029

Graduates across all disciplines are increasingly likely to find themselves working as part of a global development team on a wide variety of business, consumer, and intellectual products and services.

The Global Systems and Management minor (GSM) is intended for students wishing to develop skills essential for participating in emerging opportunities in global business systems, systems development, product development and global project management. GSM exposes students to contemporary issues and practices facing organizations, managers and individuals working on a global scale across political, cultural and temporal boundaries. GSM presents an opportunity for students to learn about being part of an organization that works globally with its employees, business partners, customers and supply chains.

Students will learn about global project management, outsourcing and cross-cultural communications from theoretical and practical viewpoints. An organized elective structure enables students to tailor the minor to reflect their specific interests.

Curriculum 63

GSM is offered jointly across the departments and programs of the Dietrich College of Humanities and Social Sciences with participation from the Tepper School of Business. The minor is administered by the Dietrich College Information Systems program. The minor requires students to complete 63 units. Note that the courses listed below may be subject to change:

- one Information Systems course: 67-329 Contemporary Themes in Global Systems (offered annually)
- two courses in Communications
- a combination of 36 units with at least 9 units in each of the categories of:
  - Humanities, Heritage and Culture
  - International Management

Study Abroad Options

Students are encouraged to complete a semester of study abroad. With prior approval from the GSM Advisor, study abroad courses may be applied to GSM minor requirements except for 67-329 Contemporary Themes in Global Systems. Please consult with the GSM Advisor before embarking on the semester of study abroad.

Double Counting of Courses

Students may double count up to three courses with other major and minor programs.

Core Course

Required course:		
67-329	Contemporary Themes in Global Systems (offered annually)	9

Communications 18 units

Complete two courses:		
05-341	Organizational Communication	9
70-321	Negotiation and Conflict Resolution	9
70-340	Business Communications	9
70/85/88-341	Team Dynamics and Leadership	9
70-342	Managing Across Cultures	9
70-350	Acting for Business	9
70-483	Advertising and Marketing Communications	9
73-341	Within the Firm: Managing through Incentives	9
76-270	Writing for the Professions	9
76-318	Communicating in the Global Marketplace	9
76-386/786	Language & Culture	9
76-428	Visual Verbal Communication	9
85-375	Crosscultural Psychology	9
88-419	International Negotiation	9

Humanities, Heritage and Culture (HHC) & International Management (IM) 36 units

(Complete at least 9 units of HHC or IM)

Humanities, Heritage and Culture

Humanities Heritage and Culture consists of:

- History Department courses: 79-200 level or above covering international/regional studies that are outside of U.S. history
- Modern Languages Department courses: 82-200 level or above, covering international or regional studies but not including elementary or intermediate language courses
- At least 9 units in total

History course 79-200 level or above covering international/ regional studies that are outside of U.S. history		
82-215	Arab Culture Through Film & Literature	Var.
82-238	Topics in Chinese Culture	9
82-253	Korean Culture Through Film	9
82-254	World of Korea, Then and Now	9
82-273	Introduction to Japanese Language and Culture	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-303	Introduction to French Culture	9
82-304	The Francophone World	9
82-305	French in its Social Contexts	9
82-311	Advanced Arabic I	9
82-312	Advanced Arabic II	9
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-323	Germany, Austria and Switzerland in the 20th Century	9
82-333	Introduction to Chinese Language and Culture	Var.
82-342	Spain: Language and Culture	9
82-343	Latin America Language and Culture	9
82-345	Introduction to Hispanic Literary & Cultural Studies	9
82-361	Italian Language and Culture I	9
82-362	Italian Language and Culture II	9
82-399	Special Topics: Russian in Context	Var.
82-400	Russian Studies Topics	6
82-415	Topics in French and Francophone Studies	9
or 82-416	Topics in French and Francophone Studies	
82-425	Topics in German Literature and Culture	9
82-433	Topics in Contemporary Culture of China	9
82-441	Studies in Peninsular Literature and Culture	9
82-450	Advanced Research in Hispanic Language & Culture	9
82-456	Topics in Hispanic Studies	9
82-473	Topics in Japanese Studies	9
or 82-474	Topics in Japanese Studies	
82-474	Topics in Japanese Studies	9
84-275	Comparative Politics	9
84-312	Gender and Development in Sub-Saharan Africa	6
84-315	Contemporary Debates in Human Rights	9
84-389	Terrorism and Insurgency	9

International Management

- At least 9 units in total

19-411	Global Competitiveness: Firms, Nations and Technological Change	9
67-319-67-331	Global Technology Consulting Groundwork - Technology Consulting in the Global Community (these two courses are taken sequentially)	6
67-331	Technology Consulting in the Global Community	3
70-342	Managing Across Cultures	9
70-364	Business Law	9
70-365	International Trade and International Law	9
70-430	International Management	9
70-480	International Marketing	9

73-341	Within the Firm: Managing through Incentives	9
73-372	International Money and Finance	9
84-310	International Political Economy	9
84-311	International Development: Theory and Praxis	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-320	Domestic Politics and International Affairs	9
84-321	Autocrats and Democrats	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-362	Diplomacy and Statecraft	9
84-363	Comparative Legal Systems	9
84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-405	The Future of Warfare	9
84-414	International and Subnational Security	9
88-411	Rise of the Asian Economies	9
88-418	Domestic Negotiation	9

MINIMUM NUMBER OF UNITS REQUIRED FOR MINOR 63

Minor in Health Care Policy and Management

Sponsored by:
Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:
Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 27 units from the following:		
79-330	Medicine and Society	9
90-836	Health Systems	6
90-721	Healthcare Management	6
90-861	Health Policy	6

Elective Courses

Complete a minimum of 18 units from these two sections:

Heinz College Courses		
90-831	Advanced Financial Management of Health Care	6
94-705	Health Economics	12
90-832	Health Law	6
90-833	Population Health	6
90-818	Health Care Quality & Performance Improvement	6
90-834	Health Care Geographical Information Systems	12
Other courses as approved		

Humanities and Social Sciences Courses (9 units each)		
80-245	Medical Ethics	9
76-494	Healthcare Communications	9
88-365	Behavioral Economics and Public Policy	9
67-476	Innovation in Information Systems: Health Care	9
42-444	Medical Devices	9
Other courses as approved		

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

Health Management/Administration Focus		Units
90-831	Advanced Financial Management of Health Care	6
90-832	Health Law	6
90-818	Health Care Quality & Performance Improvement	6
80-245	Medical Ethics	9
76-494	Healthcare Communications	9

Health Policy Focus		Units
94-705	Health Economics	12
90-832	Health Law	6
90-833	Population Health	6
88-365/90-882	Behavioral Economics and Public Policy	9
Other courses as approved		

Health Analytisc & IT Focus		Units
90-834	Health Care Geographical Information Systems	12
67-476	Innovation in Information Systems: Health Care	9
42-444	Medical Devices	9
Other courses as approved		

The Minor in Linguistics

Tom Werner, *Director*
Location: Baker Hall 155F
twerner@andrew.cmu.edu

The Interdepartmental Minor in Linguistics combines courses from the departments of Philosophy, English, Modern Languages, Psychology and the Language Technologies Institute. It synthesizes the linguistics related offerings in these departments and provides students with an academic experience that reflects the interdisciplinary character of the subject.

The Minor in Linguistics requires a total of 6 courses: the introductory linguistics course; two fundamental skills courses; and three additional electives. All courses counted towards the Minor must be taken for a letter grade and passed with a grade of "C" or above.

Introductory Course

80-180	Nature of Language	9

Fundamental Skills

Take **one** course from **two** of the following core subject areas:

Sounds		
80-282	Phonetics and Phonology I	9

Structure		
76-389	Rhetorical Grammar	9
80-280	Linguistic Analysis	9
80-285	Natural Language Syntax	9

Meaning		
80-381	Meaning in Language	9
80-383	Language in Use	9
76-385	Introduction to Discourse Analysis	9
or 76-484	Discourse Analysis	

Electives

Take three additional linguistics courses. These can be additional courses from the Fundamental Skills categories above, or any other course which is approved by the Director as a linguistics elective. For electives taught on a regular basis, see courses listed as Breadth or Electives in the Undergraduate Catalog entry for the Linguistics Major.

Neural Computation Minor

Dr. Tai Sing Lee, *Director*
Melissa Stupka, *Administrative Coordinator*
www.cnbc.cmu.edu/upnc/nc_minor

Neural computation is a scientific enterprise to understand the neural basis of intelligent behaviors from a computational perspective. Study of neural computation includes, among others, decoding neural activities using statistical and machine learning techniques, and developing computational theories and neural models of perception, cognition, motor control, decision-making and learning. The neural computation minor allows students to learn about the brain from multiple perspectives, and to acquire the necessary background for graduate study in neural computation. Students enrolled in the minor will be exposed to, and hopefully participate in, the research effort in neural computation and computational neuroscience at Carnegie Mellon University.

The minor in Neural Computation is an intercollege minor jointly sponsored by the School of Computer Science, the Mellon College of Science, and the Dietrich College of Humanities and Social Sciences, and is coordinated by the Center for the Neural Basis of Cognition (CNBC) (http://www.cnbc.cmu.edu).

The Neural computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, H&SS and MCS.

The Neural Computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, Dietrich College and MCS. The primary objective of the minor is to encourage students in biology and psychology to take computer science, engineering and mathematics courses, to encourage students in computer science, engineering, statistics and physics to take courses in neuroscience and psychology, and to bring students from different disciplines together to form a community. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in cognitive science and neuroscience that are central to computational neuroscience.

APPLICATION

tudents must apply for admission no later than November 30 of their senior years; an admission decision will usually be made within one month. Students are encouraged to apply as early as possible in their undergraduate careers so that the director of the Neural Computation minor can provide advice on their curriculum, but should contact the program director any time even after the deadline.

To apply, send email to the director of the Neural Computation minor Dr. Tai Sing Lee (tai@cnbc.cmu.edu) and copy Melissa Stupka (mstupka@cnbc.cmu.edu). Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Your class and College/School at Carnegie Mellon
- Semester you intend to graduate
- All (currently) declared majors and minors
- Statement of purpose (maximum 1 page) – Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses for the Minor (this is your plan, NOT a commitment)
- Research projects you might be interested in

Curriculum

The Minor in Neural Computation will require a total of five courses: four courses drawn from the four core areas (A: neural computation, B: neuroscience, C: cognitive psychology, D: intelligent system analysis), one from each area, and one additional depth elective chosen from one of the core areas that is outside the student's major. The depth elective can be replaced by a one-year research project in computational neuroscience. No more than two courses can be double counted toward the student's major or other minors. However, courses taken for general education requirements of the student's degree are not considered to be double counted. A course taken to satisfy one core area cannot be used to satisfy the course requirement for another core area. The following listing presents a set of current possible courses in each area. Other computational neuroscience courses are being developed at Carnegie Mellon and University of Pittsburgh that will also satisfy core area A requirement and the requirements will be updated as they come on-line. Substitution is possible but requires approval.

A. Neural Computation

		Units
15-386	Neural Computation	9
15-387	Computational Perception	9
15-883	Computational Models of Neural Systems	12
85-419	Introduction to Parallel Distributed Processing	9
86-375	Computational Perception	9
Pitt-Mathematics-1800 Introduction to Mathematical Neuroscience		9

B. Neuroscience

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
42-630	Introduction to Neuroscience for Engineers (crosslisted with 18-690)	12
85-765	Cognitive Neuroscience	Var.
Pitt-Neuroscience 1000 Introduction to Neuroscience		9

C. Cognitive Psychology

85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artifical Intelligence	9
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-426	Learning in Humans and Machines	9
85-765	Cognitive Neuroscience	Var.

D. Intelligent System Analysis

10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (Undergrad)	
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
15-387	Computational Perception	9
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-299	Introduction to Feedback Control Systems	12
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
18-290	Signals and Systems	12
24-352	Dynamic Systems and Controls	12
36-225	Introduction to Probability Theory	9
36-247	Statistics for Lab Sciences	9
36-401	Modern Regression	9
36-410	Introduction to Probability Modeling	9
36-746	Statistical Methods for Neuroscience and Psychology	12
42-631	Neural Data Analysis	9
42-632	Neural Signal Processing	12
86-375	Computational Perception	9
86-631	Neural Data Analysis	9

Prerequisites

The required courses in the above four core areas require a number of basic prerequisites: basic programming skills at the level of 15-110 Principles of Computing and basic mathematical skills at the level of 21-122 Integration and Approximation or their equivalents. Some courses in Area D require additional prerequisites. Area B Biology courses require, at minimum, 03-121 Modern Biology. Students might skip the prerequisites if they have the permission of the instructor to take the required courses. Prerequisite courses are typically taken to satisfy the students' major or other requirements. In the event that these basic skill courses are not part of the prerequisite or required courses of a student's major, one of them can potentially count toward the five required courses (e.g. the depth elective), conditional on approval by the director of the minor program.

Research Requirements (Optional)

The minor itself does not require a research project. The student however may replace the depth elective with a year-long research project. In special circumstances, a research project can also be used to replace one of the five courses, as long as (1) the project is not required by the student's major or other minor, (2) the student has taken a course in each of the four core areas (not necessarily for the purpose of satisfying this minor's requirements), and (3) has taken at least three courses in this curriculum not counted toward the student's major or other minors. Students interested in participating in the research project should contact any faculty engaged in computational neuroscience or neural computation research at Carnegie Mellon or in the University of Pittsburgh. A useful webpage that provides listing of faculty in neural computation is www.cnbc.cmu.edu/computational-neuroscience. The director of the minor program will be happy to discuss with students about their research interest and direct them to the appropriate faculty.

Fellowship Opportunities

The Program in Neural Computation (PNC) administered by the Center for the Neural Basis of Cognition currently provides 3-4 competitive full-year fellowships ($11,000) to Carnegie Mellon undergraduate students to carry out mentored research in neural computation. The fellowship has course requirements similar to the requirements of the minor. Students do not apply to the fellowship program directly. They have to be nominated by the faculty members who are willing to mentor them. Therefore, students interested in the full-year fellowship program should contact and discuss research opportunities with any CNBC faculty at Carnegie Mellon or University of Pittsburgh working in the area of neural computation or computational neuroscience and ask for their nomination by sending email to Dr. Tai Sing Lee, who also administers the undergraduate fellowship program at Carnegie Mellon. See www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/ for details.

The Program in Neural Computation also offers a summer training program for undergraduate students from any U.S. undergraduate college. The students will engage in a 10-week intense mentored research and attend a series of lectures in neural computation. See www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/ for application information.

The Minor in Religious Studies

Professor Allyson Creasman, *Faculty Advisor*
acreasman@cmu.edu (aeowen@cmu.edu), Baker Hall 242D, 412-268-9832

Dr. Andrew Ramey, *Academic Advisor*
aramey@andrew.cmu.edu, Baker Hall 240, 412-268-7906

The Religious Studies minor offers students a range of intellectual tools for thinking about religious ideas, behaviors and institutions. It also enables students to build a base of knowledge that extends beyond any one particular religious tradition.

Curriculum 54 units

The minor consists of six courses, totaling at least 54 units. Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Religious Studies minors must satisfy the requirements listed below:

Required Core Course 9 units

All Religious Studies minors are required to take 79-281, Introduction to Religion. This required course introduces several modes of inquiry into religion, such as the philosophy of religion, sociological and behavioral approaches to religion, historical analysis of religious subject, literary and critical analysis of religious texts, theological modes of thought, and anthropological treatments of religion. This course is offered regularly, usually in the Spring semester.

79-281	Introduction to Religion	9

Distribution Requirements 18 units

In addition to the required Core Course, students must complete Distribution Courses totaling 18 units (usually two 9-unit courses). A Distribution Course is one that applies a particular discipline to more than one religion. Some examples of qualifying Distribution Courses that have been offered include:

Historical Approaches		
79-208	Witchcraft and Witch-Hunting	9
79-307	Religion and Politics in the Middle East	9
79-352	Christianity Divided: The Protestant and Catholic Reformations, 1450-1650	9
Philosophical Approaches		
80-276	Philosophy of Religion	9
Textual Approaches		
76-346	Angels and Diplomats -- Renaissance Poetry from Wyatt to Milton	9

In addition to the courses listed above, participating departments often offer other courses that may qualify as Distribution Courses for the minor. The Faculty Advisor should be consulted to identity qualifying courses (especially after the Schedule of Courses for a given semester becomes available).

Elective Courses 27 units

In addition to the required Core Course and the Distribution Courses, students must complete Elective Courses totaling at least 27 units (usually three 9-unit courses). Unlike Distribution Courses, an Elective Course may focus on the study of only one religion (although courses examining more than one religious tradition can also count as Elective Courses if not otherwise used to fulfill the Distribution Requirement).

Some examples of qualifying Elective Courses that have been offered include:

76-337	Representations of Islam in Early Modern England	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-296	Religion in American Politics	6
79-349	United States and the Holocaust	6
79-350	Early Christianity	9
79-375	Science & Religion	6

In addition to the courses listed above, participating departments often offer other courses that may qualify as Elective Courses for the minor. The Faculty Advisor should be consulted to identify qualifying courses (especially after the Schedule of Courses for a given semester becomes available).

In addition to courses offered at CMU, relevant courses taken at the University of Pittsburgh, Duquesne University, or other Pittsburgh institutions may count toward the Elective Requirement with the permission of the Religious Studies minor’s Faculty Advisor. The option to cross-register for relevant courses at other local institutions allows students some flexibility in meeting the minor’s requirements and gives them the opportunity to explore interests in religious subjects that might not otherwise be covered at CMU. Students who wish to cross-register for courses at other institutions should consult with the Faculty Advisor about whether the selected course(s) will meet the minor’s Elective Requirement.

The Minor in Science, Technology and Society

Professor Christopher J. Phillips, *Faculty Advisor*
cjp1@cmu.edu, Baker Hall 235C, 412-268-1753

Dr. Andrew Ramey, *Academic Advisor*
aramey@andrew.cmu.edu, Baker Hall 240, 412-268-7906

This minor provides interdisciplinary perspectives on the development and meaning of science and technology in modern society. The core courses enable you to explore the philosophical underpinnings, cultural and historical contexts, and economic and literary assessments of the interplay among science, technology, and society. Elective courses enable you to pursue in greater depth and variety subjects and approaches that build on both the core courses and your primary major.

Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Curriculum 54 units

Core Courses 27 units

Complete one course from each area. Additional courses from the History of Science Core and the History of Philosophy Core may count as electives for the minor.

Area 1. History of Science Core

Take at least 1 course from the list below.

79-234	Technology and Society	9
79-299	From Newton to the Nuclear Bomb: History of Science, 1750-1950	9
79-305	Moneyball Nation: Data in American Life	9
79-330	Medicine and Society	9
79-342	Introduction to Science and Technology Studies	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

Area 2. Philosophy of Science Core

Take at least 1 course from the list below.

80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-226	Revolutions in Science	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9

Area 3. Science Core

Take at least 1 course (9 units total) from the following departments: 15-xxx Computer Science, 09-xxx Chemistry, 03-xxx Biological Sciences, 33-xxx Physics

Electives 27 units

Complete three courses from the approved list of elective courses. Courses listed in Areas 1 and 2 may also be taken as electives if not already completed for an Area requirement. To petition for a course not listed to be approved as an elective, contact the Faculty Advisor, cjp1@cmu.edu, directly.

18-482	Telecommunications Technology and Policy for the Internet Age	12
48-448	History of Sustainable Architecture	9
73-427	Sustainability, Energy, and Environmental Economcs	9
76-319	Environmental Rhetoric	9
76-395	Science Writing	9
76-425	Science in the Public Sphere	9
76-476	Rhetoric of Science	9
76-492	Rhetoric of Public Policy	9
76-494	Healthcare Communications	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-208	Witchcraft and Witch-Hunting	9
79-213	The American Railroad: Decline and Renaissance in the Age of Deregulation	6
79-246	Industrial America	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
79-331	Body Politics: Women and Health in America	9
79-354	Kids and Schools in the 20th Century	6
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
80-110	Nature of Mathematical Reasoning	9
80-150	Nature of Reason	9
80-214	Computing, AI, and Philosophy	9
80-222	Measurement and Methodology	9
80-223	Causality and Probability	9
80-248	Engineering Ethics	9
80-312	Mathematical Revolutions	9
80-321	Causation, Law, and Social Policy	9
80-322	Philosophy of Physics	9
80-323	Philosophy of Biology	9
80-324	Philosophy of Economics	9
84-387	Technology and Policy of Cyber War	9
85-380	In Search of Mind: The History of Psychology	9

The Minor in Sociology

Saurabh Bhargava, *Faculty Director*
Connie Angermeier, *Program Advisor*
Location: Porter Hall 208A
cla2@andrew.cmu.edu

The Sociology minor introduces the student to central concepts in sociological theory and methods of empirical inquiry needed to broadly understand social behavior, including its structure, history, and dynamics. Students choose among a range of methodological approaches and substantive topic areas including social psychology, work and organizations, social networks, technology and society, medical sociology, and gender and family. Exposure to these topics will help students understand and appreciate the processes by which families, groups, and organizations form and evolve over time; by which individuals affect and are affected by the society in which they live; and by which technology and institutions shape and influence society. This background in empirical tools and social theory will strengthen the student's ability to pursue graduate studies in sociology, social history, social science, and organizational theory; to begin professional careers involving social analysis, network analysis, data analysis of teams, groups and organizations, social analysis within journalism, political institutions, the government, and online; and to enter the corporate environment with a thorough understanding of organizational activity.

Curriculum 54 units

In addition to the general education requirements of the student's college and the requirements of the student's major, Sociology minors must satisfy the following requirements. The Core courses comprise 18 units of the minor. One course is taken from the Organizations cluster, and one course is taken from the Methodology cluster. The Elective courses comprise 36 units of the minor. Sociology minors should consult with the program advisor to plan a course schedule prior to registration.

NOTE: The core courses are offered regularly; the elective courses are offered with at least general regularity. Participating departments may subsequently develop and offer other courses that, while not listed here, are deemed appropriate for this minor. The program advisor should be consulted (especially when the schedule of courses to be offered for a given semester becomes available) to identify such additional courses.

No more than 9 units in the Sociology minor may be counted to fulfill any other major or minor's requirements.

Core Courses 18 units

A. Organizations

Complete one course.

70-311	Organizational Behavior	9

B. Methodology

Complete one course.

36-202	Statistics & Data Science Methods	9
70-208	Regression Analysis	9
85-310	Research Methods in Cognitive Psychology	9
85-340	Research Methods in Social Psychology	9
88-251	Empirical Research Methods	9
88-252	Causal Inference in the Field	9

Elective Courses 36 units

Complete four courses (a minimum of 36 units) from the following list. Two courses (18 units) must be taken from one category to complete the depth requirement. One course (9 units) must be taken from the other category. The remaining course (9 units) may be taken from either category. Appropriate courses offered by the Department of Sociology at the University of Pittsburgh (available during the academic year through cross-registration) may also be included as part of this option. Contact the Sociology program advisor for more information.

1. Sociology of Gender, Family, and Culture

70-342	Managing Across Cultures	9
70-385	Consumer Behavior	9
76-241	Introduction to Gender Studies	9
79-244	Women in American History	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-308	Crime and Justice in American Film	9
79-320	Women, Politics, and Protest	9
79-323	Family, Gender, and Sexuality in European History, 500-1800	9
79-331	Body Politics: Women and Health in America	9
79-343	Education, Democracy, and Civil Rights	9
79-377	Food, Culture, and Power: A History of Eating	9
80-224	Race, Gender and Science	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-256	Modern Moral Philosophy	9
80-305	Choices, Decisions, and Games	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
84-369	Decision Science for International Relations	9
85-241	Social Psychology	9
85-350	Psychology of Prejudice	9
85-352	Evolutionary Psychology	9
85-358	Pro-Social Behavior	9
85-377	Attitudes and Persuasion	9
85-442	Health Psychology	9
85-446	Psychology of Gender	9
88-230	Human Intelligence and Human Stupidity	9
88-380	Dynamic Decisions	9
88-388	Psychological Models of Decision Making	9

2. Sociology of Work, Organizations, and Technology

70-332	Business, Society and Ethics	9
73-348	Behavioral Economics	9
79-275	Introduction to Global Studies	9
79-342	Introduction to Science and Technology Studies	9
88-275	Bubbles: Data Science for Human Minds	9
80-341	Computers, Society and Ethics	9
88-255	Strategic Decision Making: Cooperation and Competition in Social Interactions	9
88-341	Team Dynamics and Leadership	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-402	Modeling Complex Social Systems	9
88-406	Behavioral Economics in Organizations	9
88-409	Behavioral Economics Perspectives on Ethical Issues	9
88-418	Domestic Negotiation	9
88-419	International Negotiation	9
88-435	Decision Science and Policy	9
88-451	Policy Analysis Senior Project	12
or 88-452	Policy Analysis Senior Project	

Note: Some courses have additional prerequisites.

Dietrich College Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

Dietrich College Interdisciplinary Courses

66-103 HSP First-Year Seminar: Appalachia (for HSP students only)
Fall: 9 units
The Appalachian region - which stretches from Georgia to New York's southern plateau - has a particular place in American history and memory. This course will examine the political, literary, economic and historical narratives that surround the region, as well as examining the role that Appalachia can play as a model for developing regions in other parts of the world. This course fulfills the First-Year Seminar requirement for the Humanities Scholars Program. Enrollment is restricted to first-year HSP students.

66-106 QSSS First-Year Seminar: Applied Quantitative Social Science I (QSSS students)
Fall: 9 units
The QSSS First-Year Seminar provides a fast-paced introduction to a range of methods in the quantitative social sciences. Organized around a set of case studies, the course introduces the language and methods of empirical research through a combination of seminar-style discussions of academic papers, and hands-on lab work using the statistical software R. Students will replicate results from a high-profile labor market discrimination paper, explore agent-based models of neighborhood segregation, and scrape Wikipedia data to examine imbalances in gender representation. Enrollment restricted to first-year QSSS students.

66-107 First-Year Seminar: Modeling Complex Systems
Fall: 9 units
Most of the major issues confronting humanity—-such as climate change, financial collapse, ecosystem survival, terrorism, and disease epidemics —-are the result of complex systems where the interactions of the pieces of the system create a whole that is rather different than any of its parts. Unfortunately, traditional scientific methods that focus on reducing systems to their parts and then analyzing each part provide little insight into such systems. This seminar explores the behavior of complex systems as well as how to model and understand them using both traditional tools and computer-based approaches.

66-109 Grand Challenge First-Year Seminar: Climate Change
Fall and Spring: 9 units
Many consider climate change to be the most serious social, political, and environmental issue of the 21st century. As human activities increase the level of greenhouse gases in the atmosphere, scientists have established the reality of climate change and have estimated its impacts on human society and the natural world. Despite the scientific consensus on its existence, causes, and consequences, a substantial number of Americans and citizens of other countries still question these conclusions and a small but vocal group of doubters continue to challenge the science and scientific consensus on climate change. In spite of some social division over these issues, governments at local, national, and international levels have made concerted efforts to craft policies to address climate change. These policies have shifted over time as the information, attitudes, and technology associated with climate change have evolved. In this course, we will explore the challenges and complexities of climate change by investigating the subject from a variety of angles: scientific, political, rhetorical, cultural, economic, technological, and ethical. Over the course of the semester, we will inquire: What is climate change? How do scientists know it is happening? Why is there public debate over it? What solutions are available? And what are the pros and cons of the different solutions?

66-110 DC Grand Challenge First-Year Seminar: Inequality
Intermittent: 9 units
This Grand Challenge first-year seminar on inequality is inspired in part by the specter of global income inequality. Income inequality has reached such a peak that eight men own as much wealth as half the world's population, the world's poorest 3.6 billion people. Inequality may be a feature of all societies across history to some degree. But inequality strikes us an especially timely topic because of the current demands for greater political, social, and economic equality. The four of us will use the disciplines we come from - economics, anthropology, history, psychology, and literary/ cultural studies - to introduce you to the concept of inequality in the age of capitalism. We will consider how inequality emerged as a social and political problem in the 18th and 19th centuries, and how it has re-emerged as a key concept for socio-political movements in our current moment. We will conclude with an inquiry into what the future of inequality might look like, especially with the coming of increased automation and the elimination of at least 50% of the jobs currently being done by human beings.

66-114 DC Grand Challenge First-Year Seminar: Racism
Intermittent: 9 units
Racism is everywhere in the twenty-first century. In August 2009, the renowned Indian actor, Sharukh Khan, was detained at Newark International Airport. According to Khan, his Muslim surname led American immigration officials to question him about the nature of his visit for over two hours. Was his treatment racist? In 2011, Luis Suarez a Uruguayan soccer player was punished for allegedly calling French footballer Patrice Evra "negro" in England. But was the word "negro," said in Spanish, racist? Racism is a complex phenomenon that refers to historically hierarchical power differences between groups (e.g. Native populations and Europeans during the conquest), ideas about how humans can be classified into groups by "race," and also discriminatory practices against non-dominant groups. This system of social relations and ideology serves to justify social inequality and differential treatment. If we are to end racism, we must strive to understand it. What are the historical origins of racism? How is racism reproduced? How does race influence identity formation? Can racism produce positive identities? Why has the struggle against racism shifted from a demand for human rights to a search for diversity and inclusion? This course will examine racism in Pittsburgh, in the United States, and in several other countries and regions throughout the world. We will approach racism from multiple academic perspectives with a team of three faculty from the departments of History, English and Modern Languages. This team-based interdisciplinary approach to First-Year Seminars draws on several departments and guest speakers.

66-117 DC Grand Challenge First-Year Seminar: Political Rhetoric
Fall: 9 units
Without language, there would be no politics. Politics is about persuading others to adopt policies, to vote for candidates, to get out and march. Politics is about careful choices of language to frame issues, to make others see those issues in our preferred way. In this course, we will put the rhetoric of politics under the microscope, to identify its components and understand how they fit together into a powerful structure. We will use the tools of multiple disciplines in our analysis: rhetorical theory, both ancient and modern; cognitive science; contemporary discourse analysis; ethics; and philosophy of language. We will ask what it means for political rhetoric to be propaganda. We'll explore how political advertising uses marketing techniques, taking advantage of our innate biases and cognitive dispositions. We will look at how a skillful speaker can control the topic in a dialogue or a debate. And throughout, we will ask the question: is this ethical? Where does persuasion cross the boundary into manipulation, and does that matter? What type of rhetoric do we want our political process to rely on? Our goal in this course is to provide students with the skills to recognize the rhetorical tools that political agents are using, and to develop their own responses in a skillful and informed way.

66-118 DC Grand Challenge First-Year Seminar: Thinking With Evidence
Fall: 9 units
In a time of big data and widespread skepticism of science, it is crucial to understand how data and facts can be turned into conclusions, and then into public policy. Using topics from medicine, epidemiology, and public health, this course provides students an introduction into the grand challenge of understanding how evidence is used (and abused) in support of scientific conclusions. Questions of health and disease are particularly important areas for thinking about facts and figures because many life-or-death decisions have to be made on the basis of fragmentary and unreliable evidence. Every trip to the doctor, illness, and vaccination involves a complicated mix of public policy, scientific evidence, and emotional and historical factors. This course helps students understand the sciences and the humanities as united in their desire for rigorous argumentation rather than as competing or incompatible ways of thinking. Moreover, by taking a wide-angle lens to the topic, students will see how and why standards of scientific proof have changed over time, and track what these changes mean for thinking about evidence. Co-taught by a statistician and historian, this course draws on many different disciplines, providing students a broad introduction to reasoning across the humanities and social sciences. Students will be required to participate in written and oral arguments, read scientific articles as well as political, historical, and legal documents, and prepare a capstone project in which they will be asked to weigh real-life evidence and recommend a course of action to the Food and Drug Administration. Other topics may include vaccination controversies, regulation of carcinogens and toxic chemicals, mammography screening standards, and the treatment of infectious diseases in global health settings.

66-119 DC Grand Challenge First-Year Seminar: Feeding the World, Feeding Ourselves
Fall: 9 units
Food in the twenty-first century is ripe with paradox: fewer people than ever work as farmers or ranchers, but the quantity and global variety of foods available to consumers continues to expand; public health officials around the world are raising alarms about diseases linked to the over-consumption of fats and sugars, even as hundreds of millions of people do not know where their next meal is coming from; organic agriculture is booming, while agribusiness giants like Monsanto continue to expand. Producing food consumes more land and water resources than any other human activity. The individual and collective decisions people make about food shape individual and community health, social justice, and sustainability. If we are to make sound decisions about how to feed the world and feed ourselves, we need to understand the highly creative and contentious ways that people produce and consume food. In this class we will address the following central questions in order to unravel some paradoxes, and help us make informed choices, about foods we consume: (1) What are the origins of agriculture, and why does it matter for the future of food? (2) How do cultural, ecological, economic, and technological contexts shape food acquisition, preparation, and consumption? (3) What are the causes of hunger - can we feed 8 billion people healthy food and not trash the planet? And (4) what roles have science and technology played in shaping "industrial food," and in shaping the world around us?

66-122 DC Grand Challenge First-Year Seminar: Beyond Earth
Spring: 9 units
Space, as a television series once told us, is the final frontier. But what lies out there? It could be that the billions of rocky planets and moons in the Milky Way are just inert and ready to be terraformed and colonized...but what happens when we encounter life, intelligent or otherwise? In Beyond Earth, co-taught by an astrostatistician and a linguist, students will consider the various rationales for engaging with the rest of the galaxy...and the potential consequences of doing so. Why should one consider leaving the Earth, and where would he or she go? Just to Mars, or to other planetary systems? How long would it take to get to these other systems? The distances involved in space travel are immense, and we cannot rely on warp drives. Inter-generational space travel is a possibility, but who is willing to leave Earth and spend the rest of his or her life on board a spaceship? When one's descendants finally arrive in a suitable planetary system, what happens if they find life? If so, what should they do - communicate with it, control it, or fly away from it? Perhaps these are the wrong questions...perhaps we need to ask if humans have the right to occupy other planets and moons in the first place. But even if we choose not to leave Earth, there will still be the issue of communication: from radio signals to satellites leaving the Solar System to proposed light sails that will be pushed to the nearest stars, we are making ourselves known. Should we do this? And if we send signals into space, how should we design them to make ourselves understood? What should we talk about? Just how should we go about engaging with the rest of our galaxy? By the end of the course, every student will be able to make an informed and dispassionate decision: stay on Earth and improve what we all have, or strike out into the great Beyond?

66-123 DC Grand Challenge First-Year Seminar: Science on Stage
Spring: 9 units
Art and Science — two fields of study that are most often considered diametrically opposed. Art is frivolous entertainment. Science is hard rational fact. In this Grand Challenge course, we hope to break that supposition or at least examine it in great detail. Specifically, we will use theater to argue that drama can produce challenging, demanding and intelligent work that showcases the impact of science on current discourse. We want to link the two cultures. The word "theater" has the same etymological root as "theory" - both words come from the Greek thea meaning view. This shared origin demonstrates ways we can work to analyze and interpret both fields and show the common ground between these two cultures. As we attend to plays and writing ranging from Tom Stoppard¿s Arcadia and Michael Frayn¿s Copenhagen to Caryl Churchill¿s A Number and Oliver Sacks¿ Man Who Mistook his Wife for a Hat, our class discussions will consider questions that include: Why is science a trend in contemporary theater? Does it reflect on our dependence on technology? What kinds of questions are being asked when science or scientific theory is presented on the stage? Are people attracted to plays about science because of their difficult subject matter or does it does it lack the engagement of popular culture? In addition to integrating humanities and scientific approaches within Dietrich College, this course will utilize the expertise of both individuals in the School of Drama and the producers in the local theater community, and local science writers. Finally, in addition to weekly writing assignments, the course will ask students to produce original dramatic scenes that incorporate scientific exploration which will, ultimately, lead to staged readings of their work.

66-161 DC Grand Challenge First-Year Seminar: Artificial Intelligence and Humanity
Fall and Spring: 9 units
In 1965 British mathematician I.J. Good wrote, "An ultraintelligent machine could design even better machines; there would then unquestionably be an 'intelligence explosion,' and the intelligence of man would be left far behind." As we enter an age where companies like Uber are testing driverless cars in Pittsburgh and innovative interfaces like IBM's Watson can play Jeopardy and learn techniques for medical diagnoses, how are we to negotiate an 'intelligence explosion' that for many individuals might threaten the very notions of what it means to be human? The future of human-to-machine relationships will likely define our historical epoch and yet, many young technologists and humanists underestimate the downstream impact of technological innovations on human society. Presently, we have little choice but to attend to this rapidly anxiety-ridden question. This seminar will attend to the challenge of contemporary existential questions on what it means to be human (read not machine) in the context of a rapidly advancing technological age. We will consider human narratives throughout history that exam how governments and individual citizens defined humanity in the context of slavery and colonialism as a framework for exploring and projecting what it means to be human in the age of rapidly advancing 'intelligent' machines. We will trace the technological advancements of the recent five decades and identify historical precedents and speculative narratives that help us to consider issues like labor, economic disparity, negotiations of power, human dignity and ethical responsibility within the context of human relations with advancing technological tools that are now coined, artificial intelligence.

66-202 Pathways: Dietrich College Career Exploration Seminar
Intermittent: 3 units
Designed for Dietrich College students, this seminar will assist students in effective career decision making, development of internship and job search skills, and workplace readiness. Students will participate in activities involving self-reflection/self-awareness, major and career exploration, personal branding techniques, and communication skills. We will invite guest speakers including alumni, employers, and on-campus resources. Students will also be required to participate in an evening networking event with alumni throughout the country.

66-204 Film Festival
Spring
Students will take on the project of planning and managing a film festival that draws a college- and city-wide audience. Students will collaborate on all aspects of the festival: selecting films, generating and distributing marketing materials, designing and scheduling events, arranging facilities and general logistics, coordinating internal and external public relations, organizing fundraisers, rallying the local communities - in short, all the aspects involved in making the event a spectacular/sensational success! A unique feature of this course-cum-festival will be several directors' participation as guest speakers on the festival theme and other issues informing their films. Previous Film Festivals have covered such topics as: Democracy, Mechanization, Realism, Globalization, Migration, Media and Work. This course is also designed to supplement the study of film with the historical, political and sociological background that students need for critically analyzing the images and ideologies they see on the screen and understand how those images effect our views of the past and present time.

66-221 Topics of Law: Introduction to Intellectual Property Law
Intermittent: 9 units
Topics for this course vary, to include such foci as intellectual property, introduction to U.S. law, great American trials, and the U.S. Constitution. Topics and courses are designed to be broadly relevant and interesting for university undergraduates, and not narrowly tailored for students interested in law school.

66-304 DC Grand Challenge Research Seminar
Intermittent: 9 units
TBA

66-307 Independent Study
All Semesters
This course is intended for students with a special interest in an interdisciplinary area in the humanities and/or social sciences not covered by a normal course. Readings and other works are developed by the student and an individual faculty member. The number of units will be assigned at the time of registration based on the number of hours to be completed (decided in advance with the sponsoring faculty member).

66-320 Internship
All Semesters
Internships-for-credit allow students to apply course-based knowledge in a non-classroom setting, under joint supervision and evaluation by an on-site supervisor and a faculty sponsor. Approved internships must conform to college guidelines for internships-for-credit, and are available by permission only arranged through the Associate Dean's Office in Baker Hall 154.

66-400 Dietrich College Senior Honors Colloquium
Fall: 1 unit
The purpose of this course is to provide students admitted to the Dietrich College Senior Honors Program with a shared set of intellectual and practical sessions that will enhance their senior honors thesis experience. The course will consist of seven bi-weekly 80-minute meetings. Each will be organized around a theme and related topics that are relevant to the senior honors thesis experience, and that take advantage of both the high caliber and interdisciplinary diversity of the course members. Guest visitors will also be a common feature of the course. Topics could include: the meaning(s) of "honors;" getting started and keeping pace: the ebb and flow of an independent research project (including how to recognize and avoid procrastination; forging a successful relationship with your thesis advisor - the myth of the separation of research from writing; writing for publication); ethics in research; "interdisciplinarity," or the "unity of knowledge;" funding for research; preparing for and delivering effective presentations; intellectual property rights, and human subjects policy. Guest speakers invited to address and engage class members in discussion/debate of topics that lend themselves to interdisciplinary discussion and debate (e.g., stem cell research, which calls into play science, ethics, etc.). Course requirements will include mandatory attendance, occasional readings (where appropriate), acting as co-leader for at least one session, and - at course's end - (a) a written, formal preliminary thesis statement and action plan, endorsed by the thesis advisor, and tentatively, (b) a brief oral presentation of the thesis statement and plan to the class + thesis advisors during the last class meeting. All students will participate in critiques of fellow-students' presentations and plans.

66-501 H&SS Senior Honors Thesis I
Fall and Spring: 9 units
This sequence is open only to those seniors who have been admitted to the H&SS Senior Honors Program. This is the first semester of a two-semester sequence that culminates in an original, year-long independent research or creative project. Thesis topics are selected by faculty and students.

Course Website: http://www.cmu.edu/dietrich/undergraduate/programs/shp/index.html

66-502 H&SS Senior Honors Thesis II
Fall and Spring: 9 units
This sequence is open only to those seniors who have been admitted to the H&SS Senior Honors Program. This second semester course is the culmination of an original, year-long independent research project. Research topics are selected by faculty and students.
Prerequisite: 66-501

Course Website: http://www.cmu.edu/dietrich/undergraduate/programs/shp/index.html

66-503 Dietrich College Senior Honors Thesis
All Semesters: 18 units
This course is a one-semester alternative to the two-semester Dietrich College Senior Honors Thesis sequence 66-501/66-502. The course is open only to students who have been approved for entry into the Dietrich College Senior Honors Program, and whose senior honors thesis project has been approved as a one-semester undertaking. Thesis topics are selected by faculty and students, and reviewed and approved through the senior honors program application process. The thesis culminates in an original independent research or creative project. Dietrich College senior honors students are also required to participate in the annual Meeting of the Minds Undergraduate Research Symposium, offering either an oral presentation or poster session based on their senior honors thesis.

66-504 Senior Capstone I
All Semesters: 9 units
TBA

66-505 Senior Capstone II
All Semesters: 9 units
TBA

66-506 Senior Capstone
All Semesters
TBA

General Dietrich College Courses

65-201 Humanities Scholars III
Fall: 9 units
Humanities Scholars Program III: Poetry and Power (Fall 2019) Audre Lorde wrote, "Poetry is not a luxury. It is a vital necessity of our existence." Poetry is often perceived as an elite art, practiced within the confines of academia and understood only by a chosen few. But poetry is grounded historically in an oral tradition and a sense of public ownership. Does poetry have power in our society? What is its social function? How is poetry distinct from other modes of writing and art? Can poetry advance social movements and connect people with perspectives beyond their comfort zones? This course will consider arguments about poetry and its relationship with society. Students will read and discuss poetry both on and off the page, as well as explore arguments about poetry, poetics, and power via essays, literature, performance, media, and community engagement.
Prerequisite: 65-102

Course Website: http://www.hss.cmu.edu/hsp/

65-203 Applied Quantitative Social Science II
Spring: 9 units
Applied Quantitative Social Science II is the second course in the QSSS core sequence. Conducted in a seminar format, the course will feature guest lectures from a series of faculty at CMU. Students will discuss ongoing research across the social sciences, and over the course of the semester will develop a research project proposal. Seminar participation is limited to QSSS students.

Heinz College of Information Systems and Public Policy

Ramayya Krishnan, Dean
Location: 1003 Hamburg Hall
www.heinz.cmu.edu

The next generation of leaders must deeply understand this critical point of intersection: People, policy, and technology. The connections between the three define our time, and will continue to shape the future of humankind.

At Heinz College, we've understood this since our founding, and we provide students with a foundation of data analytics, technology, evidence-based management, and rich experiential learning in contexts that are crucial to society, such as public policy, health care, information systems, cybersecurity, the arts, and entertainment.

Our research programs are best described as data-intensive social science. Our economists, statisticians, operations researchers, computer scientists, and management experts sit side by side, collaborating constantly and not sitting in traditional departmental silos. For this reason, they are able to approach complex societal problems in an altogether different way and impart this interdisciplinary mindset to our students.

The unique co-location of our two schools, the School of Public Policy and Management (https://www.heinz.cmu.edu/about/public-policy-management) and the School of Information Systems and Management (https://www.heinz.cmu.edu/about/information-systems-management), offers opportunities for collaboration that simply cannot be duplicated elsewhere. We also offer two groundbreaking Joint Degree Programs with the CMU College of Fine Arts (https://www.heinz.cmu.edu/about/fine-arts).

Graduates of Heinz College are highly sought by employers across sectors for their interdisciplinary expertise and ability to use relevant data to solve complex problems. Our alumni work for government agencies at the federal, state, and local levels. They work in roles that directly impact national security. They work for tech giants, big consulting firms, major media outlets, cultural institutions, top hospitals and health systems, non-profits, and community organizations of all sizes. They work for startups—or they found their own.

Learn more about Heinz College graduate degree programs (https://www.heinz.cmu.edu/programs).

Public Interest Technology

Public Interest Technology (PIT) is an emerging field unto itself, but Carnegie Mellon University has been a leader in this space for over 50 years, promoting the use of technology to advance the public interest. Continued excellence in this space is a priority for Heinz College.

Learn more about PIT at Heinz College (https://www.heinz.cmu.edu/about/public-interest-technology).

Minor in Health Care Policy and Management

Sponsored by:
Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:
Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 27 units from the following:		
79-330	Medicine and Society	9
90-836	Health Systems	6
90-721	Healthcare Management	6
90-861	Health Policy	6

Elective Courses

Complete a minimum of 18 units from these two sections:

Heinz College Courses		
90-831	Advanced Financial Management of Health Care	6
94-705	Health Economics	12
90-832	Health Law	6
90-833	Population Health	6
90-818	Health Care Quality & Performance Improvement	6
90-834	Health Care Geographical Information Systems	12
Other courses as approved		

Humanities and Social Sciences Courses (9 units each)		
80-245	Medical Ethics	9
76-494	Healthcare Communications	9
88-365	Behavioral Economics and Public Policy	9
67-476	Innovation in Information Systems: Health Care	9
42-444	Medical Devices	9
Other courses as approved		

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

Health Management/Administration Focus		Units
90-831	Advanced Financial Management of Health Care	6
90-832	Health Law	6
90-818	Health Care Quality & Performance Improvement	6
80-245	Medical Ethics	9
76-494	Healthcare Communications	9

Health Policy Focus		Units
94-705	Health Economics	12
90-832	Health Law	6
90-833	Population Health	6
88-365/90-882	Behavioral Economics and Public Policy	9
Other courses as approved		

Health Analytisc & IT Focus		Units
90-834	Health Care Geographical Information Systems	12
67-476	Innovation in Information Systems: Health Care	9
42-444	Medical Devices	9
Other courses as approved		

Five-Year (Accelerated) Master's Programs

Students with the drive to develop as leaders and enter the job market more quickly can earn their CMU undergraduate degree **and** a professional master's degree from Heinz College together in five years instead of the typical six.

An Accelerated Master's Program (AMP) isn't just a savings of time. It's also a considerable savings in cost, and adds a tremendous level of experience and expertise in a specific industry.

In the Heinz College AMP program, students complete 3 years in a CMU undergraduate program (any major), followed by 1 year of integrated study, followed by 1 full year at Heinz College.

The following Heinz College master's degree programs offer accelerated options for CMU undergraduates:

- Master of Arts Management (MAM)
- Master of Entertainment Industry (MEIM)*
- Master of Information Systems Management (MISM)
- Master of Science in Health Care Policy and Management (MSHCPM)
- Master of Science in Information Security Policy and Management (MSISPM)
- Master of Information Security Policy and Management (MSISPM)
- Master of Science in Public Policy and Management (MSPPM)*

Students must apply and be admitted to Heinz College. Learn more about Heinz College admissions requirements (https://cms.heinz.cmu.edu/entity/open.act?type=page&id=9aeb56a680021b851d4afb14fbaf800f&confId=a9cdd07a80021b851d4afb14d072acf3).

For more information on Accelerated Master's Programs, please contact the Heinz College Office of Admissions at hnzadmit@andrew.cmu.edu or by phone 412-268-2164.

***Note on AMP planning for MEIM and MSPPM - Washington, D.C.:** Due to the rigorous format and unique academic demands of the MEIM and MSPPM – Washington D.C. programs—with their second years at CMU's Los Angeles and D.C. campuses, respectively—interested students should begin the AMP planning process as early as possible in their undergraduate career. Students must ensure that they have satisfied all requirements for their undergraduate degree, as well as their first-year master's requirements, by the end of the fourth AMP year.

Ph.D. Program

Distinguished by the interdisciplinary model of Heinz College and Carnegie Mellon University, our Ph.D. programs prepare graduates to lead change in their chosen fields through meaningful collaborations and hands-on work with our renowned and extremely accessible faculty.

Heinz College features the unique co-location of two schools: The School of Information Systems and Management and The School of Public Policy and Management; however, below that larger structure, we are a college without departments and their characteristic silos. Our faculty, students, and research centers thrive by working together to solve problems across subjects, disciplines, and business verticals.

In the Heinz College Ph.D. program, you will conduct innovative research to address increasingly complex challenges facing society, whether those challenges are technical, organizational, political, economic, social, or—as is often the case—some combination thereof.

- Ph.D. in Information Systems and Management (https://www.heinz.cmu.edu/programs/phd-programs/information-systems-management)
- Ph.D. in Public Policy and Management (https://www.heinz.cmu.edu/programs/phd-programs/public-policy-management)
- Joint Ph.D. Programs (https://www.heinz.cmu.edu/programs/phd-programs/joint-phd)
- Recent Ph.D. Placements (https://www.heinz.cmu.edu/programs/phd-programs/phd-placements)

Contact:
Martin S. Gaynor, Ph.D., Program Director
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Pittsburgh, PA 15213
412-268-7933
mgaynor@andrew.cmu.edu

Faculty and Research Centers

FACULTY

Heinz College has an international reputation for the quality of its research. Our interdisciplinary environment creates exciting opportunities for collaboration and produces a breadth of research work not typically found in schools of our size.

Our faculty and research centers consistently receive funding support from government agencies, foundations and corporate partners, like the National Science Foundation; the Heinz Endowments; the Mellon Foundation; the U.S. Departments of Defense, Commerce, Health and Human Services, and Housing and Urban Development; the Sloan Foundation; and the National Institute of Justice.

Visit our Faculty pages (https://www.heinz.cmu.edu/faculty-research) to learn more about individual faculty members, accomplishments, and current research.

RESEARCH CENTERS

We host, or are closely associated with, these CMU research centers:

- Arts Management and Technology Laboratory (AMTLab) (http://amt-lab.org)
- Block Center for Technology and Society (https://www.cmu.edu/block-center)
- Center for Behavioral Decision Research (CBDR) (http://cbdr.cmu.edu)
- Center for Economic Development (CED) (https://www.heinz.cmu.edu/ced)
- CyLab (http://www.cylab.cmu.edu)
- Event and Pattern Detection Lab (EPD Lab) (http://epdlab.heinz.cmu.edu)
- iLab (http://ilab.heinz.cmu.edu)
- Initiative for Digital Entertainment Analytics (IDEA) (http://idea.heinz.cmu.edu)
- Living Analytics Research Centre (LARC) (https://larc.smu.edu.sg)
- Metro21: Smart Cities Institute (http://www.ices.cmu.edu/metro21)
- Privacy Economics Experiments (PEEX) Lab (https://peex.heinz.cmu.edu)
- Program for Research and Outreach on Gender Equity in Society (PROGRESS) (http://progress.heinz.cmu.edu)
- Risk and Regulatory Services Innovation Center (sponsored by PwC) (https://www.cmu.edu/risk-reg-center)
- Traffic21 (https://traffic21.heinz.cmu.edu)

Diversity and Inclusion

The Heinz College of Information Systems and Public Policy represents over 50 nations and over 40 U.S. states, which increases our ability to foster a community with greater variation in perspectives and approaches to our work.

By design, Heinz College is an empathetic and open environment that inspires continuous learning, conversation, and intelligent action that will impact society for the better.

Diversity, inclusion, and equity are not radical concepts. Rather, the ongoing pursuit of these ideals is fundamental to the energetic exchange of ideas; the success of our students, faculty, and staff; and the unlocking of innovations that will improve the human condition.

Heinz College proudly champions the unique experiences of all members of our campus community. It is a priority for Heinz College to attract, maintain, and nurture a student body of diverse viewpoints, backgrounds, and talents. We are also committed to improving access to our graduate programs, in particular for underrepresented populations. We support these efforts through a variety of initiatives, programming, and partnerships in addition to Carnegie Mellon University's campus-wide efforts.

Learn more about Diversity & Inclusion at Heinz College (https://www.heinz.cmu.edu/about/diversity).

CONTACT

Director of Admissions
Heinz College of Information Systems and Public Policy
Carnegie Mellon University
Pittsburgh, PA 15213

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Toll-free (U.S.): 1-800-877-3498
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Faculty

ALESSANDRO ACQUISTI, Assistant Professor of Information Systems and Public Policy – Ph.D., UC Berkeley; Carnegie Mellon, 2003–

SHAMENA ANWAR, Assistant Professor of Economics and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2007–

LINDA BABCOCK, James M. Walton Professor of Economics – Ph.D., University of Wisconsin at Madison; Carnegie Mellon, 1988–

EDWARD BARR, Associate Teaching Professor – M.S., Indiana University of Pennsylvania; Carnegie Mellon, 2000–

ALFRED BLUMSTEIN, J. Erik Jonsson University Professor of Urban Systems and Operations Research; Director, National Consortium on Violence Research – Ph.D., Cornell University; Carnegie Mellon, 1969–

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DAVID KRACKHARDT, Professor of Organizations and Public Policy – Ph.D., University of California at Irvine; Carnegie Mellon, 1991–

RAMAYYA KRISHNAN, William W. and Ruth F. Cooper Professor of Management Science and Information Systems; Faculty Chair, Master of Information Systems Management Program – Ph.D., University of Texas at Austin; Carnegie Mellon, 1987–

KRISTIN KURLAND, Associate Teaching Professor (joint with School of Architecture) – B.A., University of Pittsburgh; Carnegie Mellon, 1999–

LESTER LAVE, James Higgins Professor of Economics and Finance, Professor of Urban and Public Affairs, Professor of Engineering and Public Policy – Ph.D., Harvard University; Carnegie Mellon, 1963–

GORDON LEWIS, Associate Professor of Sociology; Faculty Chair, Master of Public Management Program – Ph.D., Stanford University; Carnegie Mellon, 1969–

PAMELA LEWIS, Teaching Professor of Professional Speaking – D.A., Carnegie Mellon University; Carnegie Mellon, 1980–

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PETER MADSEN, Senior Lecturer in Ethics and Public Policy – Ph.D., Duquesne University; Carnegie Mellon, 1988–

DONALD MARINELLI, (Affiliated) Professor of Drama and Arts Management (College of Fine Arts) – Ph.D., University of Pittsburgh; Carnegie Mellon, 1984–

DAN MARTIN, Director, Master of Arts Management Program, and Associate Professor (College of Fine Arts) – M.F.A., Brooklyn College/City University of New York; Carnegie Mellon, 1993–

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M. GRANGER MORGAN, Lord Chair Professor of Engineering and Public Policy, and Head, Department of Engineering and Public Policy – Ph.D., University of California at San Diego; Carnegie Mellon, 1974–

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STEPHEN ROEHRIG, Associate Professor of Information Systems and Public Policy – Ph.D., University of Pennsylvania Wharton School; Carnegie Mellon, 1991–

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KIRON SKINNER, (Courtesy) Assistant Professor of History and Political Science – Ph.D., Harvard University; Carnegie Mellon, 1999–

DONALD SMITH, Professor of Practice; University Director for Economic Development – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1995–

KATHLEEN SMITH, Associate Teaching Professor – Ph.D., candidate, University of Pittsburgh; Carnegie Mellon, 1991–

MICHAEL SMITH, Assistant Professor of Information Technology – Ph.D., Alfred P. Sloan School of the Massachusetts Institute of Technology; Carnegie Mellon, 2000–

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SHELBY STEWMAN, Professor of Sociology and Demography – Ph.D., Michigan State University; Carnegie Mellon, 1973–

ROBERT STRAUSS, Professor of Economics and Public Policy; Faculty Chair, Master of Science in Educational Technology Management Program – Ph.D., University of Wisconsin; Carnegie Mellon, 1979–

LAURA SYNNOTT, Associate Teaching Professor, Healthcare Policy and Management – M.S., Health Services Administration, University of Michigan; Carnegie Mellon, 2004–

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LOWELL TAYLOR, Professor of Economics and Public Policy; Associate Dean of Faculty – Ph.D., University of Michigan; Carnegie Mellon, 1990–

RAHUL TELANG, Assistant Professor of Information Systems – Ph.D., Carnegie Mellon; Carnegie Mellon, 2001–

MARK WESSEL, Dean University of Wisconsin; Carnegie Mellon, 1992–

TIM ZAK, Associate Teaching Professor – M.B.A., New York University; Carnegie Mellon, 2011–

Mellon College of Science

Rebecca W. Doerge, Dean

Maggie Braun, Associate Dean for Undergraduate Affairs

Kenneth Hovis, Assistant Dean for Educational Initiatives

Location: Doherty Hall 1324
www.cmu.edu/mcs

The Mellon College of Science (MCS) has provided the undergraduate training for many of today's leading scientists. We have earned national recognition for our integration of undergraduate education and research from such organizations as the National Science Foundation, the Howard Hughes Medical Institute, and the Beckman Foundation. MCS students gain a broad education in science, mathematics, and the liberal arts while using state-of-the-art computational approaches in their courses, laboratories, and research activities. Our faculty members are committed to teaching as well as to a wide range of scientific research. This combined emphasis on education and research brings special benefits to students, including increased awareness of current scientific developments that are incorporated in classroom instruction, and, most importantly, opportunities to participate with faculty, graduate students, and other research scientists in a variety of research projects.

In the context of rigorous training in each field, the MCS curriculum emphasizes problem-solving, communication, and analytical skills, and it teaches our students the value of hard work and discipline. Our students go on to highly successful careers in a broad range of fields like astrophysics, biotechnology, computer science, business management, environmental science, health care policy, investment banking, marketing analysis, medicine, patent law, and pharmaceuticals. Our alumni credit their education in science for preparing them for a lifetime of learning and achievement; their employers attest to their ability to succeed and to continue learning in an ever-changing world.

The MCS Departments of Biological Sciences, Chemistry, Mathematical Sciences, and Physics each outline their degree programs and courses in the departmental sections. Students select their major in the spring of the first year so that the sophomore year begins with a focus within a department. Most of the courses required within a major are scheduled in the sophomore and junior years, leaving much of the senior year and part of the junior year open for electives. This provides the opportunity to participate in undergraduate research, explore interdisciplinary studies, study abroad, pursue additional majors or minors in other fields, or take other specialty courses oriented toward immediate job placement upon graduation or entry into graduate studies.

Science education in the 21st Century demands educational experiences that are much broader than the traditional preparation of a scholar in a chosen field of science. We want our MCS graduates to be **scholars** who are deeply trained in their discipline(s), and also **professionals** adept at communicating to broad audiences, accustomed to working in diverse, multidisciplinary teams, and keenly aware of the global context of their work. We want them to be **citizens** who are actively involved and globally engaged, and to grow as **persons** with a sense of wellness and balance.

With these ambitions in mind, we have set forth fifteen (15) outcomes that all MCS undergraduate students should complete in their time at Carnegie Mellon. Upon graduation, MCS students should be able to:

1. Apply foundational and advanced mathematical and scientific knowledge in a chosen field of study appropriately and fluently to solve complex problems, to integrate concepts across disciplines, and to adapt their knowledge to new situations.
2. Critically assess their current state of knowledge and expertise and acquire new knowledge in pursuit of both specific scientific goals and new intellectual interests broadly throughout their lifetime.
3. Communicate effectively via oral, visual, and written formats with an understanding of the perspectives and expectations of diverse audiences, including those within their chosen discipline, outside that discipline (but within STEM), and non-scientists.
4. Participate effectively in multidisciplinary research and/or other teams pursuing a shared vision while optimizing team outcomes.
5. Use the appropriate tools and required media literacy to acquire, assess, and analyze data and information from diverse sources.
6. Recognize and explain the importance of at least one current research topic in a STEM field outside of their major.
7. Recognize and explain the similarities and differences in analyzing/approaching problems, including in technical and non-technical fields other than their major.
8. Demonstrate knowledge of the arts, humanities, and social sciences.
9. Recognize the interplay of science, society, public policy, business, and economics.
10. Identify global examples of the reciprocal relationships among science, technology, political forces, societal contexts, and environmental issues.
11. Describe multiple similarities and differences between one's own culture and that of others.
12. Engage in recursive, reflective processes to assess their own levels of physical, emotional, and social wellness and then to choose activities that promote these aspects of wellness.
13. Engage in recursive, reflective processes to balance multiple endeavors by setting priorities and managing time in academic, meta-curricular, and personal dimensions.
14. Recognize ethical issues and appreciate the complexities of interrelationships among them, and the use of information in ethical and legal manners.
15. Articulate how one's own developing skills in science and technology can be increasingly used in constructive community service or engagement that recognizes the potential impact on local and global issues, including environmental impact and sustainability.

Tailoring Your Education

The Mellon College of Science offers students tremendous opportunity for tailoring their education to meet individual professional objectives. Whether you target your degree to a particular field in your discipline via departmental options and concentrations, add a secondary major, minor, or degree to your primary degree program, participate in honors programs, or pursue a master's degree along with your bachelor's degree, MCS has much to offer you. Many of these opportunities are outlined below.

Departmental Concentrations

Each department in MCS offers degrees and programs that allow students to explore particular fields within a science discipline. These are outlined below — see the departmental sections for further details.

Biological Sciences

- Biochemistry
- Biophysics

- Cell Biology
- Computational Biology
- Developmental Biology
- Genetics
- Molecular Biology
- Neuroscience

Chemistry

- Biochemistry
- Biological Chemistry
- Colloids, Polymers, and Surfaces
- Computational Chemistry
- Environmental Chemistry
- Management
- Material Chemistry
- Polymer Science

Mathematical Sciences

- Computational and Applied Mathematics
- Computational Finance
- Discrete Mathematics and Logic
- Mathematics
- Operations Research
- Statistics

Physics

- Applied Physics
- Astrophysics
- Biological Physics
- Chemical Physics
- Computational Physics

Minors, Double Majors, and Double Degrees

As an MCS student, you can pursue additional majors and minors to complement your primary degree, not only within the science college, but also through the other colleges at Carnegie Mellon. Carnegie Mellon offers many exciting interdisciplinary majors and minors, some of which are listed below. In addition, every college and most departments have designed minors or second majors in their discipline so that you can gain expertise in their fields as well.

Some students choose to gain this expertise by following a double degree program. This results in two distinct bachelor's degrees. Please see the section on Undergraduate Academic Regulations for a more formal definition of these "Multiple Degree" programs.

Interdisciplinary Majors and Minors

Here is a sampling of just a few of the interdisciplinary minors and majors offered at Carnegie Mellon (not all are in MCS). Please see the appropriate sections elsewhere in this catalog for specific descriptions and course requirements.

- Biological Sciences and Psychology Major
- Computer Science Minor
- Engineering Studies Minor
- Environmental and Sustainability Studies Minor
- Environmental Policy Major
- Health Care Policy and Management Minor
- International Affairs Minor
- Mathematics and Economics Major
- Neuroscience Major and Minor
- Robotics Minor
- Scientific Computing Minor
- Technology and Policy Minor

For a complete list of the minors offered at Carnegie Mellon, please go to Undergraduate Options (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#minorstext).

University Student-Defined Majors

With a well-thought proposal, you may be able to pursue a major you have designed to meet your particular interests and goals. Please see the catalog section on Student-Defined Majors (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#studentdefinedmajortext).

General Education Requirements

Students pursuing any MCS bachelor's degree will fulfill the 15 Core Education outcomes through their primary MCS major and by completing the following technical and nontechnical breadth requirements prior to graduation.

Technical Breadth Requirements

As a 21st Century practicing scientist or mathematician, our graduates will work with others from a variety of technical backgrounds. Therefore, all of our students will be broadly trained within the technical fields of science and math. Students will fulfill this training by completing four (4) technical courses in the Science, Technology, Engineering, and/or Mathematics (STEM) fields at Carnegie Mellon University.

A student must take at least 9 units, outside of their primary major department, from each of four categories listed below. These may include prerequisite courses or courses required by their major Department but must be outside their home Department. AP/IB/Cambridge credit may not be used to fulfill these requirements. At least three of these courses must be taken in their first year. The categories are:

A. Life Sciences

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

LIFE SCIENCES		
02-223	Personalized Medicine: Understanding Your Own Genome	9
02-250	Introduction to Computational Biology	12
or 03-250	Introduction to Computational Biology	
02-261	Quantitative Cell and Molecular Biology Laboratory	9
03-116	Phage Genomics Research	6
03-117	Frontiers, Analysis, and Discovery in Biological Sciences	6
03-121	Modern Biology	9
03-151	Honors Modern Biology	10
03-124	Modern Biology Laboratory	9
03-125	Evolution	9
03-127	How Biological Experiments Work - A Project Course	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
03-135	Structure and Function of the Human Body	9
03-161	Molecules to Mind	9
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
85-219	Biological Foundations of Behavior	9

B. Physical Sciences

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

PHYSICAL SCIENCES		
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-107	Honors Chemistry: Fundamentals, Concepts and Applications	10
09-214	Physical Chemistry	9
09-217	Organic Chemistry I	9
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12

09-225	Climate Change: Chemistry, Physics and Planetary Science	9
09-348	Inorganic Chemistry	10
33-121	Physics I for Science Students	12
33-122	Physics II for Biological Sciences and Chemistry Students	9
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12
33-151	Matter and Interactions I	12
33-152	Matter and Interactions II	12
33-211	Physics III: Modern Essentials	10
33-224	Stars, Galaxies and the Universe	9
33-225	Quantum Physics and Structure of Matter	9

C. Mathematics, Statistics, and Computer Science

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

MATH, STATS, and CS		
02-201	Programming for Scientists	10
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-124	Calculus II for Biologists and Chemists	10
21-127	Concepts of Mathematics	10
21-128	Mathematical Concepts and Proofs	12
21-228	Discrete Mathematics	9
21-241	Matrices and Linear Transformations	10
or 21-240	Matrix Algebra with Applications	
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	9
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
36-200	Reasoning with Data	9
36-202	Statistics & Data Science Methods	9
36-217	Probability Theory and Random Processes	9
36-220	Engineering Statistics and Quality Control	9
36-225	Introduction to Probability Theory	9
36-247	Statistics for Lab Sciences	9
36-309	Experimental Design for Behavioral & Social Sciences	9
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
15-251	Great Ideas in Theoretical Computer Science	12

D. STEM Course

- All of the above courses
- Any introductory engineering course from CIT
- A STEM course approved by an MCS advisor

Technical Breadth-Departmental Requirements

Some of the majors in MCS require certain courses from the technical breadth requirement that are necessary for either prerequisite knowledge in the major or scientific breadth. For each of the four majors in MCS the Technical Breadth Requirement is completed as follows. If these requirements are met by AP/IB/Cambridge A Level Exams, students can choose any course from the categories to fulfill the Technical Breadth Requirement.

Biological Sciences

1. Life Sciences: any courses in this category **except** for the 03-XXX courses
2. Physical Sciences: 09-105, 09-106, 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Chemistry

1. Life Sciences: 03-121 or 03-231 or 03-232
2. Physical Sciences: 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Mathematical Sciences

1. Life Sciences: any courses in this category
2. Physical Sciences: any course in this category
3. Math/CS/Stats: any course in this category **except** for the 21-XXX courses, 36-200 Reasoning with Data, or 36-202
4. STEM Elective: any STEM course from the approved list.

Physics

1. Life Sciences: 03-121
2. Physical Sciences: 09-105
3. Math/CS/Stats: 21-120, 21-122, 21-259
4. STEM Elective: will be fulfilled by courses above or any STEM course from the approved list.

Nontechnical Breadth Requirements

MCS aspires for all of our undergraduates to leave our campus with a strong sense of personal integrity, social responsibility, ethics, working with diverse others, global engagement, and personal health and well-being. The following nontechnical breadth requirements will require students to develop a personalized plan for their course selection and meta-curricular participation to maximize their CMU experience. Our graduates will be well trained to be life-long and life-wide learners that will lead the scientific community and the world at large.

All candidates for MCS bachelor's degrees must complete the following nontechnical breadth requirements:

A. The following three courses must be taken in the first year:

38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument A total of nine units must be completed in order to fulfill this requirement	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106	Writing about Literature, Art and Culture	
or 76-107	Writing about Data	
or 76-108	Writing about Public Problems	
99-101	Computing @ Carnegie Mellon	3

B. The following courses must be taken in the Spring of the junior year:

38-302 Science and Society and either 38-303 Professional Development and Life Skills or 70-246 Innovation & Entrepreneurial Mindset

C. ENGAGE Courses:

The ENGAGE courses are self-directed learning opportunities (using the MyCORE online platform) designed to enhance students' engagement with wellness, the arts and community service. Please see the course description for information on when these courses should be taken:

ENGAGE COURSES		
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-230	ENGAGE in Wellness: Looking Inward	1
38-330	ENGAGE in Wellness: Looking Outward	1
38-430	ENGAGE in Wellness: Looking Forward	1

D. Cultural/Global Understanding Course:

Cultural or global understanding course(s) may be taken at any time. Nine (9) or more units from the following group of courses will fulfill this requirement. Any student who finds an appropriate Carnegie Mellon course not on the list below that might fulfill this requirement should contact their academic advisor to review the course description to determine if it can be substituted. Cultural and global understanding courses that are taken while studying abroad can be used to fulfill this category. In addition, transfer courses will also be considered for this category. However, this course requirement *cannot* be satisfied with AP/IB/Cambridge exam credit.

CULTURAL/GLOBAL UNDERSTANDING		
57-173	Survey of Western Music History	9
57-209	The Beatles	9

57-306	World Music	9
70-342	Managing Across Cultures	9
76-221	Books You Should Have Read by Now: 16th & 17th C. Pop Culture	9
76-227	Comedy	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
76-386	Language & Culture	9
79-104	Global Histories	9
79-201	Introduction to Anthropology	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-205	20th Century Europe	9
79-210	Identity, Nationhood, and State	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-213	The American Railroad: Decline and Renaissance in the Age of Deregulation	6
79-214	Paris in Revolt: History, Literature, Film	6
79-216	Genghis Khan and the Mongol Empire	3
79-217	The War in Vietnam	6
79-220	Screening Mexico: Mexican Cinema, 1898 to Present	6
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-232	Arabian Peninsula Environmental History	9
79-233	The United States and the Middle East since 1945	9
79-235	Caribbean Cultures	9
79-240	Development of American Culture	9
79-241	African American History: Africa to the Civil War	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-264	Tibet and China: History and Propaganda	6
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-275	Introduction to Global Studies	9
79-307	Religion and Politics in the Middle East	9
79-345	Roots of Rock & Roll	9
79-349	United States and the Holocaust	6
79-350	Early Christianity	9
79-377	Food, Culture, and Power: A History of Eating	9
80-100	Introduction to Philosophy	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism	9
80-276	Philosophy of Religion	9
82-xxx	Any course from Modern Languages	
99-3xx	Any of the Country Today courses	3

E. Nontechnical Elective Courses

To fulfill this requirement, students must complete a minimum of four (4) nontechnical courses totaling at least 36 units in the College of Fine Arts, the Tepper School of Business, and/or the Dietrich College for Humanities and Social Sciences. A maximum of 18 units of these units may be fulfilled via AP/IB/Cambridge exam credit. Up to 36 units of these nontechnical elective units may be filled by transfer credit (with prior approval through the MCS transfer credit process). Courses counted toward the Cultural/Global Understanding requirement and the First-Year Writing requirement **do not** count toward this requirement.

Note: Check our web site for courses from DC, CFA, and Tepper that may NOT be used (http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html) to satisfy this requirement because they are too technical in nature, plus a list of courses in other colleges (including SCS, CIT, and Heinz College) that do satisfy (http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html) this requirement.

The following requirements apply to all MCS bachelor's degrees:

1. Students must complete a minimum of 360 units.
2. The four courses required for the Technical Breadth category can be completed at Carnegie Mellon or via transfer credit.
3. AP/IB/Cambridge exam credit cannot be used to fulfill the Cultural/Global Requirement. Cultural and global understanding courses that are taken while studying abroad can be used to satisfy this requirement. In addition, transfer courses will also be considered for this category.
4. For the Nontechnical Electives requirement, students must complete a minimum of four courses totaling at least 36 units with a maximum of 18 units from AP/IB/Cambridge exam credit. In addition, transfer courses will also be considered for this category.

Honors Degree Programs in MCS

Several of the departments in MCS offer students an opportunity to participate in a departmental honors degree program. Some of these programs result in a master's degree along with the bachelor's degree (see next section on accelerated master's programs). These programs are listed below; see the department's section of the catalog for more details.

- Honors Program in Research Biology
- Departmental Honors in Chemistry
- Honors B.S./M.S. Program in Chemistry
- Honors B.S./M.S. Program in Mathematical Sciences

Accelerated Master's Programs

Carnegie Mellon offers some accelerated master's programs for motivated students, whereby students complete both the bachelor's and the master's degree in four or five years. Some programs are in the student's home department in MCS as part of an honors program, while others are offered through one of our graduate schools at Carnegie Mellon. Below is a listing of the programs currently available to MCS students; please see the appropriate sections of the catalog for more details.

- Honors B.S./M.S. Program in Chemistry
- Honors B.S./M.S. Program in Mathematical Sciences
- Accelerated Master's Program in the Heinz College

Study Abroad

There are many programs for studying abroad, usually during your junior year. Please see the catalog section on Undergraduate Options for more details, and talk with the Office of International Education to get information and advice specifically for you.

Pre-Professional Programs

Many students in the Mellon College of Science decide to pursue professional training such as medical school or law school after completing their undergraduate work. Carnegie Mellon offers strong advising services to support these students. Through these programs, students get help with everything from course selection to identification of important experiential opportunities to the application process itself.

Health Professions Program

Faculty Contact: Jason D'Antonio

Please see the Undergraduate Options (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#healthproftext) section for details on the Health Professions Program.

Pre-Law Advising Program

Faculty Contact: Joseph Devine

Please see the Undergraduate Options (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#prelawtext) section for details on the Pre-Law Advising Program.

Intercollege Programs

Bachelor of Science and Arts Degree Program (BSA)

Students in the Bachelor of Science and Arts Degree Program (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/bxaintercollege/.html) are jointly admitted to MCS and the College of Fine Arts (CFA). This is a degree program for students who are naturally gifted in both the arts and the sciences, and allows for the combining of talents in these areas.

Science and Humanities Scholars Program (SHS)

Students who entered Carnegie Mellon prior to the fall of 2018 are eligible for this program and should see their entering year catalog (http://coursecatalog.web.cmu.edu/previous) for more information and the SHS general education requirements.

Applying Your Education Through Research

An important feature of education in MCS is the opportunity for undergraduate research experience. This experience may be arranged as a course taken for credit or occasionally as a part-time job.   Our website (http://coursecatalog.web.cmu.edu/schools-colleges/melloncollegeofscience/www.cmu.edu/mcs) offers a range of useful information including links to faculty research areas, links to undergraduate research programs at other institutions, and ideas on how to get involved. Because of the strong research base of MCS, undergraduate research positions offer an exciting opportunity to apply your theoretical training to participate in the discovery of new knowledge.

Students can earn MCS Research Honors for significant research accomplishments; see the policy outlined below for the requirements.

Mellon College of Science Research Honors

Undergraduates in the Mellon College of Science will be awarded MCS College Honors at the completion of their degree if they have met one of these requirements:

1. Successfully completed the Honors BS/MS program in the Department of Chemistry or Department of Mathematical Sciences.
2. Successfully completed the departmental honors program in the Department of Biological Sciences or the Department of Chemistry.
3. Earned a cumulative grade point average of ≥3.20 (by their seventh semester or by the time of graduation) and carried out significant research. Typically, this would consist of an academic project carried out for at least two semesters. However, a single project that spans a summer and a semester or that the research mentor deems to be significant and sustained, even if the student worked for pay rather than credit, will be allowed. In addition, some form of public dissemination of this research, which has been approved by the MCS Associate Dean for Undergraduate Affairs, such as a peer reviewed publication, research thesis, or presentation at an external scientific meeting is required. The Meeting of the Minds by itself is not sufficient and participation in a pre-approved judged competition (eg. Sigma Xi, Math Department competition, or Psychology department competition) is necessary.

Final approval of nominations for MCS Honors will come from the Dean of MCS and the MCS Associate Dean for Undergraduate Affairs.

Research Centers

The Mellon College of Science is home to a number of innovative research centers. These centers are particularly strong because of the interdisciplinary collaboration of their scientists. This interdisciplinary research brings international prestige to the college. Many students conduct undergraduate research with one of these centers.

The Bruce and Astrid McWilliams Center for Cosmology joins research efforts in astrophysics and particle physics and partners with computer science, statistics, and other disciplines to unravel the mysteries of the universe.

The Center of Atmospheric Particle Study’s goal is to be the world leader in science, engineering, and policy covering the full role of fine particulate matter in the atmosphere. Our goal in research is to advance the state of knowledge across this spectrum substantially, to provide both policy-relevant research, and to participate directly and actively in the evolution of environmental policy related to particulate matter.

The Center for Computational Finance’s mission is to improve the interaction between academic research and the finance industry.

The Center for Macromolecular Engineering’s goals are to enhance the benefits of polymer science to society by developing new methods to prepare advanced polymer materials, train and develop tomorrow’s scientists, and transfer technology to industry.

The Center of Nano-enabled Device and Energy Technologies’ mission is to work on real-world problems that can be solved potentially with appropriate nano-enabled technologies.

The Center for the Neural Basis of Cognition is a joint program between Carnegie Mellon University and the University of Pittsburgh. It synthesizes the disciplines of basic and clinical neuroscience, cognitive psychology, and computer science, combining neurobiological, behavioral, computational, and brain imaging methods.

The Center for Nonlinear Analysis was established in 1991. A special focus for applications emphasizes new and innovative methods to study contemporary issues in materials science. The center has created a vigorous environment for collaboration among mathematical and allied scientists.

The Center for Nucleic Acids Science and Technology is a community of Carnegie Mellon scientists and engineers unified by interests in the chemistry, biology, and physics of DNA, RNA, and PNA (peptide nucleic acid).

The Institute for Green Science has been established as a research, education, and development center in which a holistic approach to sustainability science is being developed. The focus of the institute is in three areas: renewable energy technologies, chemical feedstocks, and benign alternatives to polluting technologies.

The Molecular Biosensor and Imaging Center uses an interdisciplinary approach to develop reagents, microscopes, and imaging tools and applies them to the investigation of fundamental problems in biology and biotechnology.

The Pittsburgh Supercomputing Center provides information on advanced scientific computing for engineering and research.

Academic Standards

Academic Actions

MCS Dean’s List

Each semester MCS recognizes those students with outstanding academic records by naming them to the Dean’s List. The criteria for such recognition are as follows:

Dean’s List

The student must earn a quality point average of at least 3.50 while completing a minimum of 36 factorable units and earning no incomplete grades.

Dean’s List High Honors

The student must earn a quality point average of at least 3.75 while completing a minimum of 36 factorable units and earning no incomplete grades.

Probation, Suspension, and Drop

In the first year, quality point averages below 1.75 in either semester invoke an academic action. For all subsequent semesters an academic action will be taken if the semester QPA or the cumulative QPA (excluding the first year) is below 2.00.

The progression below between probation, suspension, and drop is typical. However, in unusual circumstances, MCS College Council may choose to suspend or drop a student without prior probation.

Warning of probation

First-year students who earn between a 1.75 and 1.99 semester QPA will receive a Warning of Probation. This indicates that the student did not qualify for probation because they are a first-year student (see below for details of probation standards), but if their semester

QPA is below 2.0 in subsequent semesters, it will result in academic probation.

Probation

The action of probation will be taken if:

- One semester of the first year is below 1.75 QPA.
- The semester QPA of a student in good standing beyond the first year falls below 2.00.
- A student drops below full-time status (less than 36 units) after the 10th day of classes in a semester. The student would be on probation for the next semester (fall and spring only).

The term of probation is one semester as a full-time student. A student is occasionally continued on probation who has had one semester on probation and is not yet meeting minimum requirements but whose record indicates that the standards are likely to be met at the end of the next semester of study. First-year students are no longer on probation at the end of the second semester if their semester QPA is 1.75 or above.

Suspension

A student who does not meet minimum standards at the end of one semester of probation will be suspended.

A first-year student will be suspended if the QPA from the first two semesters is below 1.75.

A student in the third or subsequent semester of study will be suspended if the semester factor or the cumulative factor (excluding the first year) is below 2.00 for two consecutive semesters.

The minimum period of suspension is one academic year (two semesters). At the end of that period a student may return to school on probation by:

- Receiving permission in writing from the MCS Associate Dean for Undergraduate Affairs.
- Completing a Return from Leave form from Enrollment Services.
- Providing transcripts and clearance forms if the student has been in a degree program at another college or university, even though academic credit earned will not transfer to Carnegie Mellon unless prior approval has been granted by the MCS Associate Dean for Undergraduate Affairs.

Employment within the university in non-student jobs is possible for students on academic suspension, subject to the hiring criteria of the hiring department. However, a student on academic suspension wishing to accept a job on campus must speak with the Associate Dean of the student’s college to ensure that the employment will not constitute a violation of the terms of suspension. The Associate Dean will generally allow such employment, in consultation with the Dean of Student Affairs. One employment benefit not available to students on academic suspension who accept a full-time job with the University is the option to take courses through tuition remission. The option to take courses becomes available only after the academic suspension is over.

Drop

This is a permanent severance from the Mellon College of Science. Students are dropped when it seems clear that they will never be able to meet minimum standards. A student who has been suspended and who fails to meet minimum standards after returning to school is dropped.

A student who has been academically dropped or academically suspended and who is not employed by the University must absent themselves from campus and is, for the term of the suspension, barred from all activities and affiliations that stem from one’s status as an enrolled student. These include registering or enrolling for courses, sitting in on classes, living in residence halls or Greek houses, membership and participation in student activities, and employment in student jobs. (NOTE: Exceptions to the restriction from student jobs for students on academic suspension will in general be granted for summer employment if the position was accepted prior to the decision to drop.)

Transfer into MCS Departments

This section describes the variety of entry points into the Mellon College of Science for students already admitted to a university (Carnegie Mellon or another university). All prospective students should contact the Office of Admission for details about the application process for Carnegie Mellon University.

Students entering MCS or already declared in MCS:

Entering undergraduate students admitted to MCS can choose to pursue any major within MCS. This choice must be made prior to the first semester of the sophomore year (normally during the second semester of the first year) and does not require approval by any department.

Students who have declared a major in MCS and wish to transfer into another department within MCS must have approval (https://www.cmu.edu/mcs/undergrad/advising/forms) from the new department (generally through the primary academic advisor (https://www.cmu.edu/mcs/undergrad/advising) in the new department) and from the MCS Associate Dean for Undergraduate Affairs. Students wishing to transfer into the Mathematical Sciences Department must have completed 21-127 Concepts of Mathematics or 21-128 Mathematical Concepts and Proofs AND 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory with grades of B or better in both courses as well as an overall QPA of 3.5 or higher.

MCS undergraduate students beyond the first year wishing to transfer into another MCS department may do so if they are not on academic probation and if there is room in the department of their choice. If the demand for any department exceeds the space available, then the department will admit students based on a comparative evaluation of all applicants at the end of each semester, up to the limit of available space.

Students enrolled in another college at Carnegie Mellon:

Undergraduate students admitted to colleges other than MCS and wishing to transfer into an MCS department during their first year should consult with the MCS Associate Dean for Undergraduate Affairs (https://www.cmu.edu/mcs/undergrad/advising). Students may submit an internal transfer request (https://www.cmu.edu/mcs/undergrad/advising/forms) no earlier than the first day of their second semester.

Potential transfer students into the departments of Biological Sciences, Chemistry, or Physics must also have credit for 21-120 Differential and Integral Calculus and, depending on major choice, should have completed one of the following courses at Carnegie Mellon: 03-121 Modern Biology, 09-105 Introduction to Modern Chemistry I, or 33-111 Physics I for Science Students. Higher level courses will also be considered by the MCS Associate Dean as alternatives to these courses. Students wishing to transfer into the Mathematical Sciences Department must have completed 21-127 Concepts of Mathematics or 21-128 Mathematical Concepts and Proofs AND 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory with grades of B or better in both courses as well as an overall QPA of 3.5 or higher.

Undergraduate students not in MCS and wishing to transfer into a department in MCS beyond the first semester will be considered for transfer on a space available/academic performance basis. An MCS department may refuse a transfer to a non-MCS student if there are space restrictions and/or if the student’s chance for success is determined to be questionable based on past academic performance.

Students wishing to transfer from another university into an MCS department:

A student first applies through the Office of Admission. If the Office of Admission believes the applicant is acceptable, the student’s record is sent to the appropriate department for evaluation and a decision on acceptance. The MCS department head has the right to refuse to accept the student if there are space restrictions and/or if the student’s chance for success in the MCS department is determined to be questionable based on past academic performance.

Graduation Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.00 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.00, this requirement is modified to be a cumulative QPA of at least 2.00 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

A minimum of 360 units must be completed. This will include the MCS Core Courses (technical and nontechnical electives) and all departmental course requirements.

Students will be required to meet the residency requirement and to have met all financial obligations to the university before being awarded a degree. The residency requirement is detailed in the Academic Regulations section of the catalog. A student may seek permission to modify graduation requirements by petition to the MCS College Council.

Graduation Honors

There are two types of honors awarded at graduation.

University Honors

University Honors are automatically awarded to students who have earned a cumulative Q.P.A. of 3.5 or better after either seven semesters or by the time they are certified for graduation.

College Research Honors

Please see the section “Mellon College of Science Research Honors (p. 541)” for information on how to qualify for College Research Honors.

Faculty

WILLIAM ALBA, Assistant Dean for Diversity – Ph.D.,

MAGGIE BRAUN, Associate Dean for Undergraduate Affairs – Ph.D. ,

JASON D'ANTONIO, Director of Health Professions Program – Ph.D.,

KENNETH HOVIS, Assistant Dean for Educational Initiatives – Ph.D.,

MANFRED PAULINI, Associate Dean for Graduate and Faculty Affairs – Ph.D.,

Administration

CHARLOTTE BARTOSH, Interdisciplinary Laboratory Research Technician

CHRISTINE GILCHRIST, Senior Academic Coordinator, MCS

TARA PRIMIERO, Administrative Coordinator

MAY SIMAAN, Administrative Coordinator

Department of Biological Sciences

Veronica Hinman, Department Head

Becki Campanaro, Assistant Department Head for Undergraduate Affairs

Location: Doherty Hall 1321
www.cmu.edu/bio

A major revolution is occurring in the field of biological sciences. Biology is undergoing unprecedented technological advances in biochemistry, biophysics, cell biology, genetics, molecular biology, developmental biology, neuroscience and computational biology. Carnegie Mellon's Department of Biological Sciences is nationally recognized as one of the outstanding departments in these areas. Advances in basic research are already being used to solve problems, not only in medicine and public health, but also in areas such as agriculture, forestry, mining, energy, and in industrial and pharmaceutical manufacturing processes. The department provides its students with an education that has both intellectual breadth and depth of exposure to modern research biology. This education can be used to gain employment immediately after graduation in government, industry or academic research laboratories, or to pursue graduate studies in a variety of areas such as science, medicine, public health, law, or business. A degree in biological sciences provides excellent preparation for medical school or other graduate programs in the health professions. These students are aided by the Carnegie Mellon Health Professions Program (HPP), an advisory and resource service for all Carnegie Mellon students who are considering careers in the health care field. (See the HPP (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateoptions/#healthprofessionsprogram) section in this catalog or www.cmu.edu/hpp for more information.)

The department offers a Bachelor of Science (B.S.) degree in Biological Sciences. This program has a distinctive core curriculum that provides a foundation in biology, chemistry, computer science, mathematics, and physics. In addition to the core courses, the program includes six biology electives, free electives as well as humanities, social science and fine arts electives. With these electives, students can shape a degree program according to their own interests and career goals. For students who have an interest in a particular field of biology and wish to have a specialized focus, the department offers options in biochemistry, biophysics, cell biology, computational biology, developmental biology, genetics, molecular biology and neuroscience that provide the relevant training in each area. The options are especially recommended for students who are considering graduate school in one of these areas.

In this exciting era that includes the influence of biology and the life sciences on many fields from medicine to law, the in-depth exposure to multiple disciplines provides opportunities for students to prepare for involvement at the forefront of emerging new fields, markets, and policy changes. The Department of Biological Sciences at Carnegie Mellon is working at these new interfaces through interdisciplinary research and educational programs. Innovative interdisciplinary degrees which are offered by the department include the inter-college B.S. degree in Neuroscience as well as the unified B.S. degree in Biological Sciences and Psychology. Students also explore interdisciplinary studies through the Science and Humanities Scholars program, or pursue interests at the interface between the arts and sciences through the Bachelor of Science and Arts (B.S.A.) degree program combining biological sciences with a discipline in the College of Fine Arts. A stand-alone Bachelor of Arts (B.A.) degree is available for students who wish to expand their educational training into other fields. Many students choose to broaden their education by pursuing minors and additional majors in disciplines throughout the university, not just within the Mellon College of Science.

One of the most important features of the Department of Biological Sciences is the opportunity for undergraduate students to interact with faculty. Providing a solid foundation to scientific practice is critical; therefore, the department offers first-year students a variety of inquiry-based, hands-on courses that incorporate a wide range of topics and interests within Biological Sciences. These courses kick-start the transformation of science students to scientists. We encourage our students to get to know their faculty through one of these courses, or through mentored, independent research projects in the faculty laboratories. Our faculty members are prominent research scientists who also teach beginning and advanced courses. The upper level teaching laboratories are located in the same building as the faculty research laboratories and share scientific equipment. We encourage students to make themselves aware of the research areas of the faculty and to develop research projects with faculty. While such research is usually most important in the senior year, it may begin earlier in a student's undergraduate training. The department has an Honors Program in Research Biology to facilitate a more intensive involvement in research for eligible students. During the past four years, more than 85 percent of the undergraduate biology majors have worked with faculty on their research and, in some cases, have been co-authors of research papers and have given presentations at national meetings.

Since the fall of 2011, the Department of Biological Sciences has offered B.S. degrees in Biological Sciences as well as Computational Biology at Carnegie Mellon University in Doha, Qatar. Students enrolled in either of these degree programs will also complete the requirements outlined below. However, a limited number of required courses for the CMU-Qatar program are offered through a collaboration with the Weill Cornell Medical College in Qatar. For a listing of how the degree requirements are fulfilled for students enrolled in Doha, please consult the CMU-Qatar website (www.qatar.cmu.edu/curriculum-bs).

Program Outcomes

Upon graduation recipients of the BS or BA degree in Biological Sciences will:

- Use the basic concepts and experimental, computational, and theoretical methods of the core fields of science, mathematics and technology.
- Use foundational knowledge from the natural sciences and mathematics for advanced work in the discipline.
- Understand and apply the scientific method.
- Apply disciplinary knowledge toward solving problems.
- Use modern methods for finding and sharing current scientific information and primary literature.
- Convey information including scientific content in written and oral formats within Biological Sciences.
- Work in multidisciplinary and culturally diverse teams.
- Demonstrate proper values and ethics within Biological Sciences, the University, and the larger scientific community.

B.S. Biological Sciences

The Bachelor of Science (B.S.) in Biological Sciences is built around a core program and elective units as detailed in the following section.

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
03-250	Introduction to Computational Biology	12
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-344	Experimental Biochemistry	12
or 03-345	Experimental Cell and Developmental Biology	
or 03-346	Experimental Neuroscience	
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	Biological Sciences Electives [1]	54
Total Biology units		131

[1] Details on electives can be found in the "Biological Sciences Electives" section (see below).

Mathematics, Physics and Computer Science		Units
02-201	Programming for Scientists	10
or 15-110	Principles of Computing	
or 15-112	Fundamentals of Programming and Computer Science	
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10

or 21-122	Integration and Approximation	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
33-122	Physics II for Biological Sciences and Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	
99-101	Computing @ Carnegie Mellon	3
Total Science units		54

Chemistry		Units
09-105	Introduction to Modern Chemistry I [2]	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
or 09-219	Modern Organic Chemistry	
09-218	Organic Chemistry II	9
or 09-220	Modern Organic Chemistry II	
09-207	Techniques in Quantitative Analysis	9
or 09-221	Laboratory I: Introduction to Chemical Analysis	
09-208	Techniques for Organic Synthesis and Analysis	9
or 09-222	Laboratory II: Organic Synthesis and Analysis	
Total Chemistry units		56

[2] Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Elective Units	Units
Free Electives	48
MCS Nontechnical Breadth Requirements	72
Total Elective units	120

Minimum number of units required for degree: 360

MCS Technical Breadth Requirements

Majors entering CMU and majoring in Biological Sciences (or affiliated majors) in the Fall of 2015 or beyond will fulfill the MCS Technical Breadth requirements as follows:

1. Life Sciences: any courses in this category except for the 03-XXX courses (these can be counted as general bio electives towards your degree)
2. Physical Sciences: 09-105, 09-106, 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Biological Sciences Electives

The following specifications apply to Biological Sciences electives:

- At least 18 units must be at the 03-3xx level or above, exclusive of 03-445 and 03-370.
- Up to three interdisciplinary electives may count as biology electives.
- Up to 18 units of 03-445 Undergraduate Research may count as general biology electives; a maximum of 36 units can count for the minimum units required for graduation.
- Courses in biology taken through cross-registration or study abroad at another university may count as electives if prior permission is obtained from the Carnegie Mellon Department of Biological Sciences advisor.

Departmental Electives Group

03-117	Frontiers, Analysis, and Discovery in Biological Sciences	6
03-124	Modern Biology Laboratory	9
03-125	Evolution	9
03-126	Cellular Response to the Environment	4
03-127	How Biological Experiments Work - A Project Course	9
03-133	Neurobiology of Disease	9
03-161	Molecules to Mind	9
03-326	Evolution of Regulatory Genomics	4.5
03-327	Phylogenetics	9
03-350	Developmental Biology	9
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-364	Developmental Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
03-366	Biochemistry of the Brain	9
03-370	Principles of Biotechnology	9
03-390	Molecular and Cellular Immunology	9
03-391	Microbiology	9
03-392	Microbiology Laboratory	6
03-428	Genome Editing Biotechnology	4.5
03-435	Cancer Biology	9
03-439	Introduction to Biophysics	9
03-442	Molecular Biology	9
03-445	Undergraduate Research	Var.
03-451	Advanced Developmental Biology and Human Health	9
03-511	Computational Molecular Biology and Genomics	9
03-512	Computational Methods for Biological Modeling and Simulation	9
03-534	Biological Imaging and Fluorescence Spectroscopy	9
03-545	Honors Research	9
03-620	Techniques in Electron Microscopy	9
03-711	Computational Molecular Biology and Genomics	12
03-712	Computational Methods for Biological Modeling and Simulation	12
03-713	Bioinformatics Data Integration Practicum	6
03-726	Evolution of Regulatory Genomics	6
03-727	Phylogenetics	12
03-728	Genome Editing Biotechnology	6
03-730	Advanced Genetics	12
03-740	Advanced Biochemistry	12
03-741	Advanced Cell Biology	12
03-742	Advanced Molecular Biology	12
03-744	Membrane Trafficking	9
03-751	Advanced Developmental Biology and Human Health	12
03-762	Advanced Cellular Neuroscience	12
03-763	Advanced Systems Neuroscience	12
03-765	Advanced Neural Correlates of Learning and Memory	12
03-770	Principles of Biotechnology	12
03-791	Advanced Microbiology	12
03-871	Structural Biophysics	12

Interdisciplinary Electives Group

Up to three of the following courses may count as biology electives:

09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	9
09-521	Metals in Biology: Function and Reactivity	6
09-535	Applied topics in Macromolecular and Biophysical Techniques	9
21-127	Concepts of Mathematics	10
21-259	Calculus in Three Dimensions	9
21-260	Differential Equations	9
36-200	Reasoning with Data	9
36-247	Statistics for Lab Sciences	9
42-202	Physiology	9
85-219	Biological Foundations of Behavior	9

Options for the B.S. in Biological Sciences

Students who wish to specialize in a particular area of biology can do so through a set of departmentally defined options. A student who completes the required biology electives for any option can have up to two noted on his or her transcript. Options need not be declared. The elective courses required for each of the options are listed below.

Biochemistry Option

Required Biology Electives:

03-740	Advanced Biochemistry	12
21-259	Calculus in Three Dimensions	9
or 21-260	Differential Equations	

Any ONE of the following courses:

09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	9
09-521	Metals in Biology: Function and Reactivity	6

Recommended Biology Electives:

03-442	Molecular Biology	9
03-534	Biological Imaging and Fluorescence Spectroscopy	9
03-439	Introduction to Biophysics	9
03-871	Structural Biophysics	12

Biophysics Option

Required Biology Electives:

03-740	Advanced Biochemistry	12
03-439	Introduction to Biophysics	9
21-259	Calculus in Three Dimensions	9
or 21-260	Differential Equations	

Recommended Biology Electives:

03-534	Biological Imaging and Fluorescence Spectroscopy	9
03-871	Structural Biophysics	12

Cell Biology Option

Required Biology Electives:

03-350	Developmental Biology	9
03-741	Advanced Cell Biology	12

Any ONE of the following courses:

03-362	Cellular Neuroscience	9
03-390	Molecular and Cellular Immunology	9

Computational Biology Option

Required Biology Electives:

03-711	Computational Molecular Biology and Genomics	12
15-210	Parallel and Sequential Data Structures and Algorithms	12

Any ONE of the following courses:

36-247	Statistics for Lab Sciences	9
21-260	Differential Equations	9
21-241	Matrices and Linear Transformations	10

Recommended Biology Electives:

03-512	Computational Methods for Biological Modeling and Simulation	9
15-451	Algorithm Design and Analysis	12
09-560	Computational Chemistry	12

Developmental Biology Option

Required Biology Electives:

03-350	Developmental Biology	9
03-442	Molecular Biology	9
03-751	Advanced Developmental Biology and Human Health	12

Recommended Biology Electives:

03-326	Evolution of Regulatory Genomics	4.5
03-741	Advanced Cell Biology	12

Genetics Option

Required Biology Electives:

03-326	Evolution of Regulatory Genomics	4.5
03-327	Phylogenetics	9
03-442	Molecular Biology	9
03-730	Advanced Genetics [6]	12

[6] Minimum grade of B in 03-330 or 03-220 required.

Recommended Biology Electives:

03-391	Microbiology	9

Molecular Biology Option

Required Biology Electives:

03-442	Molecular Biology	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
03-726	Evolution of Regulatory Genomics	6
03-727	Phylogenetics	12

Recommended Biology Electives:

03-390	Molecular and Cellular Immunology	9
03-391	Microbiology	9
03-730	Advanced Genetics	12

Neuroscience Option

Required Biology Electives:

03-362	Cellular Neuroscience [7]	9
03-363	Systems Neuroscience [7]	9

Any ONE of the following courses:

03-133	Neurobiology of Disease	9
03-350	Developmental Biology	9
03-364	Developmental Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
03-366	Biochemistry of the Brain	9
03-534	Biological Imaging and Fluorescence Spectroscopy	9
42-202	Physiology	9
85-219	Biological Foundations of Behavior	9

[7] One of these courses must be completed at the Graduate Level (Complete either 03-762 or 03-763).

B.S. Biological Sciences/Neuroscience Track

The Bachelor of Science in Biological Sciences/Neuroscience Track provides an option for those Biological Sciences majors who are interested in an intensive curricular focus in neuroscience. The requirements of the Track are the same as those listed for the B.S. in Biological Sciences with the following changes to the biological sciences elective requirements:

Degree Requirements:

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-765	Advanced Neural Correlates of Learning and Memory	12

Plus three of the following electives:

03-133	Neurobiology of Disease	9
03-350	Developmental Biology	9
03-364	Developmental Neuroscience	9
03-366	Biochemistry of the Brain	9
03-534	Biological Imaging and Fluorescence Spectroscopy	9
15-385	Introduction to Computer Vision	6
15-386	Neural Computation	9

42-202	Physiology	9
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artifical Intelligence	9
85-219	Biological Foundations of Behavior	9

B.S. Neuroscience

The Bachelor of Science in Neuroscience is listed in the Intercollege Programs (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#bachelorofscienceinneurosciencetext) section of this catalog. It is a joint degree program offered between the Mellon College of Science and the Dietrich College of Humanities and Social Sciences. Current MCS students interested in pursuing this degree should contact Biological Sciences Undergraduate Programs Office (bio-ungrad@andrew.cmu.edu). More information can also be found on the CMU Neuroscience website (http://www.cmu.edu/neuro).

B.S. Biological Sciences and Psychology

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/#hampssgeneraleducationprogram160) and MCS (http://coursecatalog.web.cmu.edu/melloncollegeofscience) are found on their respective Catalog pages.

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	General Biology Elective [1]	9
03-3xx	Advanced Biology Elective [1]	18
Total Biology units		78

[1] Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Mathematics, Statistics, Physics and Computer Science		Units
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10
or 21-122	Integration and Approximation	
36-247	Statistics for Lab Sciences	9
or 36-200	Reasoning with Data	
36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	
33-121	Physics I for Science Students [2]	12
or 33-141	Physics I for Engineering Students	
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
or 02-201	Programming for Scientists	
99-101	Computing @ Carnegie Mellon	3
Total Science units		63-65

[2] MCS students must also complete 33-122 Physics II for Biological Sciences and Chemistry Students.

Chemistry		Units
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
or 09-219	Modern Organic Chemistry	
09-218	Organic Chemistry II	9
or 09-220	Modern Organic Chemistry II	
09-207	Techniques in Quantitative Analysis	9-12
or 09-221	Laboratory I: Introduction to Chemical Analysis	
09-208	Techniques for Organic Synthesis and Analysis	9-12
or 09-222	Laboratory II: Organic Synthesis and Analysis	
Total Chemistry units		56-62

Psychology Courses		Units
85-102	Introduction to Psychology	9
85-219	Biological Foundations of Behavior	9
85-2xx	Survey Psychology Courses *	18
85-310	Research Methods in Cognitive Psychology	9
or 85-340	Research Methods in Social Psychology	
or 85-320	Research Methods in Developmental Psychology	
or 85-314	Cognitive Neuroscience Research Methods	
or 85-330	Analytic Research Methods	
85-3xx	Advanced Psychology Electives	18
Total Psychology units		63

* Excluding 85-261 Abnormal Psychology

Additional Advanced Elective 9 units

(Choose one of the following courses)		
85-3xx	Advanced Psychology Elective	9
or		
03-3xx	Advanced Biology Elective	9

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)		
03-344	Experimental Biochemistry	12
03-345	Experimental Cell and Developmental Biology	12
03-346	Experimental Neuroscience	12
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-340	Research Methods in Social Psychology	9

Elective Units	Units
Free Electives	33-36
MCS Nontechnical Breadth or DC General Education requirements	36-48
Total Elective units	69-84

Minimum number of units required for degree: 360

B.A. Biological Sciences

The Department of Biological Sciences offers a Bachelor of Arts (B.A.) degree that is intended for students who wish to combine their interest in science with their interest(s) in other discipline(s) across campus. The requirements for the B.A. degree are distributed as follows:

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics	9

or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	9-12
or 03-124	Modern Biology Laboratory	
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	General Biology Electives [8]	18
03-3xx	Advanced Biology Electives [8]	18
Total Biology units		86-89

[8] Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Chemistry		Units
09-105	Introduction to Modern Chemistry I [9]	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
or 09-219	Modern Organic Chemistry	
09-218	Organic Chemistry II	9
or 09-220	Modern Organic Chemistry II	
09-207	Techniques in Quantitative Analysis	9-12
or 09-221	Laboratory I: Introduction to Chemical Analysis	
Total Chemistry units		47-50

[9] Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Mathematics, Physics, and Computer Science		Units
02-201	Programming for Scientists	10
or 15-110	Principles of Computing	
or 15-112	Fundamentals of Programming and Computer Science	
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10
or 21-122	Integration and Approximation	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
33-122	Physics II for Biological Sciences and Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	
99-10x	Computing at Carnegie Mellon	3
Total Science units		54

Elective courses	Units
MCS Nontechnical Breadth Requirements	72
Free Electives	96-99
Total Elective units	168-171

360Minimum number of units required for degree:

Minor in Biological Sciences

All university students are eligible to pursue a minor in biological sciences in conjunction with a major in any other department in the university. A minimum of six biological sciences courses (and two chemistry prerequisites) must be completed to fulfill the minor in biological sciences. The curriculum includes four required courses and two elective courses as specified below. Units awarded for undergraduate research are not applicable to elective courses. Courses taken in other departments or colleges will be considered on an individual basis.

Courses for the Minor in Biological Sciences

Prerequisites:		Units
09-105	Introduction to Modern Chemistry I	10
09-217	Organic Chemistry I	9

Required courses:		Units
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
03-320	Cell Biology	9
03-xxx	General Biology Elective	9
03-3xx	Advanced Biology Elective	9

73Minimum number of units required for the Minor in Biological Sciences:

Minor in Neuroscience

The curriculum within the Neuroscience minor will allow students from various disciplines to gain fundamental knowledge of neuroscience concepts. The interdisciplinary nature of the coursework echoes the nature of the field itself; students will select courses from the natural, social, and computer sciences. Neuroscientists not only require foundational knowledge of molecular, cellular, and systems neuroscience, but they should also understand the behavioral significance and appreciate how computational work and imaging techniques can aid in clarifying normal and abnormal functioning of these fundamental processes.

Students pursuing the minor in Neuroscience will:

- Acquire foundational knowledge of the basic biological foundations of the nervous system, from the cellular through systems levels.
- Understand the effects of basic neurological function on behavior, including cognition.
- Gain an appreciation of the interdisciplinary nature of the field of neuroscience.

NOTE: Because the curriculum within this minor may overlap with some degree requirements, no more than 2 courses fulfilling Neuroscience Minor requirements may count towards the requirements of a student's major or other minor.

Course Requirements

Minimum units required for Neuroscience minor 63

Required courses (4):

		Units
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
85-219	Biological Foundations of Behavior	9
or 03-161	Molecules to Mind	

Distribution Requirements:

Three courses, including at least 1 from each of the following categories:

Approaches to Neuroscience Category		Units
15-386	Neural Computation	9
15-883	Computational Models of Neural Systems	12
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-429	Cognitive Brain Imaging	9

Cognitive Neuroscience Category		Units
03-133	Neurobiology of Disease	9
03-364	Developmental Neuroscience	9
85-211	Cognitive Psychology *	9
85-356	Music and Mind: The Cognitive Neuroscience of Sound	9
85-370	Perception	9
85-390	Human Memory	9
85-406	Autism: Psychological and Neuroscience Perspectives	9

*NOTE: 85-213 may be used instead of 85-211 when offered

Masters Degree in Computational Biology

Students who are interested in more advanced training in this emerging field may want to consider the Master of Science Program in Computational Biology. For more information about this program, contact the Biological Sciences Graduate Programs Office (bio-gradoffice@andrew.cmu.edu).

Honors Program in Research Biology

The departmental Honors Program offers an opportunity to become extensively involved in research. The program requires students to conduct an independent project and to prepare a formal thesis that is written and defended in the senior year. This program does not preclude a student from completing any of the options within the department nor is it the only way in which students can participate in undergraduate research, although it is excellent preparation for graduate studies.

Transfer credit for Modern Biology

Students wishing to transfer credit for 03-121 Modern Biology from another institution must meet the following requirements:

1. The course in question should have at least an 80% match in topics with 03-121. Topics in 03-121 cover the genetic, molecular, cellular, developmental, and evolutionary mechanisms that underlie biological processes and include: Cell theory; Cell chemistry; Cell structure; Function and structure of proteins, DNA, RNA, lipids and carbohydrates; Cell respiration and fermentation; The cell cycle; Cell-cell interactions and communication; Transcription; Translation; RNA processing in Eukaryotes; DNA replication; DNA mutation and repair; Meiosis; Mitosis; and Regulation of Gene Expression.
   This information is sometimes available in the course description, but more detail is often found in a course syllabus.
2. The textbook used in the transfer course should be at a comparable level to S. Freeman (2010) "Biological Science, Vol. 1 (The Cell, Genetics, and Development)," Fourth Edition, Pearson Benjamin Cummings, ISBN 0-321-61347-3.
3. Introductory level courses that focus on other biology areas (i.e. anatomy, physiology, ecology, evolution, and/or development) will not be accepted for 03-121 credit. These courses may receive credit for a general biology elective.
4. Students should contact their departmental academic advisor for the transfer credit approval process in their college.

Faculty

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Department of Biological Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

03-050 Study Abroad
Fall
Missing Course Description - please contact the teaching department.

03-051 Study Abroad
Spring
Missing Course Description - please contact the teaching department.

03-101 Biological Sciences First Year Seminars
Fall and Spring: 3 units
Various seminars are offered that introduce first-year students to current topics of modern biology. These are mini courses that meet for half a semester. Topics have included: Proteins in Disease, Genes and Diseases, Pills and Poisons, Curing Cancer, Organ Transplantation & Blood Substitutes, and Prions - Mad Cows and Englishman. Courses restricted to first year students in the Mellon College of Science.

03-116 Phage Genomics Research
Spring: 6 units
Spring Semester: The DNA sequences will be analyzed with bioinformatic tools and compared with those of phages isolated at other locations to identify genes, their organization, the differences that may characterize different phage groups, and how these have arisen during evolution.
Prerequisite: 03-115

03-117 Frontiers, Analysis, and Discovery in Biological Sciences
Fall and Spring: 6 units
In this hands-on laboratory class, students will investigate a current biology problem. Students will read literature articles, design hypotheses, plan and carry out experiments, analyze and interpret data, and design future questions as part of a collaborative research team. In addition, teams will work with faculty and fellow students to understand and explore the relevance of their projects in the field of biology and other disciplines. Finally, teams will communicate results in an oral presentation to peers and faculty. Students will gain research skills, analytical skills, communication skills (both written and oral), and project design skills.
Prerequisites: 03-121 or 03-110 or 03-151

03-118 Beer: A Yeast's Perspective
Spring: 6 units
This is a combined lecture and laboratory course in which students will investigate the biochemistry of fermentation using strains of yeast commonly used in brewing science. Lectures and readings will cover all necessary information to succeed in the course, including topics like yeast metabolism, fermentation at the micro and industrial levels, and a history of fermentation's influence on society. Lab experiments will investigate yeast growth and fermentation processes in various strains used in brewing, and quantitative assessments of beer at the molecular level. The course puts a focus on microbiology lab techniques and yeast biochemistry; however, no previous lab experience or biology coursework is required, and anyone with an interest in the science behind brewing yeast can succeed in the class.

03-120 Biology for Life Special Topics Mini
Fall and Spring: 6 units
Special Topics in Biological Sciences Mini Courses. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Fall 2019 Section A1: "Germs": The Good, The Bad, and The Ugly Bacteria are a scourge to humankind, causing life-threatening infections like tuberculosis, meningitis, and pneumonia to the less severe ear infections and strep throats that plague many childhoods. On the other hand, the healthy human microbiota is a community of microorganisms dominated by trillions of bacteria that reside everywhere from our skin to nasal passages and gut. This "virtual organ" is estimated to weigh as much as the human brain and contributes to essential bodily functions like food metabolism and defense against infection, while also impacting memory, anxiety, and depression. Changes in the gut microbiota are also associated with diseases including autism, obesity, allergies, and inflammatory bowel disease. Why the incidence of these chronic diseases is increasing is unclear, but it may be the result of excessive antibiotic use, dietary changes that harm our gut microbes, or both. This century will be marked by both the challenge of antibiotic resistant infectious "bad" bacteria, and the possibilities to harness "good" bacteria to promote human health. In this course, we explore how bacteria make you healthy and what we can do to nurture our microbiota, and how bacteria make you sick and what we can do to stop them.

Course Website: https://www.cmu.edu/bio/undergrad/academics/intro_courses.html

03-121 Modern Biology
All Semesters: 9 units
This is an introductory course that provides the basis for further studies in biochemistry, cell biology, genetics and molecular biology. This course emphasizes the chemical principles underlying biological processes and cell structures as well as the analysis of genetics and heredity from a molecular perspective. This is the introductory biology course for all science and non-science majors.

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

03-124 Modern Biology Laboratory
Fall and Spring: 9 units
This laboratory is designed to introduce students to modern concepts in the biological sciences. The experiments illustrate many of the principles covered in 03-121 and 03-230. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

03-125 Evolution
Fall: 9 units
Evolutionary theory is the unifying principle of biology. A good comprehension of the concepts that underlie this theory is therefore important to properly appreciate and understand any biological process. This course is designed for students intending to continue studies in biology so that they may gain an understanding of the evolutionary framework in their more advanced courses, and also non-biology majors who want to extend their knowledge of biology at an introductory level. The lectures will include (i) an examination of the history and development of evolutionary theory, (ii) consideration of some of the facts that have established the theory, (iii) an introduction to the concepts of phylogenetics, (iv) discussion of the patterns and mechanism that lead to the diversity and origins of the groups of life, (v) an introduction to genetics and population genetic theory, and (vi) discussion of and how this applies to natural selection and speciation. The course will also include some more specialist topics, including evolution of development, sexual selection, evolutionary applications to medicine and conservation biology, and genome evolution. Assessment will be based on several in-class exams and quizzes, homework assignments, a written term paper, and a final exam.

03-126 Cellular Response to the Environment
Spring: 4 units
This laboratory course provides a multifaceted view of the cell, with the opportunity for new discovery, through microscopic imaging of a cell's response to environmental changes. We will identify yeast gene products that undergo changes in expression or subcellular localization after simple environmental perturbations or drug treatments. Students will be trained in basic molecular biological methods, including recombinant DNA manipulation, and basics of functional genomic resources. Enrollment is limited to first-year students in MCS. Special permission required.

03-127 How Biological Experiments Work - A Project Course
Spring: 9 units
The goal of this course is to provide an understanding of the nuts and bolts of biological experimentation. We will discuss the molecular principles behind the wide variety of experiments that were used to discover how cells work. The first half of the class will be a lecture based discussion of key experimental methods used in biological research. The second half of the class will be dedicated to group projects that create "story boards" to explain in molecular terms how these experiments work. The story boards will be used by modelers at the Pittsburgh Supercomputing Center to generate high-end animations of these experimental processes. This will prepare students for working in research labs and biology courses beyond "Modern Biology". This course is limited to first, second, and third year students.
Prerequisites: 03-121 or 03-151

03-128 Biology for Life Special Topics
Fall and Spring: 9 units
Special Topics in Biological Sciences. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Fall 2019 Section A: Environmental Science Environmental science is a highly interdisciplinary field that integrates knowledge and modes of inquiry from across the sciences to understand some of the most important challenges of 21st century. This course provides a foundational background in scientific method, critical thinking and problem solving strategies used to study and evaluate the environment. Modules include, principles of ecology and eco-systems, biological diversity, biogeochemical cycles, endangered species management, human population growth, atmosphere, climate and global warming. Assessment will include class attendance, quizzes, individual and small group projects, in class exams. Projects may involve visits to local sites.

Course Website: https://www.cmu.edu/bio/undergrad/academics/intro_courses.html

03-131 Genes Drugs & Diseases
Fall: 9 units
The central goals of this course are to explore the genetic basis of diseases and to explain the molecular basis of action for various drugs used to treat diseases. The first part of the course provides the student with sufficient background to understand the biological basis of drug action with emphasis on retroviral inhibitors. The usefulness of genetic engineering in the production of proteins for drug discovery is then explored. This is followed by an overview of DNA replication, transcription, and protein synthesis, with an emphasis on the inhibitory action of antibiotics on prokaryotic processes. The fundamental properties of carbohydrates, lipids, and membranes are discussed at a level to develop an understanding of penicillin and the treatment of elevated cholesterol levels. Signaling processes in eukaryotic cells is discussed with reference to cancer treatment and pain management. The treatment of disease using antibody, and the treatment of inappropriate immune responses (allergy) is also discussed. The course ends with a discussion of inheritance and genetic deficiencies that give rise to disease.

Course Website: http://www.andrew.cmu.edu/user/rule/03_131/

03-132 Basic Science to Modern Medicine
Fall and Summer: 9 units
This course will focus on the genetics, cell biology, and developmental biology behind human biology and human disease, as well as the growing opportunities for novel therapeutic options that basic science delivers. This is a topics based course, with topics chosen to cover aspects of human biology and health that students are likely to encounter in their daily lives such as cancer, stem cells, genome sequencing, and the human microbiota. Students will explore these topics from both a basic science and a human health perspective.

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

03-133 Neurobiology of Disease
Fall and Summer: 9 units
This course will explore the biological basis of several neurological and neuropsychiatric diseases, with an emphasis on medical diagnostic tools and techniques. It will include discussions of the anatomical basis of neurological diseases as well as recent research into understanding the mechanisms of disease. This course is intended to broaden students' understanding of how diseases are diagnosed and studied. Students will also learn how basic neurological and psychiatric evaluations are conducted and gain proficiency in these evaluation techniques. We will begin with a discussion of clinical neuroanatomy to serve as a basis for understanding brain structures and functional alterations in a variety of developmental, degenerative, neurological, and psychiatric disorders. Specific diseases covered may vary from year to year.

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

03-135 Structure and Function of the Human Body
Fall: 9 units
Structure and Function of the Human Body is a non-majors course designed to explore fundamental relationships between form and function of the human body. The anatomy and physiology of major organ systems will be studied in the context of normal and disease states. Because no prerequisite knowledge is required, students will learn about critical biological processes such as the central dogma, membrane diffusion and transport, cell signaling, gas exchange, blood flow, nutrient absorption, blood pH balance, and action potential generation and propagation. Students will then apply this knowledge to understand how organs respond to various inputs in maintaining homeostasis. Hands-on demonstrations will be incorporated to provide a practical framework for the information presented in lectures. At the culmination of the semester, students will gain a broad understanding of how the body systems function at the cellular, tissue and organ levels and be able to relate simple physiological processes to better understand highly prevalent diseases in society.

03-151 Honors Modern Biology
Fall: 10 units
This course will cover in some depth, the basics of the structure and function of the major biomolecules in the cell, cellular structure and function, genetic replication, transmission and expression of biological information, and cell-cell interactions. While similar core topics will be covered in all sections of Modern Biology, this section will be offered at an accelerated pace, requiring more independent learning. The extra class time this pacing provides will allow the exploration of the molecular basis of life to help students integrate and apply the core principles of biology covered in the course. THIS SECTION IS RESERVED FOR INCOMING FIRST-YEAR MCS STUDENTS.

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

03-161 Molecules to Mind
Spring: 9 units
This course provides a depth-first approach to understanding neuroscience. We will begin with a clinical focus on neuroanatomy, introducing students to some basic neurological diagnostic techniques. We will then explore the biological basis of neuronal function and link the function of individual neurons to a broader context of neural systems. This will be done in the context of primary literature. Students who complete this course will therefore have an understanding of research methods and be prepared to evaluate scientific literature. The course will have a strong focus on the biological and cellular basis of neuronal excitability and also give students significant, in depth exposure to the function of synapses and their plasticity. Finally, the course will give students an in depth look at sensory and/or motor systems by focusing on one system in particular, rather than providing a broad overview of many different sensory and motor systems.

03-201 Undergraduate Colloquium for Sophomores
Fall
The purpose of this seminar series is to update biology undergraduates about university and departmental functions, seminars, etc. that are pertinent or useful. In addition, research talks by faculty and undergraduates will be used to introduce students to the research being conducted in faculty laboratories. Additional topics may include graduate and medical school applications, career options, topics in the press, and important scientific discoveries.

03-202 Undergraduate Colloquium for Sophomores
Spring
Missing Course Description - please contact the teaching department.

03-206 Biomedical Engineering Laboratory
Fall and Spring: 9 units
This laboratory course is designed to provide students with the ability to make measurements on and interpret data from living systems. The experimental modules reinforce concepts from 42-101 Introduction to Biomedical Engineering and expose students to four areas of biomedical engineering: biomedical signal and image processing, biomaterials, biomechanics, and cellular and molecular biotechnology. Several cross-cutting modules are included as well. The course includes weekly lectures to complement the experimental component. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering. Notes: This course number is reserved for students who are CIT majors and registered with the HPP program. If you require a biology lab for pre-health admissions requirements, please contact Dr. Conrad Zapanta and Dr. Maggie Braun (in the same email) for permission to register for 03-206 instead of 42-203. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering.
Prerequisites: (03-121 or 03-151) and 42-101

03-210 Independent Study
Fall and Spring
Students will read papers from the original literature under the direction of a faculty member. Students will be required to demonstrate mastery of the readings by discussions with the sponsoring faculty member, oral presentations, or writing of one or more papers summarizing and extending the information in the readings. If appropriate, students may write a program(s) to satisfy this last requirement. A student may take this course only once. This is a mini format course. Special permission required.

03-220 Genetics
Fall: 9 units
The mechanisms of transmission of inherited traits in viruses, bacteria, fungi, plants and animals are discussed. Molecular mechanisms of gene expression and gene regulation are analyzed. Recombinant DNA and its applications in genetic analysis, biotechnology, forensics, agriculture, medicine, and the pharmaceutical industry are presented. Special topics in human genetics are considered, such as the genetics of cancer. Principles and methods for the study of developmental genetics, population genetics and complex traits are also introduced.
Prerequisites: 03-151 or 03-121

03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis
Fall: 9 units
Scientific and technical advances in genetics have accelerated dramatically since the draft human genome sequence was published in 2001. The development of massively parallel DNA sequencing and associated technologies has transformed the way we approach genetic questions. Contemporary genetics is increasingly concerned with generating, processing and analyzing vast amounts of data to extract information about genetic variation, expression, interactions and associations. At the same time, comparative genomics, bioinformatic and reverse genetic methods are transforming the way in which gene functions are investigated, while the development of powerful methods for precise modification of genomes is opening the way to cell- and gene-based therapies for disease. In parallel, the promise of precision or personalized medicine is predicated on advances in understanding of complex traits, genetic interactions and networks. These and other topics will be covered following a review of basic principles of gene structure and expression, the fundamental principles of Mendelian genetics, and their underpinnings in cellular mechanisms for the replication, recombination and transmission of genetic material. Although the topics overlap extensively with 03220 (Genetics), they will be presented at a more advanced level, with a greater emphasis on current methods of quantitative and statistical analysis. This course is recommended for students with a particular interest in emerging technologies for analysis of human genetics, genomics, gene therapy and precision medicine.
Prerequisites: (03-121 Min. grade B or 03-151 Min. grade B) and (15-359 Min. grade C or 36-247 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C or 36-201 Min. grade C or 21-124 Min. grade C or 36-200 Min. grade C or 36-217 Min. grade C)

03-230 Intro to Mammalian Physiology
Spring: 9 units
This course will survey the major organ systems, with an emphasis on cellular physiology and biochemistry. Current ideas of research and scientific controversy will also be presented. This course is intended to broaden students' exposure to cellular processes in the context of complex organ systems.
Prerequisite: 03-121

03-231 Honors Biochemistry
Spring: 9 units
This course provides an introduction to molecules and processes found in living systems. Amino acids, sugars, lipids and nucleotides and their corresponding higher structures, the proteins, polysaccharides, membranes and nucleic acids are studied. Kinetics and mechanisms of enzymes as well as elementary metabolic cycles and the energetics of biological systems are discussed.
Prerequisites: (03-121 or 03-151) and (09-217 or 09-219)

03-232 Biochemistry I
Spring: 9 units
This course provides an introduction to the application of biochemistry to biotechnology. The functional properties of amino acids, nucleotides, lipids, and sugars are presented. This is followed by a discussion of the structural and thermodynamic aspects of the organization of these molecules into higher-order structures, such as proteins, nucleic acids, and membranes. The kinetics and thermodynamics of protein-ligand interactions are discussed for non-cooperative, cooperative, and allosteric binding events. The use of mechanistic and kinetic information in enzyme characterization and drug discovery are discussed. Topics pertinent to biotechnology include: antibody production and use, energy production in biochemical systems, expression of recombinant proteins, and methods of protein purification and characterization. The course is an alternate to 03-231.
Prerequisites: (09-219 or 09-217) and (06-221 or 09-106)

03-250 Introduction to Computational Biology
Spring: 12 units
This class provides a general introduction to computational tools for biology. The course is divided into two modules, which may be taken individually as courses 03-251/02-251 and 03-252/02-252. Module 1 covers computational molecular biology/genomics. It examines important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research.
In the process, it covers basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. Module 2 covers computational cell biology, including biological modeling and image analysis. It includes homeworks requiring use or modification of Matlab scripts. The modeling component includes computer models of population dynamics, biochemical kinetics, cell pathways, neuron behavior, and stochastic simulations. The imaging component includes basics of machine vision, morphological image analysis, image classification and image-derived models. Lectures and examinations are joint with 02-250 but recitations are separate. Recitations for this course are intended primarily for biological sciences or biomedical engineering majors at the undergraduate or graduate level who have had little or no prior experience with computer science or programming. Students may not take both 03-250/02-250 and either 03-251/02-251 or 03-252/02-252 for credit.
Prerequisites: (03-121 or 03-131 or 03-151) and (15-110 or 02-201 or 15-112)

03-251 Introduction to Computational Molecular Biology
Spring: 6 units
This class provides a general introduction to computational tools for biology with specific emphasis on molecular biology and genomics. Along with 03-252, it makes up one half of the full Introduction to Computational Biology, 03-250, although either half can be taken individually. 03-251 will examine important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research. In the process, it will cover basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics to be covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. Lectures and examinations are joint with 02-251 but recitations are separate. Recitations for this course are intended primarily for biological sciences or biomedical engineering majors at the undergraduate or graduate level who have had little or no prior experience with computer science or programming. Students may not take both 03-251/02-251 and 03-250/02-250 for credit.
Prerequisite: 03-121 or permission of the instructor.
Prerequisites: 03-121 or 03-151

03-252 Introduction to Computational Cell Biology
Spring: 6 units
This course presents an overview of important modeling and image analysis applications of computers to solve problems in cell biology. Along with 03-251, it makes up one half of the full Introduction to Computational Biology, 03-250, although either half can be taken individually. Major topics covered are computer models of population dynamics, biochemical kinetics, cell pathways, neuron behavior, and stochastic simulations. The imaging component includes basics of machine vision, morphological image analysis, image classification and image-derived models. It includes homeworks requiring use or modification of Matlab scripts. Lectures and examinations are joint with 02-252 but recitations are separate. Recitations for this course are intended primarily for biological sciences or biomedical engineering majors at the undergraduate or graduate level who have had little or no prior experience with computer science or programming. Students may not take both 03-252/02-252 and 03-250/02-250 for credit. Prerequisite: 03-121 or permission of the instructor.
Prerequisites: 03-151 or 03-121

03-302 Undergraduate Colloquium for Juniors
Spring
Missing Course Description - please contact the teaching department.

03-320 Cell Biology
Fall: 9 units
This course provides descriptive information and mechanistic detail concerning key cellular processes in six areas: membrane function, protein targeting, signaling, cytoskeleton, cell division, and cell interaction. An attempt is made to introduce the methodology that was used to obtain this information and to discuss how our understanding of these processes relates to the treatment of human disease.
Prerequisites: (03-121 or 03-151 or 03-120) and (03-232 or 03-233 or 03-231)

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

03-326 Evolution of Regulatory Genomics
Fall: 4.5 units
This course will introduce central concepts of evolutionary theory, e.g. drift, selection, phylogenetics and an introduction into how genomes are sequenced, assembled and annoted. This will require a basic undertsanding of genetics. Course topics will then unify these two areas of biology to examine process by which genomes evolve and how this in turn has lead to the diversity of animal pheonotypes. This will include discussion of how genomes control embryonic development, how gene regulation has evolved (focusing on cis regulatory evolution and non-coding RNA regulatory evolution) and the concept of gene regulatory network evolution. Concepts and specific examples will come through lectures, selected readings from advanced texts and primary literature.
Prerequisites: 03-231 or 03-232

03-327 Phylogenetics
Intermittent: 9 units
An advanced introduction to theory and practice of phylogenetic analysis (evolutionary tree reconstruction), with a focus on molecular evolution. Basic concepts will be introduced in the context of a historical survey of phylogeny reconstruction. A comprehensive introduction to phylogenetic methods will be presented, including data selection, multiple sequence alignment, character state data versus distance matrices, sequence evolution models, and the four major approaches to phylogeny reconstruction: Parsimony, Distance matrix, Maximum likelihood, and Bayesian analysis. Sources of error and methods for assessing the reliability of phylogenetic inference will be discussed. We will cover additional topics as time allows, such as phylogenetic hypothesis testing, genome scale approaches, the interface between phylogenetics and population genetics, gene tree reconciliation, horizontal gene transfer, and phylogenetic networks.
Prerequisites: 03-232 or 03-231 or 03-250

Course Website: http://www.cs.cmu.edu/~durand/Phylogenetics/

03-330 Genetics
Intermittent: 9 units
The mechanisms of transmission of inherited traits in viruses, bacteria, fungi, plants and animals are discussed. Molecular mechanisms of gene expression and gene regulation are analyzed. Recombinant DNA and its applications in genetic analysis, biotechnology, forensics, agriculture, medicine, and the pharmaceutical industry are presented. Special topics in human genetics are considered, such as the genetics of cancer. Principles and methods for the study of developmental genetics, population genetics and complex traits are also introduced.
Prerequisites: 03-121 or 03-151

03-342 Introduction to Biological Laboratory Practices
Fall: 1 unit
This course is designed for students in the BS in Computational Biology degree program. It is a required co-requisite for 03-343, Experimental Genetics and Molecular Biology and is designed to be an introduction to basic laboratory practices. The course will introduce biological and chemical safety training and basic laboratory practices. Techniques of solution preparation and titration, pipetting, UV/VIS spectroscopy, and quantitation of biological compounds will be covered.

03-343 Experimental Techniques in Molecular Biology
Fall: 12 units
This laboratory course is designed to teach experimental methods of modern biology. Experiments in microbial genetics, molecular biology and eukaryotic genetics are performed. Emphasis is placed on understanding and applying the biological principles of each experiment. This course is designed to be taken during the junior year and is intended to prepare students for undergraduate research. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.
Prerequisites: (03-231 or 03-232) and (09-208 or 09-222)

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

03-344 Experimental Biochemistry
Spring: 12 units
This course is designed to be taken as a sequel to 03-343. Experiments cover a variety of methods for investigating the structure and function of biological molecules. Experimental methods with proteins, enzyme kinetics, lipids, spectroscopy, and isolation and quantization of biological molecules are covered. During several experiments, students design their own projects. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.
Prerequisites: 03-343 and (03-231 or 03-232)

03-345 Experimental Cell and Developmental Biology
Spring: 12 units
This laboratory is designed to teach concepts and experimental methods in cell and developmental biology. Students work with a variety of organisms to examine how cells traverse development from rapidly dividing, undifferentiated cells, through cell commitment and the establishment of spatial and temporal patterns of gene expression, to the specific characteristics and responses of terminally differentiated cells. The course makes extensive use of video microscopy with phase contrast, DIC and fluorescence microscopes. Biochemical, immunological and molecular biological techniques are used to probe the molecules and processes of cells undergoing development. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.
Prerequisites: 03-343 and (03-231 or 03-232) and (03-320 or 03-240)

03-346 Experimental Neuroscience
Intermittent: 12 units
This laboratory is designed to teach concepts and experimental methods in neurobiology. Students work with a variety of organisms to study the anatomy, function, and development of the nervous system. Immunological, molecular, biochemical, and ballistic labeling techniques are used to examine the gene expression and structure in the mature and developing nervous system. Students study the function of neurons through neurophysiological techniques in invertebrates and computer simulation. This course makes extensive use of video microscopy and phase contrast, DIC, and fluorescence microscopes.
Prerequisites: (03-240 or 03-320) and 03-362 and 03-343

03-350 Developmental Biology
Spring: 9 units
How does a complex, multicellular organism arise from a single cell? How do cells with identical genomes acquire distinctive properties? What are the medical consequences of abnormal embryonic development? How does regeneration occur? How has evolution modified developmental programs to produce different body plans? These are some of the central questions in the field of developmental biology. This course serves as an introduction to current concepts and experimental approaches in this rapidly advancing field. Topics in the course include genomics, differential gene expression, cell signaling, cell movements, tissue morphogenesis, stem cells, human development, and regeneration. The course examines the genes and signaling pathways that control development and the role that mis-regulation of these pathways plays in human disease.
Prerequisites: 03-240 or 03-320

03-355 Stem Cell Engineering
Spring: 9 units
This course is offered only at CMU's campus in Qatar. This course covers the progress of stem cell research and its application to tissue engineering and regenerative therapy. The students will learn about the different types of stem cells, the biochemical stimuli that are responsible for regulating stem cell differentiation and techniques involved in the culture of stem cells. This subject will also highlight the development of various biomaterials that are used as biological substitutes in regenerative therapy. Current and emergent stem cell technologies in selected applications of tissue engineering in bone, skin and vascular tissues will be emphasized. The course will be delivered through problem-based learning where students are expected to participate in discussions, perform literature search, present their findings through presentations and written reports on selected topics. The class is designed for undergraduates with a strong interest in stem cell biology and tissue engineering, and the desire to actively contribute to discussions in the class.
Prerequisite: 03-240

03-362 Cellular Neuroscience
Fall: 9 units
Modern neuroscience is an interdisciplinary field that seeks to understand the function of the brain and nervous system. This course provides a comprehensive survey of cellular and molecular neuroscience ranging from molecules to simple neural circuits. Topics covered will include the properties of biological membranes, the electrical properties of neurons, neural communication and synaptic transmission, mechanisms of brain plasticity and the analysis of simple neural circuits. In addition to providing information the lectures will describe how discoveries were made and will develop students' abilities to design experiments and interpret data.
Prerequisites: 85-219 or 42-202 or 03-161 or 03-320 or 03-240

03-363 Systems Neuroscience
Spring: 9 units
Modern neuroscience is an interdisciplinary field that seeks to understand the function of the brain and nervous system. This course provides a comprehensive survey of systems neuroscience, a rapidly growing scientific field that seeks to link the structure and function of brain circuitry to perception and behavior. This course will explore brain systems through a combination of classical, Nobel prize-winning data and cutting edge primary literature. Topics will include sensory systems, motor function, animal behavior and human behavior in health and disease. Lectures will provide fundamental information as well as a detailed understanding of experimental designs that enabled discoveries. Finally, students will learn to interpret and critique the diverse and multimodal data that drives systems neuroscience.
Prerequisites: 42-202 or 03-240 or 03-320 or 03-161 or 85-219

03-364 Developmental Neuroscience
Fall: 9 units
This course examines the principles that govern the developmental assembly of a complex nervous system. Topics range from the earliest steps of induction of neural tissue and birth of neurons to the plasticity within developing circuits and the development of behavior. By the end of this course students should be able to describe the major steps in neural development and to interpret key experiments using vertebrate and invertebrate models have helped to elucidate these steps. This course is taught on the University of Pittsburgh campus by faculty from Carnegie Mellon and Pitt.
Prerequisites: 03-363 or 03-362 or 03-240

03-365 Neural Correlates of Learning and Memory
Spring: 9 units
This course will examine the biological substrates of learning, memory, and behavioral adaptation. The focus will be on addressing how neural circuits change during new skill acquisition and adapt to variations in the environment. An introduction to experience-dependent changes in neural structure and function, in addition to behavioral learning paradigms, will be provided. Then we will consider the ways in which specific changes in biological substrates give rise to the emergent properties that drive behavioral adaptation, followed by in depth coverage of deciphering which biological substrates constitute a lasting memory trace. Finally, the concept of age-dependent learning will be examined. Concepts and specific examples will come through reading of primary literature and selected readings from advanced texts.
Prerequisites: 03-161 or 85-219 or 03-240 or 03-320

03-366 Biochemistry of the Brain
Fall: 9 units
This course is designed to give students a comprehensive understanding of the major neurotransmitter systems in the brain. Students will explore qualitative and quantitative approaches to understanding how various neurotransmitters function as well as how they are modulated by endogenous and exogenous agents. The qualitative exploration will include basic principles of neural communication, signal transduction and second messenger systems, main classes of neurotransmitters, and the effects of medications and drugs of abuse. Quantitatively, we will explore the kinetics of neurotransmitter binding, affinity of different receptors for their neurotransmitters, and apply concepts of competitive, uncompetitive, and mixed inhibition to understanding the effects of exogenous agonists and antagonists on these receptors. Students will learn how these qualitative and quantitative biochemical processes affect the endocrine system, neuroinflammatory responses, addictive behaviors, and neurotoxic or degenerative conditions.
Prerequisites: (03-231 or 03-232) and (03-161 or 85-219 or 03-362)

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

03-370 Principles of Biotechnology
Spring: 9 units
This course is intended to provide an introduction to a set of core areas important for understanding and managing biotechnology business. Essentially, the focus of the course will be the basics of the biotechnology entrepreneurial process and a deep background on biotechnology enabled products. The objective is to provide the background for management-level personnel to make decisions based on knowledge of contemporary biotechnologies and the legal and regulatory environment. Because it is impossible to be comprehensive with regard to all applications, the goal is to provide students with sufficient familiarity with current biotechnology and with a framework for assessing bio-related business questions that they may encounter in the future through a combination of independent research, assessment of opportunities and pitfalls, and historical comparisons. NOTE: This course CANNOT be counted towards the advanced biology electives for any major or minor in Biological Sciences.
Prerequisites: (03-231 or 03-232) and (03-240 or 03-320)

03-380 Virology
Fall: 9 units
The concepts and methods of virology are covered, with emphasis on animal viruses, within the framework of cell biology, genetics, molecular biology, immunology, pathology, and epidemiology. The strategies that a wide variety of different DNA and RNA viruses, including some new and emerging ones, use to replicate and express their genomes during infection of host cells will be examined in some detail. The effects that viruses inflict on these cells will also be examined, as will some of the host cell responses generated by such virus-cell interactions, including interferon induction, the antiviral response generated by interferon, and oncogenic transformation. In addition, anoverview of procedures used for prevention and treatment of viral diseases via vaccinesand antiviral drugs, respectively, will be presented, as will a brief discussion of viroids and prions, and the characteristics of these agents which distinguish them from viruses.
Prerequisite: 03-240

03-390 Molecular and Cellular Immunology
Spring: 9 units
This course offers the student a comprehensive view of modern immunology at the molecular and cellular level. The first half of the course presents the fundamentals of immunology, beginning with innate immunity, followed by a discussion of the structure and function of important molecules in the immune system, such as antibodies, major histocompatibility antigens, complement, and the T-cell receptor. This portion of the course is concluded with a discussion of the development and function of the cellular immune response. The second half of the course is focused on applied immunology and discusses hypersensitivity, autoimmunity, immunodeficiencies, tumor immunology, infectious disease, and transplantation immunology. Presentations at the end of the course provide an opportunity for the student to explore additional topics in contemporary immunology.
Prerequisites: (03-232 or 03-231) and (03-240 or 03-320)

03-391 Microbiology
Spring: 9 units
The course provides introductory level microbial science and molecular biology that is aimed for students from all disciplines of natural science. It covers microbiology, genetics, genomics, as well as bacterial, fungal, and protozoan pathogenesis. Topics include: the human microbiome, genome sequencing, gene transfer across species, virulence, and drug resistance.
Prerequisites: 03-231 or 03-232

03-392 Microbiology Laboratory
Intermittent: 6 units
This is an upper level biology course for students who have taken or are currently taking the Microbiology course and are interested in laboratory experience in microbiology. It is designed with the recommendations of the American Society for Microbiology for a student laboratory course in mind in order to introduce the student to a broad spectrum of techniques in microbiology. You will learn the skills needed to perform experiments that help to differentiate various types of microbes, examine antimicrobial and antibiotic sensitivity and resistance, and begin to explore microbial diversity. Finally, you will develop an understanding of the theory behind the techniques you use and will be given the opportunity to further develop your skills in the process of experimental design. THIS COURSE WILL BE OFFERED EVERY OTHER SPRING, BEGINNING IN THE SPRING 2017 (NOT offered spring 2016).

03-402 Undergraduate Colloquium for Seniors
Spring
Missing Course Description - please contact the teaching department.

03-409 Special Topics
Intermittent: 3 units
Note: This class is available only on the Qatar campus. This course covers the progress of stem cell research and its application to tissue engineering and regenerative therapy. This is an advanced Biology elective. The students will learn about the different types of stem cells, the biochemical stimuli that are responsible for regulating stem cell differentiation and techniques involved in the culture of stem cells. This subject will also highlight the development of various biomaterials that are used as biological substitutes in regenerative therapy. Current and emergent stem cell technologies in selected applications of tissue engineering in bone, skin and vascular tissues will be emphasized. The course will be delivered through problem-based learning where students are expected to participate in discussions, perform literature search, present their findings through presentations and written reports on selected topics. The class is designed for upper undergraduates with a strong interest in stem cell biology, and the desire to actively contribute to discussions in the class.

03-410 Special Topics in Biological Sciences
Fall and Spring: 9 units
Special Topics in Biological Sciences. Topics will vary depending on the semester and instructor. Please read the individual section descriptions for more information. Genome Editing Biotechnology Description: This course will introduce students to the revolution in genome editing biotechnology based on the CRISPR bacterial immune system. Specific topics include CRISPR moving parts, discovery and diversity of CRISPR systems, CRISPR implementation in mammals, and other mammalian genetic engineering systems. We will view these topics in the context of human genetic diseases and the use of mouse genetics for disease research. We will consider ethical challenges including triparental embryos and CRISPR patent rights.
Prerequisites: 03-151 or 03-709 or 03-121

03-411 Topics in Research
Fall
During the year students attend and submit brief summaries of weekly seminars given by outside speakers or members of the Biology Department on current research topics in modern biology; some seminars outside of the department may be substituted.

03-412 Topics in Research
Spring
During the year students attend and submit brief summaries of weekly seminars given by outside speakers or members of the Biology Department on current research topics in modern biology. Some seminars outside of the department may be substituted.

03-428 Genome Editing Biotechnology
Fall: 4.5 units
How can we create genetically engineered cells, animals, plants, and even humans? This course will focus on the technologies that enable genome modification, with an emphasis on the recently developed CRISPR-Cas9 system. Specific topics will include an introduction to CRISPR technology and its history; DNA double strand break repair; Off target effects; Gene regulator CRISPRs; Alternate technologies; Ethics of modifying our genomes; Applications - cell screening; Applications - organism engineering; Applications - anti-HIV and immunotherapy; Overview of Gene therapy.
Prerequisites: 03-151 or 03-121 or 03-709

03-435 Cancer Biology
Fall: 9 units
Cancer affects roughly 1 in 3 people worldwide, and originates from both hereditary as well as environmental causes. Its prevalence makes it practically inescapable. Its of great relevance from both scientific and sociocultural perspectives. This course aims to examine various hallmarks of the biology of cancer while exploring novel concepts that challenge our understanding of cell biology. From the perspective of a cancer cell, we will learn about basic concepts of cell division, DNA replication, cell signaling, cell cycle control, cell metabolism, the regulation of gene expression in human cells, oncogenes, tumor suppressor genes, mutations, the process of metastasis, cancer diagnosis, cancer treatments and ethical questions surrounding treating patients, the epidemiology of cancer including prevalence and historical trends in diagnosis, as well as social impacts of a cancer diagnosis. Students will also explore the primary literature and scientific review articles to better understand research and methods of investigation into the cellular and molecular processes of tumorigenesis. This course will include interactive lectures, guest speakers, and in class discussion exercises aimed at building class participation and association, as well as confidence in public speaking about the sciences. Given the well-documented link between stress and cancer, there will also be a small component aimed at making students aware of health and wellness, such as reducing stress and anxiety.
Prerequisites: 03-330 or 03-220

03-439 Introduction to Biophysics
Fall: 9 units
This intermediate level course is primarily offered to Physics and Biology undergrads (junior/senior) and provides a modern view of molecular and cellular biology as seen from the perspective of physics, and quantified through the analytical tools of physics. This course will not review experimental biophysical techniques (which are covered, e.g., in 03-871). Rather, physicists will learn what sets "bio" apart from the remainder of the physics world and how the apparent dilemma that the existence of life represents to classical thermodynamics is reconciled. They also will learn the nomenclature used in molecular biology. In turn, biologists will obtain (a glimpse of) what quantitative tools can achieve beyond the mere collecting and archiving of facts in a universe of observations: By devising models, non-obvious quantitative predictions are derived which can be experimentally tested and may lead to threads that connect vastly different, apparently unrelated phenomena. One major goal is then to merge the two areas, physics and biology, in a unified perspective.
Prerequisites: (03-121 or 03-151) and (33-152 or 33-107 or 33-122 or 33-132 or 33-112 or 33-142)

Course Website: http://www.cmu.edu/smsl/teaching/IntroBioPhys.html

03-442 Molecular Biology
Fall: 9 units
The structure and expression of eukaryotic genes are discussed, focusing on model systems from a variety of organisms including yeast, flies, worms, mice, humans, and plants. Topics discussed include (1) genomics, proteomics, and functional proteomics and (2) control of gene expression at the level of transcription of mRNA from DNA, splicing of pre-mRNA, export of spliced mRNA from the nucleus to the cytoplasm, and translation of mRNA.
Prerequisites: 03-221 Min. grade B or 03-220 Min. grade B or 03-330 Min. grade B

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

03-445 Undergraduate Research
Fall and Spring
Students may investigate research problems under the supervision of members of the faculty. Permission of a faculty advisor required.

03-451 Advanced Developmental Biology and Human Health
Fall: 9 units
This course will examine current research in developmental biology, focusing on areas that have important biomedical implications. The course will examine stem cell biology, cellular reprogramming, cell signaling pathways, tissue morphogenesis, and genetic/developmental mechanisms of birth defects and human diseases. Emphasis will be placed on the critical reading of recent, original research papers and classroom discussion, with supporting lectures by faculty.
Prerequisites: (03-320 or 03-240) and (03-220 or 03-330)

03-511 Computational Molecular Biology and Genomics
Fall: 9 units
An advanced introduction to computational molecular biology, using an applied algorithms approach. The first part of the course will cover established algorithmic methods, including pairwise sequence alignment and dynamic programming, multiple sequence alignment, fast database search heuristics, hidden Markov models for molecular motifs and phylogeny reconstruction. The second part of the course will explore emerging computational problems driven by the newest genomic research. Course work includes four to six problem sets, one midterm and final exam.
Prerequisites: (03-121 or 03-151) and 15-122

Course Website: http://www.cs.cmu.edu/~durand/03-711/

03-512 Computational Methods for Biological Modeling and Simulation
Fall: 9 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problems sets with significant programming components and independent or group final projects.
Prerequisites: (03-121 or 03-151) and 15-122

03-534 Biological Imaging and Fluorescence Spectroscopy
Fall: 9 units
Fluorescence detection is a powerful technology that is the basis of most biomedical imaging, high speed flow cytometry, cell sorting, DNA sequencing, gene expression arrays, diagnostics and drug discovery. It is not surprising, then, that it is the basis of many commercial technology organizations with billions of dollars in sales. It is almost impossible to turn the page of a biomedical journal without seeing multicolor images acquired with powerful microscopes and fluorescent probes of cell structure and function. The sensitivity of fluorescence detection is so high that single biological molecules can be monitored as they function in living cells. This course covers principles and applications of optical methods in the study of structure and function in biological systems. Topics to be covered include: absorption and fluorescence spectroscopy; interaction of light with biological molecules, cells, and systems; design of fluorescent probes and optical biosensor molecules; genetically expressible optical probes; photochemistry; optics and image formation; transmitted-light and fluorescence microscope systems; laser-based systems; scanning microscopes; electronic detectors and cameras: image processing; multi-mode imaging systems; microscopy of living cells; and the optical detection of membrane potential, molecular assembly, transcription, enzyme activity, and the action of molecular motors. This course is particularly aimed at students in science and engineering interested in gaining in-depth knowledge of modern light microscopy.
Prerequisites: 09-106 and (03-320 or 03-240) and (21-122 or 21-124) and (33-111 or 33-121 or 33-141) and (03-231 or 03-232)

03-545 Honors Research
Spring: 9 units
This semester of research consists primarily of research and preparation of an acceptable written thesis. Oral presentation and defense of the thesis research will be required. This course ordinarily will be taken in the second semester of the senior year. Permission of the research advisor required.
Prerequisite: 03-445

03-601 Computational Biology Internship
All Semesters
This course allows a student to gain computational biology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice computational biology skills acquired in the classroom. Typically, students seek and secure their own internships.

03-620 Techniques in Electron Microscopy
Spring: 9 units
This course is designed to teach basic methods in transmission electron microscopy to graduate and undergraduate students. Sophomores with an interest in electron microscopy are encouraged to enroll, and will have the option and opportunity to utilize their skills in various laboratories during their junior or senior year. The course will be offered once each year, during the spring semester. Course enrollment will be limited to 4-6 students. Preferential enrollment will be given to graduate students and undergraduate students who have demonstrated a need for this technique in their research. The class will include one hour of lecture and 4 hours of laboratory each week (some additional laboratory time outside of the scheduled laboratory time is required). Students will learn basic methods in specimen preparation for both transmission and scanning electron microscopy (fixation, embedding and ultramicrotomy, drying and metal coating) and will be trained in the operation of both the Hitachi 7100 and 2460N electron microscopes. Lectures and laboratories during the last few weeks of the semester will introduce the students to special techniques (e.g. immunoelectron microscopy , cryoultramicrotomy, freeze substitution, variable pressure SEM, etc.) and will allow them to work with samples from their own research. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

03-700 MS Thesis Research
All Semesters
A student enrolled in this course conducts an independent investigation on a project in a faculty advisor's lab. The project is selected from a major area of research study with the advice and approval of the faculty advisor. This course is required of students who are enrolled in the Master of Science program and wish to write and defend a thesis.

03-709 Applied Cell and Molecular Biology
Fall: 12 units
The purpose of this course is to review key cellular and molecular phenomenon in biological pathways with strong emphasis on latest experimental techniques used in applications including but not limited to disease diagnosis, therapeutics, large-scale genomic and proteomic analysis. Knowledge gained from this course will be both conceptual and analytical. Students will periodically write extensive research reports on select topics and give oral presentations on a select few, while critically analyzing primary literature.

03-711 Computational Molecular Biology and Genomics
Fall: 12 units
An advanced introduction to computational molecular biology, using an applied algorithms approach. The first part of the course will cover established algorithmic methods, including pairwise sequence alignment and dynamic programming, multiple sequence alignment, fast database search heuristics, hidden Markov models for molecular motifs and phylogeny reconstruction. The second part of the course will explore emerging computational problems driven by the newest genomic research. Course work includes four to six problem sets, one midterm and final exam.
Prerequisites: (03-121 or 03-151) and 15-122

Course Website: http://www.cs.cmu.edu/~durand/03-711/

03-712 Computational Methods for Biological Modeling and Simulation
Spring: 12 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problems sets with significant programming components and independent or group final projects.
Prerequisites: 15-110 or 02-201 or 15-112 or 02-613

03-713 Bioinformatics Data Integration Practicum
Spring: 6 units
This course provides a hands-on, self-directed experience dealing with biological data and integrating it to produce software and analyses that are of use to biologists. Data are taken from a variety of sources, including academic research labs, large scale public genomics projects and data from private industry partners. Students will be given a project and asked to design a solution using a combination of existing tools and their own developed software.

03-726 Evolution of Regulatory Genomics
Fall: 6 units
This course in will examine the processes by which genomes evolve and how this genetic variation leads to phenotypic diversity. An introduction to gene regulation, how the genome controls development, comparisons of development and the phenotypic diversity in animals will be provided. Then we will consider ways in which genomes evolve, followed by in depth coverage of how gene regulation has evolved (focusing on cis regulatory evolution and non-coding RNA regulatory evolution). Finally the concept of gene regulatory network control of development and understanding evolution as change in these networks will be examined. Concepts and specific examples will come through reading of primary literature and selected readings from advanced texts. Grading will be based on written assignments from readings of literature, participation in class discussion, and two in class exams. The graduate level course (03-726) will in addition require a term paper based on thorough and critical reading of primary literature focused on one of the general topics presented in the course.

03-727 Phylogenetics
Intermittent: 12 units
An advanced introduction to theory and practice of phylogenetic analysis (evolutionary tree reconstruction), with a focus on molecular evolution. Basic concepts will be introduced in the context of a historical survey of phylogeny reconstruction. A comprehensive introduction to phylogenetic methods will be presented, including data selection, multiple sequence alignment, character state data versus distance matrices, sequence evolution models, and the four major approaches to phylogeny reconstruction: Parsimony, Distance matrix, Maximum likelihood, and Bayesian analysis. Sources of error and methods for assessing the reliability of phylogenetic inference will be discussed. We will cover additional topics as time allows, such as phylogenetic hypothesis testing, genome scale approaches, the interface between phylogenetics and population genetics, gene tree reconciliation, horizontal gene transfer, and phylogenetic networks. Course work will include readings from textbooks and seminal articles from the primary literature, problem sets, a final exam and possibly in class exams. Students in 03-727 will also carry out a major data analysis project, intended to familiarize the student with the practical application of principles taught in class. A short paper summarizing the results of this project will be required.

Course Website: http://www.cs.cmu.edu/~durand/Phylogenetics/

03-728 Genome Editing Biotechnology
Fall: 6 units
How can we create genetically engineered cells, animals, plants, and even humans? This course will focus on the technologies that enable genome modification, with an emphasis on the recently developed CRISPR-Cas9 system. Specific topics will include an introduction to CRISPR technology and its history; DNA double strand break repair; Off target effects; Gene regulator CRISPRs; Alternate technologies; Ethics of modifying our genomes; Applications - cell screening; Applications - organism engineering; Applications - anti-HIV and immunotherapy; Overview of Gene therapy. Student in-class presentations will cover late-breaking topics and specific areas of student interest.

03-730 Advanced Genetics
Spring: 12 units
This course considers selected current topics in genetics at an advanced level. Emphasis is on classroom discussion of research papers. Topics change yearly. Recent topics have included nucleocytoplasmic trafficking of RNA in yeast, genome imprinting in mammals, genetics of learning and memory in Drosophila, and viral genomics.
Prerequisites: (03-330 Min. grade B or 03-220 Min. grade B) and (03-742 or 03-442)

03-740 Advanced Biochemistry
Spring: 12 units
This is a special topics course in which selected topics in biochemistry will be analyzed in depth with emphasis on class discussion of papers from the recent research literature. Topics change yearly. Recent topics have included single molecule analysis of catalysis and conformational changes; intrinsically disordered proteins; cooperative interactions of aspartate transcarbamoylase; and the mechanism of ribosomal protein synthesis.

03-741 Advanced Cell Biology
Spring: 12 units
This course covers fourteen topics in which significant recent advances or controversies have been reported. For each topic there is a background lecture by the instructor, student presentations of the relevant primary research articles and a general class discussion. Example topics are: extracellular matrix control of normal and cancer cell cycles, force generating mechanisms in trans-membrane protein translocation, signal transduction control of cell motility, and a molecular mechanism for membrane fusion.
Prerequisites: (03-240 or 03-320) and (03-231 or 03-232)

03-742 Advanced Molecular Biology
Fall: 12 units
The structure and expression of eukaryotic genes are discussed, focusing on model systems from a variety of organisms including yeast, flies, worms, mice, humans, and plants. Topics discussed include (1) genomics, proteomics, and functional proteomics and (2) control of gene expression at the level of transcription of mRNA from DNA, splicing of pre-mRNA, export of spliced mRNA from the nucleus to the cytoplasm, and translation of mRNA.

03-744 Membrane Trafficking
Spring: 9 units
While the focus of this course is to analyze membrane/protein traffic along both the biosynthetic and endocytic pathways, our general goal is to teach students how to read and interpret the literature. In particular, we emphasize the conclusions and discuss their validity. The course is updated each year to include topics in which new and interesting developments have occurred. Emphasis is placed on how membrane traffic is regulated and where applicable how it is disrupted or subverted during disease processes. The course is of general interest to students, fellows, and faculty interested in cell biology, immunology, neurobiology, pharmacology and virology.
Prerequisites: 03-320 or 03-240

03-745 Core Course in Biochemistry
Fall: 6 units
This course is designed to provide first year doctoral students in the Department of Biological Sciences with a broad foundation in biochemistry and biophysical techniques. Topics include protein structure, enzymology, and methods to characterize protein structure and function. Students will be evaluated throughout the course, and with a final exam.

03-746 Core Course in Cell Biology
Fall: 6 units
This course is designed to provide first year doctoral students in the Department of Biological Sciences with a broad foundation in cell biology. Topics include, but are not limited to, intracellular trafficking, signal transduction, the cytoskeleton, the cell cycle, and cell-cell interactions. This is a lecture-based course and will include some discussion of the primary literature. Students will be evaluated weekly, and with a final exam. Enrollment requires instructor permission.

03-747 Proposal Preparation and Peer Review
Fall: 4 units
The concise and clear presentation of an experimental research plan is an essential skill for research scientists. This mini course is designed to introduce 2nd year students to the structure and preparation of a structured research proposal as well as formalize instruction in professional standards in research ethics, CV preparation, and scientific writing and data presentation. Course material is taken from actual grant proposals and previous years' qualifying exam proposals, as well as primary research publications and faculty grant proposals. The course is highly interactive, and students are required to participate in review of each others' work throughout the duration of the course. Coursework is expected to form the basis of the Ph.D. qualifying exam proposal in the winter of the second year.

03-748 Scientific Speaking and Peer Review
Fall: 3 units
Effective public presentation of scientific data is an important skill for every scientist. This interactive course will provide students with specific guidelines on organizing, preparing, and delivering an effective and engaging scientific talk. The topics covered include data organization, choice of content based on audience, PowerPoint and graphic design, charts and graphs representation, use of animation, fonts and color schemes, body language, overcoming stage-fear, and compensation for accents. The course is designed for third year graduate students. Students will present their upcoming Journal Club talk a week or two before in class, and receive formal review from a panel comprising of other students in the class, departmental multimedia designer, and the instructor. Further, each talk will be video recorded, and students will use the recording for self-critique and further input from the instructor. Each students Journal Club talk will then be recorded to provide a benchmark for the final talk incorporating the critiques provided. Students are required to participate in review of each others work throughout the duration of the course, and will therefore actively learn the elements of an effective presentation.

03-750 Graduate Seminar
Fall and Spring: 1 unit
Each semester, all Department of Biological Sciences graduate students are required to register for and attend the weekly departmental Research Seminar (03-750; 1 unit). Graduate students are strongly urged to meet the speakers to broaden their knowledge of cutting-edge biological science, to discuss career paths and strategies and to make useful contacts; the faculty host can arrange group meetings for interested students.

03-751 Advanced Developmental Biology and Human Health
Fall: 12 units
This course will examine current research in developmental biology, focusing on areas that have important biomedical implications. The course will examine stem cell biology, cellular reprogramming, cell signaling pathways, tissue morphogenesis, and genetic/developmental mechanisms of birth defects and human diseases. Emphasis will be placed on the critical reading of recent, original research papers and classroom discussion, with supporting lectures by faculty.
Prerequisites: (03-240 or 03-320) and (03-330 or 03-220)

03-755 Graduate Research Seminar
Fall and Spring: 3 units
Each semester, all Departmental of Biological Sciences graduate students are required to register for and attend the weekly departmental Journal Club (Graduate Research Seminar 03-755; 3 units) during which students and faculty members give 25-minute presentations. Second-year students present a research paper or topic from the literature, and more senior students present their research results; typically, graduate students give four Journal Club presentations during their time in the department. Each succeeding year those students who speak at the Departmental Retreat or who are graduating by May of their fifth year are not required to present at Journal Club that year.

03-757 Special Topics
Intermittent: 12 units
Special topics course for graduate students.

03-758 Special Topics
Fall: 6 units
Special topics course for graduate students. 03-758-A1: Biosensors Biological systems are essentially 3D, highly-linked networks that sense, compute and respond to internal or external stimuli via widely distributed and diversified cells interacting over various timescales. To understand such complex biological systems, ideally, it would require observation of the activity of numerous populations of cells with a high degree of precision and resolution down to molecular building block. In this way, we can understand the functions and dynamics that are produced by the interactions between different cells as well as subcellular signaling events within individual cells. This course explores up-to-date tools that enable insight into how biological components work together to implement physiological functions, and how these interactions go awry in disease states. 03-758-A2: Synthetic Biology This course explores the following: Structure of, expression and regulation in prokaryotic and eukaryotic systems, including their viruses. Advanced biotechnological methods comprising cloning, mutagenesis, polymerase chain reaction, synthesis of nucleic acids, DNA sequence determination, synthetic genomics, CRISPR-Cas9, directed evolution, alternative splicing and computational modeling. Experimental characterization of structural and functional properties of biomolecules. Bioinformatic analysis and characterization of genes and biomolecules.

03-762 Advanced Cellular Neuroscience
Fall: 12 units
This course is an introductory graduate course in cellular neuroscience. As such it will assume little or no background but will rapidly progress to discussions of papers from the primarily literature. The structure of the course will be about half lectures and half discussions of new and classic papers from the primary literature. These discussions will be substantially led by students in the course. Topics covered will include ion channels and excitability, synaptic transmission and plasticity, molecular understanding of brain disease and cell biology of neurons. Assessment will be based on class participation, including performance on in-class presentations and a writing assignment.

03-763 Advanced Systems Neuroscience
Spring: 12 units
This course is a graduate version of 03-363. Students will attend the same lectures as the students in 03-363, plus an additional once weekly meeting. In this meeting, topics covered in the lectures will be addressed in greater depth, often through discussions of papers from the primary literature. Students will read and be expected to have an in depth understanding of several classic papers from the literature as well as current papers that illustrate cutting edge approaches to systems neuroscience or important new concepts. Use of animals as research model systems will also be discussed. Performance in this portion of the class will be assessed by supplemental exam questions as well as by additional homework assignments.
Prerequisites: 03-121 or 03-762 or 03-362 or 03-151

03-765 Advanced Neural Correlates of Learning and Memory
Spring: 12 units
This course will examine the biological substrates of learning, memory, and behavioral adaptation. The focus will be on addressing how neural circuits change during new skill acquisition and adapt to variations in the environment. An introduction to experience-dependent changes in neural structure and function, in addition to behavioral learning paradigms, will be provided. Then we will consider the ways in which specific changes in biological substrates give rise to the emergent properties that drive behavioral adaptation, followed by in depth coverage of deciphering which biological substrates constitute a lasting memory trace. Finally, the concept of age-dependent learning will be examined. Concepts and specific examples will come through reading of primary literature and selected readings from advanced texts.

03-770 Principles of Biotechnology
Spring: 12 units
This course is intended to provide an introduction to a set of core areas important for understanding and managing biotechnology business. Essentially, the focus of the course will be the basics of the biotechnology entrepreneurial process and a deep background on biotechnology enabled products. The objective is to provide the background for management-level personnel to make decisions based on knowledge of contemporary biotechnologies and the legal and regulatory environment. Because it is impossible to be comprehensive with regard to all applications, the goal is to provide students with sufficient familiarity with current biotechnology and with a framework for assessing bio-related business questions that they may encounter in the future through a combination of independent research, assessment of opportunities and pitfalls, and historical comparisons. NOTE: This course CANNOT count towards the advanced electives required for majors or minors in Biological Sciences.

03-791 Advanced Microbiology
Spring: 12 units
This course will use both lectures and current research literature in the area of Microbiology and Infectious Diseases to introduce such topics as prokaryotic cytoskeletal functions, the human microbiome and its impact, metabolic engineering, transposon mutagenesis for gene function elucidation, synthetic genome construction and applications, pathogenicity islands, functional and expression-based identification of pathogenicity determinants, horizontal gene transfer, regulatory RNAs, biofilm formation quorum sensing, and antimicrobial drug development.

03-871 Structural Biophysics
Fall: 12 units
The physical properties of biological macromolecules and the methods used to analyze their structure and function are discussed. Topics covered include: protein architecture and folding; nucleic acid structures and energetics; structure determination by X-ray crystallography and NMR; biological spectroscopy with emphasis on absorption, fluorescence, and NMR spectroscopies; other methods to characterize proteins and protein-ligand interactions, such as mass spectrometry, calorimetry, and surface plasmon resonance. Sufficient detail is given to allow the student to critically evaluate the current literature.
Prerequisites: (03-231 or 03-232) and (09-345 or 09-214) and (21-122 or 21-120)

03-900 Doctoral Thesis Research
All Semesters
Doctoral Thesis Research consists of an independent investigation on a project selected from a major area of research study with the advice and approval of the faculty advisor.

Department of Chemistry

Linda Peteanu, Department Head

Karen H. Stump, Director of Undergraduate Studies

Location: Doherty Hall 1316
www.chem.cmu.edu

Chemistry at Carnegie Mellon University is a shared mission to advance energy and sustainability solutions and to improve human health by generating, exploring, and harnessing new molecular design paradigms.

Chemistry is an area of science involved with the study of the properties and reactions of substances ranging from living cells to subatomic particles. It is at the center of many sciences and technical fields, providing the fundamental knowledge and tools needed to address many of society's needs and to explore the unknown. Fields as diverse as genetic engineering, materials science and nanotechnology look to chemistry when they look to the future, for that is where the ultimate in understanding — the molecular level — resides.

The chemistry profession is extraordinarily diverse, with career opportunities available in the chemical, petroleum, renewable energy, nuclear power, novel polymeric materials, metals, personal care and pharmaceutical industries, among many others. Chemistry plays an increasingly important role in the rapidly expanding biomedical and biotechnology industries. In addition to careers in industry and academia, many chemists find rewarding careers in the public sector in the laboratories of the National Institutes of Health, the Department of Agriculture, the Environmental Protection Agency, the National Institute of Standards and Technology, and the Department of Energy as well as in consulting. Chemistry graduates also find employment in technical fields unrelated to science but where their problem solving and communication skills are highly valued.

Chemistry is a particularly suitable major for pre-medical and other pre-health profession students. Medical schools look favorably on the rigorous reasoning skills chemists develop, as evidenced by an excellent record for student admission to advanced education in these areas. An increasing number of our graduates are seeking careers in dentistry, pharmacy or pharmacology. The Health Professions Program advises all Carnegie Mellon students considering careers in health fields. (See Health Professions Program description in this catalog for more information.) Chemistry is also excellent preparation for careers in law, especially for those with an interest in specializing in patent, intellectual property or environmental law. The curriculum has the flexibility to allow these students to participate in the CMU Washington Semester Program with the possibility of an internship in science policy should they desire. Students interested in industrial careers often combine their chemistry program with undergraduate courses in business administration or eventually go on to study for an M.B.A.

The Department offers three Bachelor's degrees: the B.S. in Chemistry, The B.S. in Chemistry/Biological Chemistry Track and the B.A. in Chemistry. One third of the courses for the B.A. degree are free electives that may be taken in any of the departments of the University and therefore offers a high degree of flexibility. For the B.S. degrees, electives often are technical courses in chemistry or related fields of science, technology and engineering, such as biology, physics, mathematics, chemical, biomedical or materials science engineering or computer science, although they can be in other non-technical areas as well. It is possible to have all of the technical requirements completed after the junior year in the B.S. and B.A. degree programs, allowing students the flexibility to combine electives in the senior year into a focused program of specialization or to allow for additional breadth in their undergraduate experience. Students interested in graduate studies in chemistry may enroll in graduate courses. Those desiring immediate job placement may be interested in one or more of the formal options that supplement the chemistry B.S. degree. These are described in detail later in this section of the catalog. Carnegie Mellon has one of the strongest polymer science programs in the world and the undergraduate polymer science, materials chemistry or colloids, polymers and sciences options offer training that is particularly valuable for an industrial career. The Computational Chemistry option provides students with expertise in scientific computing that is highly sought after by employers in the pharmaceutical industry.

The overlap between the fields of chemistry and biological sciences continues to grow, with increased emphasis on synthetic chemicals that are used as probes or reporters of biological function and diagnostic and/or therapeutic agents. In addition, the application of sophisticated spectroscopic, structural and scanning probe/force methods on scales as low as single molecules is driving innovation and education at the chemistry/biology interface. Based on these trends the department offers the B.S. in Chemistry/Biological Chemistry Track to better prepare students for advanced studies and a job market that values knowledge and skills from both disciplines. A combination of advanced research-focused lecture course offerings and a novel laboratory course in bioorganic chemistry allows students to build the strong foundation typical of a successful chemistry major, while expanding out into applications of chemistry in the biological sciences. Students who complete the track will have been exposed to the latest research accomplishments and unanswered questions in biological chemistry while also gaining experience in experimental methods unique to research at this interface.

An honors program is offered for highly motivated undergraduates. It is designed primarily for students who wish to undertake a strong research-intensive program of study in contemporary chemistry. The program B.S. in Chemistry with Departmental Honors requires the completion of at least one graduate level course in chemistry, a research project, and the writing and defense of a bachelor's level honors thesis. An advanced track leading to the B.S. in Chemistry with Departmental Honors together with a Master of Science degree in chemistry involves completion of five graduate level courses and a more extensive thesis research project. This degree path is especially attractive to students who plan to pursue an industrial career. With enough advanced placement credit or by carrying heavier than usual course loads, students can complete the Honors/M.S. degree program in 8 semesters, with research during one to two summers. The majority of openings in the chemical industry presently are at the Bachelors and Masters degree levels.

Additional majors (double majors) are available with nearly all other departments in the university provided the student can fit the required courses into the schedule. Generally, all the requirements for both departments must be met for an additional major (except for some courses with similar content). Programs are also available that lead to the degree B.S. in Chemistry with a minor in another discipline. Requirements for most minor programs are described by individual departments in this catalog. However, it is recommended that students who are interested in pursuing a minor as part of their degree consult with the department involved for the current requirements and further guidance about scheduling. Dual degree programs are available in which students receive two separate undergraduate degrees from two different departments in the University. These require students to complete at least 90 units of work per additional degree in addition to the units required for the first degree and the core curriculum from both colleges if the programs are in different units. Several five-year programs have been developed to allow a Carnegie Mellon undergraduate student to earn both a B.S. in Chemistry and a Master of Science degree in fields such as Health Care Policy and Management, Materials Science Engineering, Colloids, Polymers and Surfaces or Biomedical Engineering.

Study abroad programs are available for chemistry majors and programs of one to two semesters can generally be accommodated without delaying time to graduation beyond 8 semesters. One example of a formal exchange program is spending two semesters at École Polytechnique Féderále de Lausanne (EPFL) in Switzerland. Students can also study at the Carnegie Mellon campus in Qatar. Study abroad is encouraged by the chemistry department and can be arranged on an individual basis at universities throughout the world including Europe, Asia, Africa, New Zealand, and Australia during the academic year, the summer and winter or spring breaks. Students interested in study abroad should consult with their academic advisor and the MCS Study Abroad Advisor in the Office of International Education.

One of the most attractive features of the Department of Chemistry is the opportunity for students to interact with prominent research scientists in entry-level as well as advanced courses and in research. Undergraduate laboratory instruction takes place in a state-of-the-art facility located in Doherty Hall. Participation in undergraduate research is encouraged and qualified students may begin projects as early as their second year. Chemistry majors interested in beginning research should consult with the Director of Undergraduate Studies to begin the process of identifying a research mentor. Approximately 90 to 98% of the graduating chemistry majors during the past ten years have taken part in research either for pay or for credit as part of their undergraduate training. Chemistry majors have been very successful in obtaining Small Undergraduate Research Grants (SURG) and Summer Undergraduate Research Fellowships (SURF) from the University to help support their research projects. Several students each summer obtain iSURF support, International Summer Undergraduate Research Fellowships, to work with research collaborators abroad. Undergraduate and research laboratories are equipped with the latest scientific instrumentation. The use of computational tools is emphasized throughout the curriculum.

Program Outcomes

The faculty members of the Department of Chemistry have approved the following as a statement of our learning outcomes for recipients of an undergraduate degree in chemistry.

Upon graduation recipients of the BS or BA degree in Chemistry will:

Foundational knowledge/theory

- Have a firm foundation in the quantitative and computational thinking that underlies chemistry, including use of modern computational tools.
- Have a firm foundation in the theories and models that form the basis for reasoning about molecular systems.
- Understand how the different subdisciplines of chemistry relate to and complement one another.
- Be able to apply chemical reasoning across disciplines, such as biology, environmental science, materials science, nanotechnology, and engineering.

Practical/Experimental

- Understand that chemistry is fundamentally an experimental science, and be able to identify or create an appropriate model, formulate a hypothesis, choose an appropriate set of tools and techniques, and design an experiment that tests the hypothesis and analyze the results from that experiment drawing sound scientific conclusions from the results obtained.
- Be proficient in the use of both classical and modern tools for analysis of chemical systems.
- Be able to design and carry out synthesis of both organic and inorganic systems.
- Be able to use experience and knowledge gained through theoretical and practical design projects to conduct further research.
- Know and follow the proper procedures and regulations for safe handling and use of chemicals and chemical equipment.

Communication

- Be able to convey information, both orally and in writing, to a range of audience levels and for a variety of purposes.
- Understand how scientific information is shared between peers in modern science, including responsible conduct for acknowledging prior and current contributions.
- Be able to locate, identify, understand and critically evaluate the chemical literature.
- Develop the interpersonal skills to function cooperatively in a team setting.

Society and ethics

- Understand the opportunities and consequences of chemistry for the environment and society for both the short term and for long-term sustainability.
- Understand and apply ethics and values to all professional activities.

Professional development

- Develop an understanding of career opportunities both within and outside of chemistry, including through contacts with faculty, the career and professional development center and alumni.
- Be prepared to pursue a life and career that builds on their experiences at Carnegie Mellon to achieve their personal goals and to contribute positively to society.

B.S. in Chemistry

The majority of undergraduate degrees awarded by the Department of Chemistry are Bachelor of Science degrees. This degree program provides the most appropriate preparation for further graduate study and for industrial positions in research and development or analytical chemistry. The curriculum provides a strong foundation in the fundamental areas of study in chemistry: organic, physical, inorganic and analytical chemistry, along with a rich set of research-focused, instrumentation intensive laboratory experiences aligned with those areas. Students interested in less technical areas of employment or graduate study in areas such as business, policy or law may find the Bachelor of Arts degree a more suitable alternative.

Curriculum in B.S. in Chemistry and Requirements for an Additional Major in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2019 or later. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses:

Technical Breadth Requirements		Units
33-121	Physics I for Science Students	12
33-122	Physics II for Biological Sciences and Chemistry Students	9
03-121	Modern Biology	9
or 03-231	Honors Biochemistry	
or 03-232	Biochemistry I	
15-110	Principles of Computing - or other approved programming course	10
or 15-112	Fundamentals of Programming and Computer Science	
or 02-201	Programming for Scientists	
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	

Students should complete this technical core as early as possible and preferably by the end of their fifth semester.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), ENGAGE in Service (38-110, 1 units), ENGAGE in the Arts (38-220, 2 units), EUREKA!: Discovery and Its Impact (38-101, 6 units), the MCS first-year seminar, and the junior seminar PROPEL or a total of 72 units. The junior seminar requirement (PROPEL) for MCS Is fulfilled by taking the required Science and Society (38-302, 4 units) and a second approved course. Approved as of the publication of this catalog is Professional Development and Life Skills (38-303, 2 units). A more expanded listing will be published by the MCS Dean's Office. For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

Freshman Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Computing @ Carnegie Mellon	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

02-201 Programming for Scientists is an acceptable alternative to 15-110 for chemistry majors as are any upper level courses in programming.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences, 09-122 Molecular Tools for Biological and Chemical Studies or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective or 09-116 a new course for the spring of 2020 that will allow you to shadow upperclass mentors in undergraduate research in chemistry. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
33-121	Physics I for Science Students	12
or 03-121	Modern Biology	
or 15-110	Principles of Computing	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9.0
		50

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences and Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		41

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-204	Professional Communication Skills in Chemistry (It is recommended that this course be completed prior to taking the junior level labs, 09-321 or 09-323.)	3
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-348	Inorganic Chemistry (Students wishing to pursue careers in the health professions or are pursuing the Biological Chemistry Track may wish to take biochemistry, 03-232, and delay inorganic until the junior or senior year spring semester)	10
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		46

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two; though you should be careful about moving too many courses to the senior year as that may create additional stress at a time when you are preparing to move forward from CMU. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year.	9
09-321	Laboratory III: Molecular Design and Synthesis This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses.	12
or 09-323	Bioorganic Chemistry Laboratory	
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring).	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
09-331	Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
xx-xxx	Cultural/Global Understanding Requirement	9
38-302	Science and Society The junior seminar requirement (PROPEL) for MCS Is fulfilled by taking the required 38-302 and a second approved course.	4
xx-xxx	Approved PROPEL elective	2-9
		46-53

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Chemistry Elective (see notes on electives)	9
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Free Electives	30
		44

Spring		Units
09-402	Undergraduate Seminar VI	3
09-xxx	Chemistry Elective (see notes on electives)	9
xx-xxx	Free Electives	27
		39

Distribution of Units for B.S. in Chemistry and Requirements for An Additional Major in Chemistry

Minimum Total Chemistry Units 163; See distribution below

Required Chemistry Courses* Units		
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-204	Professional Communication Skills in Chemistry	3
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12

09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
09-xxx	Chemistry Electives	18

* These, plus 33-121 Physics I for Science Students and 33-122 Physics II for Biological Sciences and Chemistry Students, are the required courses for students earning an additional major in chemistry.

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS degree and the additional major in chemistry that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Biology (Modern Biology or Biochemistry)	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences Courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (First-year seminar)	**6**
MCS Junior Seminar	**6**
ENGAGE in Service	**1**
ENGAGE in Wellness Courses (three courses)	**3**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**62**
Minimum number of units required for the degree:	**360**

The above B.S. curriculum recommends a range of 41–50 units per semester to meet the minimum degree requirement of 360 units. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Notes on Electives

Chemistry Electives

A minimum of 18 units of chemical electives is required.

Chemistry electives can be satisfied by 09-445 Undergraduate Research, or by most other chemistry courses 09-3xx or higher, undergraduate or graduate level, for which the student has the necessary prerequisites, or by 03-231/03-232 Biochemistry. Biochemistry also fulfills the Life Sciences requirement for the MCS technical breadth requirement. 09-435 Independent Study Chemistry may only be used to fulfill this requirement with permission of the Director of Undergraduate Studies. Certain interdisciplinary courses (e.g. 39-xxx) relating to chemistry can also be used with the approval of the Director of Undergraduate Studies. The scheduling of these electives can vary and students should check with the department offering the course to see which courses are offered in any given year or semester and with the Director of Undergraduate Studies in the Department of Chemistry to ascertain whether the course is an acceptable chemistry elective.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

B.A. in Chemistry

The curriculum for the B.A. degree provides students with the opportunity to take a substantial number of elective and non-technical courses. Certain chemistry, math, and other technical courses required for the B.S. degree are replaced by free electives, making this degree an ideal choice for those who wish to earn an additional major with one of the departments in the College of Humanities and Social Sciences, College of Fine Arts, or with the Business Administration program, though this is not a requirement. It is also attractive for students wishing to pursue careers in dentistry or pharmacy, career paths that require a broader preparation at the undergraduate level and hence more coursework outside of chemistry. Students may earn one or more of the options as described for B.S. degree candidates, providing they complete the courses listed.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses 09-214 Physical Chemistry, 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and the Spring-only courses 09-220 Modern Organic Chemistry II, 09-348 Inorganic Chemistry, and 09-204 Professional Communication Skills in Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2019. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses:

Technical Breadth Requirements		Units
33-121	Physics I for Science Students	12
33-122	Physics II for Biological Sciences and Chemistry Students	9
03-121	Modern Biology	9
or 03-231	Honors Biochemistry	
or 03-232	Biochemistry I	
15-110	Principles of Computing	10
or 02-201	Programming for Scientists	
or 15-112	Fundamentals of Programming and Computer Science	
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	

Students should complete this technical core as early as possible and preferably by the end of their fifth semester.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), ENGAGE in Service (38-110, 1 units), ENGAGE in the Arts (38-220, 2 units), EUREKA!: Discovery and Its Impact (38-101, 6 units), the MCS first-year seminar, and the junior seminar PROPEL or a total of 72 units. The junior seminar requirement (PROPEL) for MCS Is fulfilled by taking the required Science and Society (38-302, 4 units) and a second approved course. Approved as of the publication of this catalog is Professional Development and Life Skills (38-303, 2 units). A more expanded listing will be published by the MCS Dean's Office. For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

First Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Computing @ Carnegie Mellon	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

02-201 Programming for Scientists is an acceptable alternative to 15-110 for chemistry majors as are any upper level courses in programming.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences, 09-122 Molecular Tools for Biological and Chemical Studies or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II *	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
15-110	Principles of Computing	10
or 33-121	Physics I for Science Students	
or 03-121	Modern Biology	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9
		48

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences and Chemistry Students This course is required before graduation but need not be taken this semester.	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		41

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-204	Professional Communication Skills in Chemistry (It is recommended that this course be completed prior to taking the junior level labs, 09-321 or 09-323.)	3
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	18
		45

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
03-121	Modern Biology	9
or 15-110	Principles of Computing	
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
xx-xxx	Free Elective	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-348	Inorganic Chemistry	10
09-xxx	Chemistry Elective (See notes below regarding chemistry electives.)	9
xx-xxx	Cultural/Global Understanding Requirement	9
38-302	Science and Society	4
xx-xxx	Approved PROPEL elective	2-9
xx-xxx	Free Elective	9
		44-51

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Chemistry Elective	9
09-214	Physical Chemistry note that this course may not be offered every fall depending upon enrollments so consider it for either the fall of the junior or senior years	9
38-430	ENGAGE in Wellness: Looking Forward	1
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
xx-xxx	Free Electives	25
		48

Spring		Units
09-402	Undergraduate Seminar VI	3
xx-xxx	Free Electives	40
		43

Distribution of Units

Minimum Total Chemistry Units 124; See distribution below:

Required Chemistry Courses		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-204	Professional Communication Skills in Chemistry	3
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-214	Physical Chemistry	9
or 09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	
or 09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-xxx	Chemistry Seminars	8
09-xxx	Chemistry Electives	18

09-322 Laboratory IV: Molecular Spectroscopy and Dynamics may be taken in lieu of 09-321 Laboratory III: Molecular Design and Synthesis or 09-323 Bioorganic Chemistry Laboratory. However the student must complete the necessary pre- and co-requisites of 09-231, 09-344, 09-331 and 09-345. In this case 09-331 and 09-344 will count as chemistry electives towards the B.A. degree.

Students who transfer into the department and have taken 09-217 Organic Chemistry I, and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.A. degree that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	Units
Biology (either Modern Biology or Biochemistry)	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (First year seminar)	**6**
MCS Junior Seminar	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**101**
Minimum number of units for the degree	**360**

The above B.A. curriculum recommends a range of 40–50 units per semester. The total units actually taken may exceed the 360 unit minimum, but students are strongly encouraged to take the extra elective courses in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Notes on Electives

Chemistry Electives

A minimum of 18 units of chemical electives is required.

Chemical electives can be satisfied by 09-445 Undergraduate Research, or by most other chemistry courses 09-3xx or higher, undergraduate or graduate, for which the student has the necessary prerequisites, or by 03-231/03-232 Biochemistry I. Biochemistry also fulfills the Life Sciences requirement for the MCS technical breadth requirement. 09-435 Independent Study Chemistry, may only be used to fulfill this requirement with permission of the Director of Undergraduate Studies. Certain interdisciplinary courses (e.g. 39-xxx) relating to chemistry can also be used with permission by the Director of Undergraduate Studies. The scheduling of these electives can vary and students should check with the department offering the course to see which courses are offered in any given year or semester and with the Director of Undergraduate Studies in the Department of Chemistry to ascertain whether the course is an acceptable chemistry elective.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

B.S. in Chemistry/Biological Chemistry Track

This degree is ideal for students who wish to better prepare themselves for advanced studies in biological chemistry or biomedical fields and a job market that values knowledge and skills from both disciplines. A combination of advanced research-focused lecture course offerings and a novel laboratory course modeling the drug discovery process will allow students to build the strong foundation typical of a successful chemistry major, while expanding out into applications of chemistry in the biological sciences.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2019. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors in the Biological Chemistry Track must at minimum take the following non-chemistry technical courses: Physics I for Science Students (33-121, 12 units), Physics II for Biological Sciences and Chemistry Students (33-122, 9 units), Modern Biology (03-121, 9 units), Principles of Computing (15-110, 10 units) (or other approved programming course), 21-120 Differential and Integral Calculus (10 units) and Integration and Approximation (21-122, 10 units) **or** Calculus II for Biologists and Chemists (21-124, 10 units). Students should complete this technical core as early as possible and preferably by the end of their fifth semester.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units) , four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units) , ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), ENGAGE in Service (38-110, 1 units) , ENGAGE in the Arts (38-220, 2 units), EUREKA!: Discovery and Its Impact (38-101, 6 units) , the MCS first-year seminar, and the junior seminar PROPEL for a total of 72 units. The junior seminar requirement (PROPEL) for MCS Is fulfilled by taking the required Science and Society (38-302, 4 units) and a second approved course. Approved as of the publication of this catalog is Professional Development and Life Skills (38-303, 2 units). A more expanded listing will be published by the MCS Dean's Office. For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

Freshman Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Computing @ Carnegie Mellon	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

02-201 Programming for Scientists is an acceptable alternative to 15-110 for chemistry majors as are any upper level courses in programming.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences, 09-122 Molecular Tools for Biological and Chemical Studies or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II *	10

21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
03-121	Modern Biology	9
or 33-121	Physics I for Science Students	
or 15-110	Principles of Computing	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	5
		43

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences and Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year	9
03-220	Genetics or other biological chemistry elective.	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		50

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-204	Professional Communication Skills in Chemistry (It is recommended that this course be completed prior to taking the junior level lab, 09-323.)	3
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
03-232	Biochemistry I	9
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		45

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year.	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring).	9
09-323	Bioorganic Chemistry Laboratory This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses.	12
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
09-331	Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
xx-xxx	Cultural/Global Understanding Requirement	9
38-302	Science and Society	4
xx-xxx	Approved PROPEL elective	2-9
		46-53

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Biological Chemistry Elective 1 (see notes on electives)	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
38-110	ENGAGE in Service	1
38-430	ENGAGE in Wellness: Looking Forward	1
38-220	ENGAGE in the Arts	2
xx-xxx	Free Electives	21
		44

Spring		Units
09-402	Undergraduate Seminar VI	3
09-348	Inorganic Chemistry	10
xx-xxx	Biological Chemistry Elective 2	9
xx-xxx	Biological Chemistry Elective 3	9
xx-xxx	Free Electives	18
		49

Distribution of Units

Minimum Total Chemistry Units 190; See distribution below

Required Chemistry Courses*		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-204	Professional Communication Skills in Chemistry	3
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-323	Bioorganic Chemistry Laboratory	12
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12

09-xxx	Chemistry Seminars	8
09-xxx	Biological Chemistry Electives	27

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS degrees that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Modern Biology	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understandling	**9**
EUREKA! (First Year Seminar)	**6**
MCS Junior Seminar	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**35**
Minimum number of units required for the degree:	**360**

The above B.S. curriculum recommends a range of 41–50 units/semester to meet the minimum degree requirement. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

NOTES ON ELECTIVES

Biological Chemistry Electives

A minimum of three biological chemistry electives for a total of 27 units or more is required.

A list of currently approved electives is provided below. Of the three elective courses at least two should be chemistry courses and a maximum of one can be taken in biology or physics. Exceptions can be granted by the Director of Undergraduate Studies. One semester of 09-445 for 9 units may be used for one biological chemistry elective with the approval of the Director of Undergraduate Studies. It must be part of a longer term experience ensuring depth of knowledge in the area.

09-403	Chemistry of Addiction	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates (One of these two courses is required for the degree. The other can be used as a Biological Chemistry elective.)	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-705	Chemosensors and Biosensors	12
09-521	Metals in Biology: Function and Reactivity	6
09-716	Bioactive Natural Products	12
09-737	Medicinal Chemistry and Drug Development	12
09-803	Chemistry of Gene Expression	12
03-220	Genetics	9
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-320	Cell Biology	9
03-344	Experimental Biochemistry	12
03-362	Cellular Neuroscience	9
03-366	Biochemistry of the Brain	9
03-390	Molecular and Cellular Immunology	9
03-391	Microbiology	9
03-439	Introduction to Biophysics	9
03-442	Molecular Biology	9
03-534	Biological Imaging and Fluorescence Spectroscopy	9
03-740	Advanced Biochemistry	12
03-871	Structural Biophysics	12
33-441	Introduction to BioPhysics	10

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Options for the Bachelor's Degrees in Chemistry

The curriculum for the degree Bachelor of Science in Chemistry permits students to take a number of elective courses in chemistry and other fields, particularly in the junior and senior years. Students may wish to complete a group of elective courses from several specialty areas, called “options,” to complement their technical education. Each option will complement the Bachelor's degree in Chemistry and will provide students with expertise in a specific area not covered by the normal undergraduate curriculum. Options are noted on the student's transcript but not on the diploma.

For each of the following options, the student should refer to the previous description of the curriculum for the B.S.or B.A. degrees in chemistry. Required courses are unchanged, and the courses that should be taken as electives for each option are listed below. Chemistry courses within an option also count towards fulfillment of the chemistry elective requirement for the B.S. degree.

A student who completes the recommended courses for any of these options will receive a certificate from the Department of Chemistry at Commencement as formal evidence of the accomplishment and a notation of this will be made on the student's transcript.

BIOCHEMISTRY OPTION		Units
03-231/232	Honors Biochemistry (or Biochemistry)	9
03-330	Genetics	9
03-344	Experimental Biochemistry	12
xx-xxx	Elective in Biochemistry	
Elective course may be chosen from the following list. (Other courses listed as electives for the Biological Chemistry Track may be possible with permission.)		
03-439	Introduction to Biophysics	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	9
03-740	Advanced Biochemistry	12

POLYMER SCIENCE OPTION		Units
06-466	Experimental Polymer Science	9
09-502	Organic Chemistry of Polymers	9
09-509	Physical Chemistry of Macromolecules	9
09-xxx	Elective in Polymer Science	9
Elective course may be chosen from the following list		
09-445	Undergraduate Research (in a polymer area as approved by the Director of Undergraduate Studies and generally part of a longer term project)	9
09-736	Transition Metal Catalysis for Organic and Polymer Synthesis	12
09-760	The Molecular Basis of Polymer Mechanics	12
27-324	Introduction to Polymer Science and Engineering	9

Other upper level courses in chemistry, biomedical engineering, materials science engineering or the colloids, polymers and surfaces program may be used with permission of the Director of Undergraduate Studies		

COLLOIDS, POLYMERS and SURFACES OPTION (offered jointly with the Department of Chemical Engineering)		Units
06-426	Experimental Colloid Surface Science	9
06-466	Experimental Polymer Science	9
09-509	Physical Chemistry of Macromolecules	9
06-607	Physical Chemistry of Colloids and Surfaces	9

MATERIALS CHEMISTRY OPTION		Units
27-100	Engineering the Materials of the Future	12
27-201	Structure of Materials	9
Two Elective Courses of at least 9 units each from the list below		
27-202	Defects in Materials	9
09-445	Undergraduate Research (in a materials area as approved by the Director of Undergraduate Studies and generally part of a longer term project)	9
09-502	Organic Chemistry of Polymers	9
09-507	Nanoparticles	9
09-509	Physical Chemistry of Macromolecules	9
27-xxx	MSE course approved by Director of Undergraduate Studies	

ENVIRONMENTAL CHEMISTRY OPTION		Units
09-510	Chemistry and Sustainability	9
09-445	Undergraduate Research 9 units of 09-445 can count towards this option if part of a longer term immersion and approved by the Director of Undergraduate Studies	Var.
Two elective courses of at least 9 units each from the list below		
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
09-529	Introduction to Sustainable Energy Science	9
19-424	Energy and the Environment	9
19-440	Combustion and Air Pollution Control	9
19-653	Climate Change Mitigation	12
12-651	Air Quality Engineering	9
12-657	Water Resource Systems Engineering	9
12-702	Fundamentals of Water Quality Engineering	12

MANAGEMENT OPTION		Units
70-100	Global Business	9
73-102	Principles of Microeconomics	9
70-122	Introduction to Accounting	9
70-364	Business Law	9

COMPUTATIONAL CHEMISTRY OPTION		Units
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	10
or 15-150	Principles of Functional Programming	
09-560	Computational Chemistry	12
21-127	Concepts of Mathematics	10
xx-xxx	One Upper Level Computational Elective Course from the list below	
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-214	Principles of Software Construction: Objects, Design, and Concurrency	12
33-241	Introduction to Computational Physics	9
03-250	Introduction to Computational Biology	12
09-701	Quantum Chemistry I	12
09-702	Statistical Mechanics and Dynamics	12

B.S. in Chemistry with Departmental Honors

Outstanding students with an interest in research are encouraged to consider the Honors program by the beginning of the junior year. The program combines a slightly modified B.S. curriculum with close faculty-student contact in an individual research project, concluding with the student's presentation and defense of a Bachelor's degree honors thesis to a Thesis Committee.

The B.S. in Chemistry with Departmental Honors curriculum follows the general sequence of courses that is listed for the B.S. degree. The honors program specifies that one of the two chemistry electives be a 12-unit graduate course, numbered 09-7xx or higher, and that of the remaining electives required, at least two be undergraduate research (18 units) and one be 09-455 Honors Thesis (taken for 6 units). Students will be encouraged to do more than the minimum amount of research, so stipends from the research advisor or other sources are sometimes available for summer B.S. honors research.

At any time before the spring term of the senior year, candidates for the B.S. in chemistry may apply to be admitted for candidacy to the Honors B.S. program. Applications are available on the department Canvas site for chemistry majors. To be accepted, students will be expected to have shown excellent performance in class work – normally at least a 3.2 average QPA. Upon acceptance into the program, a Thesis Committee must be identified, which will monitor the progress of the student. The committee shall consist of at least one member of the Undergraduate Program Committee Committee to be appointed by the Director of Undergraduate Studies, the student's research advisor and a third faculty member agreed upon by the student and advisor. This third member can be from another department or institution and can be tenure track, teaching track or research track faculty. It is the student's responsibility to contact the proposed third member of their committee and confirm their participation.

A written thesis suitable for an Honors B.S. degree is required and should be a clear exposition in proper scientific format of a research project done for at least 18 units of credit in 09-445 Undergraduate Research. The thesis should describe a substantive new contribution to a particular field of research. This could include, but is not limited to, the discovery of a new phenomenon, studies that enhance our understanding of a previously reported phenomenon, or the development of a new method or technique. The student's Thesis Committee will evaluate the thesis and will require that each student participate in a public oral presentation or defense of the thesis before it approves the Honors degree. The written thesis must be supplied to the members of the student's Thesis Committee no later than 1 week prior to the scheduled public defense. The defense is usually scheduled to take place during April or early May of the senior year and the Director of Undergraduate Studies will coordinate the selection of a suitable date. Students completing the B.S. with Departmental Honors in Chemistry will receive MCS College Honors as well.

The designations of MCS College Honors and Departmental Honors are noted on the transcript but not on the diploma. Only University Honors are noted on the diploma.

Honors B.S./M.S. Program in Chemistry

Outstanding students seeking an advanced degree are encouraged to apply for admission to the B.S./M.S. Honors program as early as they can but only after having made some progress on a research project that could eventually be suitable for production of a Master's level thesis. Please note that this degree is available only with the B.S. in chemistry and cannot be obtained by students pursuing a B.A. degree in chemistry. Typically, applications are submitted during the second half of the sophomore year but no later than the first semester of the junior year. Applications are available on the Canvas site for undergraduate chemistry majors. Participants will have the opportunity to earn in four years not only the degree B.S. in Chemistry with Departmental Honors, but also the degree Master of Science in Chemistry. This program is highly research intensive and is not appropriate for all students. Requirements include completing five graduate level courses as electives. (See notes on Honors B.S./M.S. electives.)

The schedule of courses for the B.S./M.S. program generally moves as many courses as possible forward in the curriculum, though this is not a requirement. When possible, all technical core requirements should be completed in the freshman year. This gives the student the following advantages: 1) greater perspective in selection of a research advisor, 2) greater maturity in performing independent research, and 3) the possibility of initiating the graduate course sequence in the junior year. Students can achieve this accelerated schedule through advanced placement or summer school though neither is a requirement.

A completed application and degree contract finished in collaboration with their thesis advisor must be submitted to the Director of Undergraduate Studies who will then arrange for an application meeting with the student, research advisor and the department Undergraduate Program Committee. (Both forms are available on the Canvas site for undergraduate chemistry majors.) At this meeting the student is expected to give an oral presentation with visual aids that presents relevant background, a summary of work completed to date and a detailed plan for their thesis project including a projected timeline for completion of the thesis research and the thesis itself.

Upon acceptance into the program, a Thesis Committee must be identified, which will monitor the progress of the student. The committee shall consist of at least one member of the Undergraduate Program Committee appointed by the Director of Undergraduate Studies, the student's research advisor and a third faculty member agreed upon by the student and advisor. This third member can be from another department or institution and can be tenure track, teaching track or research track faculty. It is the student's responsibility to contact the third member of their committee, confirm their participation and notify the Director of Undergraduate Studies.

The student is expected to keep the research advisor selected for the duration of the thesis project. Summer thesis research for 10 weeks in each summer following the sophomore and junior years is strongly suggested to assist the student in completing research of sufficient quantity and quality to complete their thesis. Students normally will be given stipends for their summer work either by their research advisor or by competing for a summer fellowship such as a Summer Undergraduate Research Fellowship available through the Undergraduate Research Office. A minimum of 3 semesters of undergraduate research is required (normally 10 units/semester), though this is rarely sufficient as the sole research experience, as is participation in group seminars during the junior and senior years. Students must present their research at least once at the Sigma Xi competition at Meeting of the Minds, the annual Carnegie Mellon undergraduate research symposium, typically at the end of the junior year. In addition students must meet with their Thesis Committee at minimum each fall, though additional meetings may be required by the Thesis Committee, to update the committee on their progress and in the fall of the senior year must prepare a written summary of their research progress to date (5 pages) and their plans for the academic year (1 page). This report must state clearly what stage the work is in; it must be clear what work is complete and ready for publication.

By the end of the penultimate semester (normally fall of the senior year) the student should complete a thorough literature review to begin preparation for the introduction of their thesis.

At the start of the spring semester of the senior year (or their final semester if different), the student must submit a draft of the introduction for their thesis and a detailed outline of their methods, results and discussion sections to the Director of Undergraduate Studies who also chairs the Honors Committee. This will be distributed by the department and reviewed by the student's Thesis Committee.

Each student is required to submit a formal Masters Degree dissertation to the Chemistry Department in April of the senior year or at least one week prior to the date set for the thesis defense. The thesis usually has an abstract, introduction, methods, results, discussion and conclusion sections with acknowledgements. The Thesis Committee will evaluate the written thesis and the student is required to present their final oral defense of the project before the Thesis Committee. The defense is usually scheduled to take place during April or early May of the senior year and the Director of Undergraduate Studies will coordinate the selection of a suitable date. The public defense is followed by a private question and answer session with the Thesis Committee.

The dissertation, written in proper scientific format, should describe the research project in considerable detail and must withstand the scrutiny of the Thesis Committee with respect to completeness. It need not be as extensive nor contain the element of student originality characteristic of a Ph.D. thesis; however it must contain results and conclusions that are of a high enough quality to be accepted as a publication in a respected research journal, though publication of the work is not a requirement of the degree program. The student should refer to the ACS Style Guide for recommendations on appropriate presentation and formatting of written text, tables, graphs, and figures. As for all M.S. degree candidates in the Department, the dissertation must be approved first by the faculty member in charge of the work.

Research productivity is the most important criterion for success at the evaluation points, but QPA is a strong secondary criterion. While we expect that most students will maintain a QPA of 3.5, a minimum of 3.2 must be maintained to remain in the program and will be acceptable only with a strong record of research. Candidates must also maintain a QPA of at least 3.0 in the five graduate level courses required for the degree.

Students who complete this program will receive the designations of Departmental Honors and MCS College Honors. These are designated on the transcript, not on the diploma. Only University Honors are denoted on the diploma.

Students completing the requirements for this degree receive two diplomas, one for the B.S. degree and another for the M.S. degree. Since this is a combined degree program both degrees are awarded at the same time; the awarding of the two degrees cannot be separated in time.

Failure to make progress in research or coursework of sufficient quality and quantity in a timely fashion can result in a student being removed from this degree program (removal of the M.S. degree from their record). The decision will be made by the thesis committee and the Director of Undergraduate Studies. Violations of professional ethical standards can also result in a student's removal from the program.

Notes on Honors B.S./M.S. Electives

The B.S./M.S. Honors degree requires the completion of five graduate level courses. Graduate courses in chemistry are typically those numbered 09-7xx or 09-8xx. Courses numbered 09-6xx are generally remedial graduate level courses and not acceptable towards the degree requirements as the content overlaps extensively with required chemistry courses at the undergraduate level. Graduate classes in chemistry are normally 12-unit courses (or two six unit minis numbered 09-7xx or 09-8xx counting as one graduate level course). However, in order not to penalize interdisciplinary studies which may be essential to a good thesis, up to three of the five required graduate chemistry courses may be at the advanced undergraduate level (the 9 unit 09-5xx versions). All advanced undergraduate level courses used to satisfy this requirement must be approved by the Director of Undergraduate Studies. Students must earn a grade of C or better in each of the five graduate or upper level undergraduate courses fulfilling the requirements for this degree and also in 09-455, Honors Thesis. In addition students must earn a minimum of a 3.0 average in these six courses in order to fulfill their degree requirements.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2019. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses: 33-121 Physics I for Science Students, 33-122 Physics II for Biological Sciences and Chemistry Students, either 03-121 Modern Biology **or** 03-231 Honors Biochemistry **or** 03-232 Biochemistry I, 15-110 Principles of Computing (or other approved programming course), 21-120 Differential and Integral Calculus and 21-122 Integration and Approximation **or** 21-124 Calculus II for Biologists and Chemists. Students should complete this technical core as early as possible and preferably by the end of their fifth semester.

Students should complete this technical core as early as possible and preferably by the end of their fifth semester.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), ENGAGE in Service (38-110, 1 units), ENGAGE in the Arts (38-220, 2 units), EUREKA!: Discovery and Its Impact (38-101, 6 units), the MCS first-year seminar, and the junior seminar PROPEL or a total of 72 units. The junior seminar requirement (PROPEL) for MCS Is fulfilled by taking the required Science and Society (38-302, 4 units) and a second approved course. Approved as of the publication of this catalog is Professional Development and Life Skills (38-303, 2 units). A more expanded listing will be published by the MCS Dean's Office. For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

First Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10

33-121	Physics I for Science Students	12
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

02-201 Programming for Scientists is an acceptable alternative to 15-110 for chemistry majors as are any upper level courses in programming.

There are some elective laboratory courses offered for MCS students in the first year. These include03-117 Frontiers, Analysis, and Discovery in Biological Sciences and 09-122 Molecular Tools for Biological and Chemical Studies. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take 03-121 Modern Biology so that their unit total is lower and they get a start on their required biology courses.

Spring		Units
09-106	Modern Chemistry II Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective or inquire with the Director of Undergraduate Studies about a suitable research placement.	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
15-110	Principles of Computing	10
or 33-121	Physics I for Science Students	
or 03-121	Modern Biology	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9
		48

Sophomore Year

Fall		Units
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-201	Undergraduate Seminar I	1
33-122	Physics II for Biological Sciences and Chemistry Students This course is a prerequisite for 09-331, normally taken in the spring of the junior year.	9
09-445	Undergraduate Research	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		50

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-204	Professional Communication Skills in Chemistry	3
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-220	Modern Organic Chemistry II	10
09-348	Inorganic Chemistry	10
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		46

Summer

10 weeks Honors Research recommended

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists	9
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-445	Undergraduate Research	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		50

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-445	Undergraduate Research	6
09-xxx	Graduate Chemistry Course 1 of 5 (see notes on Honors B.S./M.S. electives)	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-331	Modern Analytical Instrumentation	9
38-301	PROPEL	6
		52

Summer

10 weeks Honors Research recommended

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-445	Undergraduate Research	9
09-xxx	Graduate Chemistry Course 2 of 5	12
09-xxx	Graduate Chemistry Course 3 of 5	12
xx-xxx	Cultural/Global Understanding	9
38-430	ENGAGE in Wellness: Looking Forward	1
38-110	ENGAGE in Service	1
		45

Spring		Units
09-402	Undergraduate Seminar VI	3
09-455	Honors Thesis	15
09-xxx	Graduate Chemistry Course 4 of 5	9
09-xxx	Graduate Chemistry Course 5 of 5	9
38-220	ENGAGE in the Arts	2
xx-xxx	Free Elective	9
		47

Distribution of Units

Minimum Total Chemistry Units (241, See distribution below)

Required Chemistry Courses		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-204	Professional Communication Skills in Chemistry	3
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
		30
09-445	Undergraduate Research (in addition 2 summers recommended)	30
09-xxx	Graduate chemistry courses (see Notes on B.S./M.S. Electives)	51-60
09-455	Honors Thesis	15

Students who transfer into the department and have taken 09-217 Organic Chemistry I, and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS/MS degree that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Biology	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (first year seminar)	**6**
MCS Junior Seminar	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**3-12**
Minimum number of units required for degrees:	**388**

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Minor in Chemistry

In order for a student to receive a minor in Chemistry in conjunction with a B.S. or B.A. degree from another (primary) department, the successful completion of six courses as distributed below is required. Students pursuing the minor must inform the Chemistry Department of their intentions in writing using the MCS form for declaration of a minor so that the minor designation can be approved prior to graduation. The form may be obtained from the MCS undergraduate webpage at www.cmu.edu/mcs/undergrad/advising/forms. **It should be completed and submitted to the department office, DH 1317, no later than the end of the course add period of the final semester prior to graduation.** If you decide at a later date not to complete the minor, it would be helpful to notify the Director of Undergraduate Studies, ks01@andrew.cmu.edu, so that it can be removed from your record. Minors are listed on the transcript but not on the diploma.

Note: An introductory chemistry class equivalent to either 09-105 Introduction to Modern Chemistry I or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications is a **presumed prerequisite** to beginning the minor in chemistry.

Course Requirements

A. Four Required Core Courses

09-106	Modern Chemistry II	10
09-221	Laboratory I: Introduction to Chemical Analysis	9-12
or 09-207	Techniques in Quantitative Analysis	
09-217	Organic Chemistry I	9-10
or 09-219	Modern Organic Chemistry	
Choice of one of the following courses:		
09-214	Physical Chemistry note that this course may not be offered every fall and is dependent upon sufficient enrollment	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-347	Advanced Physical Chemistry	12
09-348	Inorganic Chemistry	10

Courses in this group that are not used to satisfy Part A core courses may be used to satisfy elective course requirements in part B below, provided they are **not** required by the student's primary department. However the only combination of physical chemistry courses (09-344, 09-345, 09-347 and 09-214) that is allowed is 09-344 and 09-345.

Enrollment in 09-347 Advanced Physical Chemistry is only open to students majoring in chemical engineering. Students who take 09-347 may not use a second physical chemistry course as an elective.

B. Two Elective Courses from the following list.

09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
or 09-214	Physical Chemistry	
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-222	Laboratory II: Organic Synthesis and Analysis	9-12
or 09-208	Techniques for Organic Synthesis and Analysis	
09-218	Organic Chemistry II	9-10
or 09-220	Modern Organic Chemistry II	
03-231/232	Honors Biochemistry	9
09-xxx	Approved Upper Level Chemistry Course (must be 09-3xx or higher but see exclusions noted below)	

Courses in this section (part B above) can not be counted toward the minor if they are required **in any way** by the student's primary department or towards an additional major or minor other than as a free elective. For example, students majoring in Biological Sciences can not double count 03-231 (or 03-232), 09-208 (or 09-222), or 09-218 (or 09-220) toward the elective courses for the minor in chemistry. Chemical engineering majors can not count 03-231 (or 03-232) or a chemistry course that is used to satisfy that department's required chemistry or advanced chem/biochem elective. Also, chemical engineering majors can not use 09-344, 09-345 or 09-214 due to the similarity of these courses to 09-347 Advanced Physical Chemistry, which is required by the chemical engineering department.

09-231 Mathematical Methods for Chemists, does not count towards the minor in chemistry. The undergraduate research course 09-445 Undergraduate Research and 09-435 Independent Study Chemistry cannot be used for the minor.

Transfer credit will be accepted only for the prerequisite 09-105, 09-106 and 09-217. All other classes towards the chemistry minor must be completed at Carnegie Mellon University.

Transfer Credit for Chemistry Courses

1. Requests for transfer credit for chemistry classes taken at other institutions should be made to Karen Stump, the Director of Undergraduate Studies in the Department of Chemistry. Students making such requests should follow the policies and procedures in place within their home colleges in assembling materials for such requests. Consult with your advisor on the appropriate steps.
2. Requests should be placed before paying tuition for a class in case transfer credit is denied. Allow 1-2 weeks for approval.
3. At minimum requests must be accompanied by a complete syllabus including the textbook that will be used, a detailed list of topic areas and an indication of whether or not the course is part of the curriculum for science majors at the other institution. Check to ensure that the institution is on a semester system. Most school on a quarter system (many in the UC system of schools) teach general chemistry and organic chemistry over three quarters each; therefore one of these classes would not be equivalent to one CMU class.
4. No transfer credit will be awarded for the laboratory classes required for the chemistry or biology major at Carnegie Mellon University, 09-207, 09-221, 09-208, 09-222, 09-321, 09-323 and 09-322. Requests for transfer credit for 09-101, Introduction to Experimental Chemistry, will be accepted with the appropriate documentation.

5. In assessing the suitability of courses for transfer credit, the following factors are considered:
    - The rigor of the course must be comparable to that offered at Carnegie Mellon. This is usually assessed via the quality of the institution and its chemistry program, the textbook used and the amount of time spent on topic areas.
    - The topic areas should match to a degree of at least 80% those covered in the comparable course at Carnegie Mellon University.
6. 09-105 Introduction to Modern Chemistry I focuses primarily on structure and bonding. Detailed topics include the following:
    - History and Conceptual Basis of Modern Chemistry
    - Radiation, Quantum Mechanics, and Atomic Structure
    - Periodic Table and Trends in Elemental Properties (including discussion of exceptions to trends)
    - Bonding (bond polarity)
    - Lewis Structures (octet rule and exceptions; formal charge)
    - Resonance Structures
    - Molecular shapes
    - Molecular Polarity
    - Naming compounds
    - Interparticle (intermolecular) forces and comparing physical properties from them
    - Valence Bond (Localized Electron) and Molecular Orbital Theory
    - Determining number of moles and chemical formulas
    - Writing and balancing chemical equations (in particular completing combustion and double displacement reactions – including acid-base and precipitation reactions)
    - Stoichiometry – limiting reactant and percentage yield
    - Gases (mainly ideal) and stoichiometric applications involving them
    - Phase transitions
    - Solutions (determining concentrations, dilution problems, stoichiometric applications, application of solubility rules to determine if a precipitate forms)
    - Acid-base reactions, titrations and other stoichiometric applications of acid-base reactions
    - Oxidations Numbers and Redox Reactions/Titrations (including balancing redox reactions) and other stoichiometric applications of redox reactions
    - Colligative Properties; Mixtures and Distillation
    - Transition Metal Complexes and Crystal Field Theory (including crystal field stabilization energy and optical properties)
7. 09-106 Modern Chemistry II focuses primarily on thermodynamics, kinetics and equilibrium. Detailed topic areas include the following.
    - Thermochemistry and Thermodynamics (First, Second, and Third Laws, with gas expansion/compression applications, including reversible, adiabatic processes)
    - Internal energy, enthalpy, entropy, Gibbs Free energy, and determination of spontaneity
    - Kinetics : Determination of rate, order, rate laws (including application of pseudo-rate laws, application of integrated rate law to determine order, relationship between time and amount in a reaction, and half-life
    - Reaction mechanisms – applying fast equilibrium and steady-state approximations to determine rate law consistent with mechanism
    - Chemical Equilibrium : determination of Q and K expressions, determination of direction in which reaction proceeds to achieve equilibrium (using Q and Le Chatelier's principles, quantitative calculations to determine K or amounts at various stages, dependence of K on temperature, relationship between Gibbs Free energy, Q, and K)
    - Acid-Base Equilibria: writing dissociation equilibrium reactions and acid-base "neutralization" reactions, autoionization of water (determination of pH and pOH, use of K_w), writing K_a and K_b expressions from dissociation equilibria, quantitative equilibrium calculations for weak acids and bases, titrations between strong species, strong-weak species, and weak-weak species, buffers (calculations of pH and amounts, including how to make a buffer), polyprotic species (quantitative applications and titrations), solubility and precipitation equilibria, determination of K_{sp} expressions and quantitative applications of those expressions, complex ion formation equilibria, emphasis is placed on equilibrium problems that involve multiple types of simultaneous equilibria
    - Electrochemistry: Electrochemical cell notation and writing half-reactions from it, Faraday constant to connect number of moles of electrons / reaction amounts with current, connection of Gibbs Free Energy to cell voltage (potential) at equilibrium and non-equilibrium conditions, determination of *K*'s (acid-base, solubility constants) or amounts using Nernst equation in concentration cells (*K* for cell reaction)

Academic Advising

"*I loved the tight-knit community within the Chemistry department, where I was able to go to my advisor's house for dinner, befriend many other Chemistry majors and flex my acting skills (for the first time) through the annual departmental murder mystery.*" *~ 2018 Chemistry B.S.*

Building meaningful relationships related to your personal, academic and professional development should be a key component of your undergraduate experience. In the Department of Chemistry we believe that strong academic advising is key in facilitating this process. The Director of Undergraduate Studies is a Teaching Professor of Chemistry who acts as the academic advisor for all students with majors, additional majors and minors in chemistry. MCS students transition from their first year advisors in the Dean's Office to their department advisor once they declare their majors, generally in the spring of their first year.

In the Department of Chemistry we are committed to the MCS philosophy that holistic advising with attention to the development of the whole person in all dimensions is key to success at CMU. Your academic advisor is certainly available for the more transactional processes such as developing a course schedule that allows you to make appropriate progress towards your degree. However more importantly she is also available to both be a resource and to point you towards additional connections to enable success in all aspects of your experience. You are encouraged to connect with your advisor early and build this relationship through scheduled and impromptu visits and e-mail, social events throughout the year as well as in the classroom. You will engage with your advisor in classes and seminars throughout your time as a major, facilitating a strong working relationship that will promote discussions of your successes, challenges and areas related to your health and well-being.

"*I loved how supportive the faculty were. They were very responsive when I had questions and they helped me discover what I'm passionate about.*" *~ 2018 Chemistry B.S.*

In the Department of Chemistry most students find additional faculty mentors in small, personalized classroom experiences but even more significantly through undergraduate research where participation generally exceeds 95% in any given graduating class.

Faculty

ASHOK AJOY, Assistant Professor of Chemistry – Ph.D., University of California at Berkeley; Carnegie Mellon, 2020–

WILLIAM ALBA, Associate Teaching Professor of Chemistry and Director of the Advanced Placement/Early Admission Program and Assistant Dean for Diversity of Mellon College of Science – Ph.D., University of California at Berkeley; Carnegie Mellon, 2005–

BRUCE A. ARMITAGE, Professor of Chemistry, Co-Director Center for Nucleic Acids Science and Technology – Ph.D., University of Arizona; Carnegie Mellon, 1997–

RAVICHANDRA BACHU, Assistant Teaching Professor of Chemistry at Carnegie Mellon University-Qatar – Ph.D., Hunter College and The Graduate Center, CUNY; Carnegie Mellon, 2015–

STEFAN BERNHARD, Professor of Chemistry – Ph.D., University of Fribourg (Switzerland); Carnegie Mellon, 2009–

MARK E. BIER, Research Professor of Chemistry and Director of the Center for Molecular Analysis – Ph.D., Purdue University; Carnegie Mellon, 1996–

EMILE BOMINAAR, Associate Research Professor of Chemistry – Ph.D., University of Amsterdam (The Netherlands); Carnegie Mellon, 1994–

MARCEL P. BRUCHEZ, Professor of Biological Sciences and Chemistry, Director, Molecular Biosensor and Imaging Center – Ph.D., University of California, Berkeley; Carnegie Mellon, 2006–

TERRENCE J. COLLINS, Teresa Heinz Professor in Green Chemistry and Director of the Institute for Green Science – Ph.D., University Auckland, (New Zealand); Carnegie Mellon, 1988–

SUBHA R. DAS, Associate Professor of Chemistry – Ph.D., Auburn University; Carnegie Mellon, 2006–

NEIL M. DONAHUE, Thomas Lord University Professor of Chemistry, Professor of Chemical Engineering and Engineering and Public Policy and Director of the Steinbrenner Institute for Environmental Education and Research – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000–

SIMON FAULKNER, Assistant Teaching Professor of Chemistry at Carnegie Mellon University- Qatar – Ph.D., University College London (United Kingdom); Carnegie Mellon, 2019–

REBECCA FREELAND, Associate Head, Department of Chemistry – Ph.D., Carnegie Mellon; Carnegie Mellon, 1993–

ROBERTO GIL, Research Professor of Chemistry and Director of the NMR Facility – Ph.D., Córdoba National University (Argentina); Carnegie Mellon, 2002–

SUSAN T. GRAUL, Associate Teaching Professor of Chemistry – Ph.D., Purdue University; Carnegie Mellon, 1992–

YISONG (ALEX) GUO, Assistant Professor of Chemistry – Ph.D., University of California at Davis; Carnegie Mellon, 2014–

MICHAEL P. HENDRICH, Professor of Chemistry – Ph.D., University of Illinois; Carnegie Mellon, 1994–

OLEXANDR ISAYEV, Assistant Professor of Chemistry – Ph.D., Jackson State University; Carnegie Mellon, 2020–

RONGCHAO JIN, Professor of Chemistry – Ph.D., Northwestern University; Carnegie Mellon, 2006–

ANNA KIETRYS, Assistant Professor of Chemistry – Ph.D., Polish Academy of Sciences; Carnegie Mellon, 2020–

HYUNG J. KIM, Professor of Chemistry – Ph.D., State University of New York at Stony Brook; Carnegie Mellon, 1992–

TOMASZ KOWALEWSKI, Professor of Chemistry – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 2000–

MARIA KURNIKOVA, Associate Professor of Chemistry – Ph.D., University of Pittsburgh; Carnegie Mellon, 2003–

DANITH LY, Professor of Chemistry – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2001–

KRZYSZTOF MATYJASZEWSKI, J.C. Warner University Professor of Natural Sciences and Co-Director of the Center for Polymer-Based Protein Engineering and Director of the Center for Macromolecular Engineering – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 1985–

KEVIN NOONAN, Associate Professor of Chemistry – Ph.D., University of British Columbia (Canada); Carnegie Mellon, 2011–

LINDA A. PETEANU, Professor and Head Department of Chemistry – Ph.D., University of Chicago; Carnegie Mellon, 1992–

GIZELLE SHERWOOD, Assistant Teaching Professor – Ph.D. , Carnegie Mellon University; Carnegie Mellon, 2009–

GLORIA SILVA, Associate Teaching Professor of Chemistry – Ph.D., Universidad Nacional de Córdoba (Argentina); Carnegie Mellon, 2002–

KAREN H. STUMP, Teaching Professor of Chemistry and Director of Undergraduate Studies and Laboratories – M.S., Carnegie Mellon University; Carnegie Mellon, 1983–

RYAN SULLIVAN, Associate Professor of Chemistry and Mechanical Engineering and Associate Director of the Institute of Green Science – Ph.D., University of California at San Diego; Carnegie Mellon, 2012–

STEFANIE SYDLIK, Assistant Professor of Chemistry – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2015–

LEONARD VUOCOLO, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

NEWELL WASHBURN, Associate Professor of Chemistry and Biomedical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

DAVID YARON, Professor of Chemistry – Ph.D., Harvard University; Carnegie Mellon, 1992–

Emeriti

GUY C. BERRY, University Professor Emeritus of Chemistry and Polymer Science – Ph.D., University of Michigan; Carnegie Mellon, 1960–

ALBERT A. CARETTO JR., Professor Emeritus of Chemistry – Ph.D., University of Rochester; Carnegie Mellon, 1959–

JOSEF DADOK, Professor Emeritus of Chemical Instrumentation – Ph.D., Czechoslovak Academy of Sciences; Carnegie Mellon, 1967–

PAUL J. KAROL, Professor Emeritus of Chemistry – Ph.D., Columbia University; Carnegie Mellon, 1969–

MIGUEL LLINAS, Professor Emeritus of Chemistry – Ph.D., University of California at Berkeley; Carnegie Mellon, 1976–

ECKARD MÜNCK, Professor Emeritus of Chemistry – Ph.D., Technical University of Darmstadt (Germany); Carnegie Mellon, 1990–

GARY D. PATTERSON, Professor Emeritus of Chemistry – Ph.D., Stanford University; Carnegie Mellon, 1984-.–

STUART W. STALEY, Professor Emeritus of Chemistry – Ph.D., Yale University; Carnegie Mellon, 1986–

CHARLES H. VAN DYKE, Associate Professor Emeritus of Chemistry – Ph.D., University of Pennsylvania; Carnegie Mellon, 1963–

Adjunct Faculty

CATALINA ACHIM, NSF Program Director and Adjunct Professor of Chemistry – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2001–

BERNARD CRIMMINS, Adjunct Associate Professor of Chemistry and Associate Professor, Department of Civil Engineering, Clarkson University and President of Academic Environmental/Analytical Consulting Services (AEACS), LLC. – Ph.D., University of Maryland; Carnegie Mellon, 2018–

JOHN PETERSON MYERS, CEO and Chief Scientist of Environmental Health Sciences – Ph.D., University of California at Berkeley; Carnegie Mellon, 2010–

JAMES PETERSON, Adjunct Associate Professor of Chemistry and Associate Professor of Environmental and Occupational Health at the University of Pittsburgh – Ph.D., University of Essex, UK; Carnegie Mellon, 2004–

Courtesy

MICHAEL BOCKSTALLER, Professor of Materials Science Engineering and Faculty of Chemistry – Ph.D., Johannes Gutenberg University (Germany); Carnegie Mellon, 2005–

ALEX EVILEVITCH, Associate Professor of Physics and Faculty of Chemistry – Ph.D., Lund University; Carnegie Mellon, 2009–

ANDREW GELLMAN, Thomas Lord Professor of Chemical Engineering, Faculty of Materials Science Engineering and Chemistry; Co-Director W.E. Scott Institute for Energy Innovation – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

NOA MAROM, Assistant Professor of Materials Science Engineering and Faculty of Chemistry – Ph.D., Weizmann Institute of Science (Israel); Carnegie Mellon, 2016–

GORDON RULE, Professor of Biological Sciences and Head of CMU Qatar Biological Sciences Program and Faculty of Chemistry – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1995–

JAMES SCHNEIDER, Professor of Chemical Engineering and Faculty of Biomedical Engineering and Chemistry – Ph.D., University of Minnesota; Carnegie Mellon, 1999–

ALAN S. WAGGONER, Maxwell H. & Gloria C. Connan Professor of Life Sciences, Faculty of Biomedical Engineering and Chemistry – Ph.D., University of Oregon; Carnegie Mellon, 1982–

LYNN WALKER, Professor of Chemical Engineering and Faculty of Chemistry and Materials Science Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1997–

JOHN L. WOOLFORD JR., Professor of Biological Sciences; Co-Director of CNAST and Faculty of Chemistry – Ph.D., Duke University; Carnegie Mellon, 1979–

Department of Chemistry Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

09-101 Introduction to Experimental Chemistry
Summer: 3 units
This is a seven week chemistry laboratory course that is designed to introduce students to some basic laboratory skills, techniques, and equipment commonly used in experimental chemical investigations. The experiments will apply concepts in organic synthesis, quantitative analysis using visible spectrophotometry, kinetics, acid-base chemistry, thermochemistry, transition metal chemistry, chromatography, and protein biochemistry. 1 hr. lec., 3 hrs. lab.

09-103 Atoms, Molecules and Chemical Change
Fall: 9 units
This is a one-semester introductory college level course designed for non-science and engineering majors who have had a high school course in chemistry. Students with primary or additional majors in MCS, CIT or SCS will not be allowed to enroll. Chemistry topics will be introduced on an as needed basis in the contexts of air pollution, the ozone layer, global warming, acid rain, safe drinking water, alternative energy sources, plastics, and drug design. Students will apply concepts in topics such as the classification of matter, the relationship between matter and energy, atomic theory and the Periodic Table, chemical bonding, molecular shapes, molecular polarity, interparticle forces, chemical reactions, stoichiometry, properties of aqueous solutions, acid-base chemistry, redox chemistry, and organic chemistry. Students will gain an understanding of how chemistry impacts major environmental, social, political, and economic issues that we encounter daily. They will also learn to apply chemical concepts to new situations or contexts. Students with credit for 09-105 or more advanced chemistry courses will not be allowed to enroll in this course. 3 hrs. lec., 1 hr. rec.

09-105 Introduction to Modern Chemistry I
Fall and Spring: 10 units
This course begins with a very brief survey of some fundamental principles of chemistry and a presentation of chemically interesting applications and sophisticated problems. These will form the basis for introducing the relationships between the structure of molecules and their chemical properties and behavior. The subject matter will include principles of atomic structure, chemical bonding, intermolecular interactions and molecular structures of organic and inorganic compounds including some transition metal complexes. Relevant examples will be drawn from such areas as environmental, materials, and biological chemistry. 3 hrs. lec, 2 hrs. rec.

09-106 Modern Chemistry II
Fall and Spring: 10 units
This course provides an overview of thermodynamics, kinetics and chemical equilibrium. Topics include the flow of energy in chemical systems; the spontaneity of chemical processes, i.e. entropy and free energy; the mechanisms and rates of chemical reactions; and the use of chemical equilibrium to reason about acid-base chemistry, solubility and electrochemistry. Applications include the energy economy, biological systems and environmental chemistry. 3 hrs. lec., 2 hrs. rec.
Prerequisites: 09-107 or 09-105

09-107 Honors Chemistry: Fundamentals, Concepts and Applications
Fall: 10 units
This is an honors introductory course designed to provide students with a rigorous coverage of general chemistry in the context of grand challenges in the field. Traditional topics, such as equilibrium, kinetics, acid-base chemistry, and quantum chemistry, will be discussed through current research on nucleic acid-based therapeutics, atmospheric chemistry of pollutants, and catalysts for the production of solar fuels. The approach will integrate traditional lectures and readings from the textbook with discussions of journal articles, on-line content on research methods, and guest lectures from CMU faculty in these areas. This course assumes strong preparation in chemistry (AP Chemistry score of 3 or greater; IB Chemistry score of 5 or greater; SAT II Chemistry exam with a score of 700 or greater) and will be offered at an accelerated pace. The goal is to teach core principles of chemistry while exposing students to the diversity of modern chemical research and how it is addressing grand challenges facing society. 3 hrs. lec., 2 hrs. rec.

09-108 The Illusion and Magic of Food
Fall: 6 units
Have you ever wondered how your morning orange juice when squeezed fresh from the fruit spoils after few hours while the one from the market lasts much longer without apparent alteration? How is that ground meat looks so red on the outside and unpleasantly brown in the inside? What is the nutritional value of milk and honey? Want to know how fruit flies helped to discover ways to make better-smelling beer? Why is wine normally stored in a dark glass bottle? These and many more questions will be answered in this course, not only by the instructor but also through the students research and curiosity. This course will introduce chemistry concepts on an as-needed basis but it will remain at the level of high school chemistry. We expect to help the student understand what food is made of, its nutritional value, how it is processed to offer longer shelf life, and how this may affect critical components. The topics will vary depending of the students motivation in learning about different concepts related to the food industry, from processing to analysis to packaging and appearance, we plan to discuss interesting things in every class and finish the course with a broad knowledge of what is on our table and better criteria to select our food. 3 hrs. lec.

09-109 Kitchen Chemistry Sessions
Intermittent: 3 units
Ever wanted to boil water in ice? Cook an egg so the yolk is set but the white still runny? Lick a lemon or drink vinegar but have it taste?sweet? Make "caviar" from fruit juice and noodles from yogurt? Explore the science of molecular gastronomy through the lectures and demonstrations that reveal the chemistry and biochemistry of food ingredients and their preparation. Then use a kitchen as your "laboratory" to test hypotheses and delve into molecular cooking - you may just get to eat your lab results. For this course high school background in chemistry would help but nothing more advanced is required. Concepts will be discussed on a need to know basis. Students with stronger chemistry backgrounds should enroll in 09-209. 3 hrs. lec. and lab

09-110 The Design and Making of Skin and Hair Products
Spring: 3 units
This hands-on course targets students from across the CMU community who are interested in learning how chemistry applies to their everyday life. We will focus on students gaining knowledge of the chemical components in cosmetics and on the methods for preparing them (from shampoos and conditioners to lotions, soaps and creams). We will emphasize good laboratory practices and safety in terms of the production of the cosmetic product as well as the fundamental chemical and physical concepts that govern the product behavior and use. The overarching goal is that the students have a hands-on laboratory experience and develop a full understanding of the science behind the products that they use every day. No human or animal testing will take place as part of the curriculum.

09-115 Introduction to Undergraduate Research in Chemistry
Fall: 2 units
Undergraduate research is an important activity in the training of undergraduate chemistry majors. This course is intended for students who are planning to declare a major in chemistry who are novices to research at the university level and have an interest in being better informed about strategies and skills that contribute to success. It is intended that this course will lead to an opportunity to participate in a series of shadowing opportunities through a second course in the spring semester where students will be mentored by upperclass students or PhD candidates in faculty laboratories. Spaces will be reserved for MCS students. Students from other colleges with a strong interest in a chemistry major or additional major should contact the Director of Undergraduate Studies in the Chemistry Department.

09-122 Molecular Tools for Biological and Chemical Studies
Spring: 6 units
The increased fluorescence of certain molecules, also known as dyes, can signal their binding to a specific biological target such as DNA. This phenomenon finds important application in the biological and medicinal field where dyes are used as molecular tools. For example, fluorescent dyes can be used to detect the expression of a gene; survival of cells; site of accumulation of a metabolite and many of them are used in diagnostics. This course is aimed at offering a hands-on laboratory experience in the interface of chemistry and biology, so called bioorganic chemistry. The student's project will be to prepare a dye, thiazole orange, that will show increased fluorescence upon binding DNA or a protein, thus, signaling the binding event. A dye designed to prevent DNA binding will be tested alongside to highlight how molecular design works. Molecular size and geometry are important elements in the design of molecules that specifically bind biological targets; 3D molecular modeling software (freeware) and hand-held models will be used to analyze how these factors play a role in target-dye interaction.

09-201 Undergraduate Seminar I
Fall: 1 unit
Issues and topics of importance to beginning chemistry majors are discussed in this course. It provides a general introduction to the facilities, faculty and programs of the Department of Chemistry and introduces students to career and research opportunities in the field of chemistry. Enrollment limited to students majoring in chemistry. 1 hr.

09-202 Undergraduate Seminar II: Safety and Environmental Issues for Chemists
Spring: 1 unit
Issues and topics focused on laboratory safety are discussed in this class. The topics are selected to supplement information covered in 09-221, Laboratory I. This course is intended to provide the necessary safety training for students wishing to undertake undergraduate research projects in the laboratory and is taught in collaboration with the Office of Environmental Health and Safety. Enrollment is limited to chemistry majors. 1 hr.

09-204 Professional Communication Skills in Chemistry
Spring: 3 units
This required course for chemistry majors promotes development of written and oral communication skills in various formats within the discipline. Students are expected to develop these skills by becoming more familiar with the style and format of the chemical literature, current topics in chemistry, and research projects in the Department. Other learning outcomes include developing critical reading skills, providing effective feedback to peers' written and oral communication, demonstrating the ability to revise written work, and using chemical structure drawing software. 1 hr. lec.
Prerequisite: 09-221

09-207 Techniques in Quantitative Analysis
Fall: 9 units
09-207 is the first of two chemistry lab courses required for the BS and BA degrees in biological sciences and the intercollege major in biological sciences and psychology. It is also suitable for fulfilling the requirement for two general chemistry labs for admission to programs in the health professions. The experimental work emphasizes the techniques of quantitative chemical analysis. Included are projects dealing with a variety of instrumental and wet chemical techniques. A mixture of individual and partner experiments concluding with one team experiment is conducted during the semester. In addition to laboratory techniques, safety, and written communication skills are emphasized.
Prerequisite: 09-106

09-208 Techniques for Organic Synthesis and Analysis
Intermittent: 9 units
09-208 is the second of two chemistry laboratory courses required for the BS in biological sciences and the intercollege major in psychology and biological sciences. It is also suitable for fulfilling the requirement for the laboratory experience for application to programs in the health professions. The course emphasizes experimental work in separations, synthesis, and analysis of organic compounds, including chromatography and spectroscopy. Written communication skills will be developed by means of laboratory reports and essays. 1 hr lec, 5 hrs lab
Prerequisites: (09-217 or 09-219) and (09-207 or 09-221)

09-209 Kitchen Chemistry Sessions
Intermittent: 3 units
Ever wanted to boil water in ice? Cook an egg so the yolk is set but the white still runny? Lick a lemon or drink vinegar but have it taste?sweet? Make "caviar" from fruit juice and noodles from yogurt? Explore the science of molecular gastronomy through the lectures and demonstrations that reveal the chemistry and biochemistry of food ingredients and their preparation. Then use a kitchen as your "laboratory" to test hypotheses and delve into molecular cooking - you may just get to eat your lab results. Students enrolling in this course are assumed to have a college level background in chemistry including introductory organic chemistry. Students without a solid chemistry background should take the lower level 09-109. 3 hrs. lec. and lab
Prerequisites: 09-217 or 09-219

09-214 Physical Chemistry
Spring: 9 units
This is a one-semester course intended primarily for students majoring in Biological Sciences, students pursuing a B.A. degree program in Chemistry, and students in the B.S.A.program with a concentration in chemistry. The course focuses on thermodynamics, transport and reaction rates and their application to chemical and biological systems. Emphasis is given to attaining a good fundamental understanding of entropy and free energy. This is more a concepts than skills building course. Topics include applications of thermodynamics to chemical and biochemical equilibria, electrochemistry, solutions, and chemical kinetics. 3 hrs. lec. Prerequisites: 09106 and 21122 and (33111 or 33106)
Prerequisites: 09-106 and (21-124 or 21-122) and (33-106 or 33-111 or 33-121 or 33-141)

09-215 Chemistry Tech I to Lab I Transition
Fall and Spring: 3 units
09-215 is a 3-unit course intended for students who have taken 09-207, Techniques in Quantitative Analysis, who decide later in their academic experience that they wish to pursue a degree or an additional major in chemistry. The chemistry major requires a 12-unit lab class, 09-221 Laboratory I: Introduction to Chemical Analysis. This course will utilize self-study and problem solving to introduce or reinforce key concepts covered in 09-221 that are not introduced or are de-emphasized in 09-207. Students will also propose an idea for an independent lab-based project and carry it through all stages of development but not perform the actual lab work. The project development will require written work products as well as an oral presentation. The course must be completed before the last semester of the students degree program.
Prerequisite: 09-207 Min. grade C

09-216 Chemistry Tech II to Lab II Transition
Fall: 3 units
09-216 is a 3-unit course intended for students who have taken 09-208, Techniques in Organic Synthesis and Analysis, who decide later in their academic experience that they wish to pursue a degree or an additional major in chemistry. The chemistry major requires a 12-unit lab class, 09-222 Laboratory II: Organic Synthesis and Analysis. This course will utilize self-study and problem solving to introduce or reinforce key concepts covered in 09-222 that are not introduced or are de-emphasized in 09-208.

09-217 Organic Chemistry I
Fall: 9 units
This course presents an overview of structure and bonding as it pertains to organic molecules. Selected topics include: introduction to functional group chemistry, stereochemistry, conformational analysis, reaction mechanisms and use of retrosynthetic analysis in the development of multistep syntheses. Methods for structure determination of organic compounds by modern spectroscopic techniques are introduced. 3 hrs. lec., 1 hr. rec.
Prerequisites: 09-107 or 09-105

09-218 Organic Chemistry II
Spring: 9 units
This course further develops many of the concepts introduced in Organic Chemistry I, 09-217. Emphasis is placed on the utilization of reaction mechanisms for understanding the outcome of chemical transformations, and the employment of a wide variety of functional groups and reaction types in the synthesis of organic molecules. Also included in the course will be special topics selected from the following; polymers and advanced materials, biomolecules such as carbohydrates, proteins and nucleic acids, and drug design. 3 hrs. lec., 1 hr. rec.
Prerequisites: 09-217 or 09-219

09-219 Modern Organic Chemistry
Fall: 10 units
Traditional introductory organic chemistry courses present structure, reactivity, mechanisms and synthesis of organic compounds. Students taking 09-219 will be exposed to the same topics, but presented in greater depth and broader context, with applications to allied fields such as (1) polymer and materials science, (2) environmental science and (3) biological sciences and medicine. This will be accomplished through an extra 50 minute lecture period, where more advanced topics and applications will be discussed. Topics will include computational chemistry, green chemistry, chiral separations, photochemistry, reaction kinetics, controlled radical polymerizations and petroleum cracking. Students who complete 09-219 will have a strong foundation in organic chemistry as well as a sophisticated understanding of how organic chemistry is currently practiced. 4 hrs. lec., 1 hr. rec.
Prerequisites: 09-107 or 09-105

09-220 Modern Organic Chemistry II
Spring: 10 units
This course builds on 09-219 by introducing students to additional functional groups, chemical reaction mechanisms and synthetic strategies commonly used in the practice of organic chemistry. Advanced topics to be presented during the extra lecture will include multidimensional NMR spectroscopy, enantioselective synthesis, ionic polymerization, bioorganic and medicinal chemistry, natural products chemistry and toxicology. Students who complete 09-220 will have a strong foundation in synthetic, mechanistic and structural organic chemistry and will understand how this applies to human health and the environment. 4 hrs. lec, 1 hr. rec.
Prerequisite: 09-219

09-221 Laboratory I: Introduction to Chemical Analysis
Fall and Spring: 12 units
This course is the first in a sequence of four laboratory courses on experimental aspects of chemistry required for the B.S. degree in chemistry. The experimental work emphasizes the techniques of quantitative chemical analysis. Included are projects dealing with a variety of instrumental and wet chemical techniques. The course is project-oriented with the experiments becoming more complex, requiring greater student input into the experimental design as the semester progresses. A mixture of individual and team experiments are conducted during the semester. In addition to techniques, safety, written and oral communication skills, and effective teamwork are emphasized. 2 hrs. lec., 6 hrs. lab.
Prerequisite: 09-106

09-222 Laboratory II: Organic Synthesis and Analysis
Fall and Spring: 12 units
In this second course in the laboratory sequence, students acquire laboratory skills relevant to synthesis and purification of organic compounds, as well as the practical use of chromatography and spectroscopy. Students will also further develop technical writing skills through preparation of lab reports. 2 hrs. lec., 6 hrs. lab.
Prerequisites: (09-219 or 09-217) and 09-221

09-224 Supramolecular Chemistry
Intermittent: 3 units
Supramolecular chemistry involves the use of noncovalent bonding interactions to assemble molecules into stable, well-defined structures. This course will provide students with an introduction to this exciting field of research, which is finding increasing applications in the biological and materials sciences, nanotechnology and medicine. Students will be introduced to essential background concepts such as types of noncovalent bonding and strategies for the design of supramolecular assemblies. Readings from monographs and classroom lectures by the instructor will cover this material. Students will then begin to read about applications of supramolecular chemistry from the scientific literature, learning to compare articles, to evaluate the quality of the data and interpretations reached by the authors, to use the knowledge gained from these readings and discussions to predict the outcomes of related experiments, and to ultimately be able to design their own experiments to answer research questions. Meeting hours set by instructor, enrollment limited with priority given to sophomore chemistry majors.
Prerequisites: 09-219 Min. grade C or 09-217 Min. grade C

09-225 Climate Change: Chemistry, Physics and Planetary Science
Fall: 9 units
Understanding the essential features of climate and climate change is a critical tool for modern citizens and modern scientists. In addition, the prevalence of climate skepticism in modern political discourse requires of citizens that they be able to think critically about a technical subject and also be able to distinguish reliable scientific experts from advocates. In this course we shall examine the climate of terrestrial planets (specifically Earth and Venus) through geological time and to the present, considering geochemical methods used to determine atmospheric composition over Earths history (specifically the onset of oxygen in the atmosphere as well as the relationship between carbon dioxide and global temperature over geological timescales. The shorter climate history of Venus will be considered as a counter example, where the brightening dim young sun overwhelmed negative feedbacks in the weathering cycle, leading to a runaway greenhouse amplified by complete evaporation of the onetime Venus ocean. Throughout the course, we will consider climate change driven by human activity since the industrial revolution as a unifying theme.
Prerequisites: (09-105 or 09-107) and (33-141 or 33-151 or 33-121)

09-231 Mathematical Methods for Chemists
Fall: 9 units
This course covers mathematical techniques that are important in the chemical sciences. The techniques will be covered in the context of chemical phenomena, and combine topics from 3-dimensional calculus, differential equations, linear algebra and statistics. This course does not count towards the minor in chemistry. 3 hrs. lec.
Prerequisites: 09-106 and (21-122 or 21-124)

09-301 Undergraduate Seminar III
Fall: 1 unit
Students attend seminars on current topics in chemistry. Students are sent a menu of choices for each week of the semester and may select topics of interest. Enrollment is restricted to students majoring in chemistry. 1 hr.

09-302 Undergraduate Seminar IV
Spring: 1 unit
Students attend seminars presented by senior chemistry majors. Students provide peer evaluations of the seminars and through the process students become familiar with special topics in chemistry. The course establishes what should be included in a good seminar. This seminar courses is one of 6 required for the chemistry major. If a schedule conflict exists, students may, with permission of the instructor, attend other chemistry seminars or make other arrangements to fulfill the requirement. 1 hr.

09-321 Laboratory III: Molecular Design and Synthesis
Fall: 12 units
In this third course in the laboratory sequence, students will learn a variety of more advanced techniques for organic synthesis and characterization, and will gain experience with developing and designing synthetic procedures. Student writing skills are further reinforced through preparation of detailed lab reports. 2 hrs. lec., 6 hrs. lab.
Prerequisites: (09-218 or 09-220) and 09-222

09-322 Laboratory IV: Molecular Spectroscopy and Dynamics
Spring: 12 units
This laboratory course is devoted to physical chemistry experiments, which involve the use of modern spectroscopic instrumentation to probe the optical and magnetic properties of molecules. The experiments include the use of high-resolution infrared, laser Raman, NMR, EPR, fluorescence, and UV-visible spectroscopies. Additional experiments demonstrate methods for measuring enzyme-catalyzed reaction rate constants, and the use of scanning probe microscopy for imaging and characterization of biological macromolecules.Throughout the course the students will learn how to use computer algebra packages for rigorous data analysis and modeling and will develop the skills in basic electronics, and vacuum techniques. 2 hrs. lec., 6 hrs. lab.
Prerequisites: 09-344 and 09-221

09-323 Bioorganic Chemistry Laboratory
12 units
Bioorganic chemistry is concerned with the action of synthesized compounds on biological systems. In order to maximize the likelihood of identifying a biologically active compound, synthetic libraries are often employed, requiring extensive familiarity with simple, efficient chemical coupling steps and protecting group chemistry. In this inquiry based laboratory course, using a process that mimics the current practice in drug discovery by pharmaceutical companies, students will rationally design a compound library in hopes of finding a compound active against a selected biological target, search for active compounds in the library, and then quantitatively characterize any identified compounds for activity. Working in small groups, students will develop proposals for and execute the target assay selected, the library synthesis, and the screening approach. Students will write reports summarizing the results in each phase of the course. Throughout the course, students will be introduced to concepts relevant to industrial scientific research, including regulatory compliance, quality control and assurance, and intellectual property.
Prerequisites: (09-220 or 09-218) and 09-222

09-331 Modern Analytical Instrumentation
Fall: 9 units
This course will cover all aspects of analytical instrumentation and its application to problems in materials, environmental, and biological chemistry. Topics covered will include mass spectrometry, optical spectroscopies and NMR. In addition, the course will emphasize how to select an analytical method appropriate to the problem at hand, how to optimize the signal to noise obtained by a measurement, and the quantitative analysis of experimental data. Some basic electronics will be covered as well. 3 hrs. lec.
Prerequisites: 09-222 and (33-122 or 33-142)

09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry
Fall: 9 units
The measurement and theoretical description of the properties of atoms and molecules are presented. The elementary principles of quantum chemistry are developed. The many types of spectroscopy used to study atoms and molecules are described. Methods of atomic structure determination are discussed. The structure and properties of solids are also presented. The basic results of statistical chemistry are outlined and a brief connection to thermodynamics is made. 3 hrs. lec., 1 hr. rec.
Prerequisites: (09-105 or 09-107) and (33-141 or 33-121 or 33-106 or 33-111)

09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry
Spring: 9 units
The measurement and theoretical descriptions of the equilibrium properties of chemical systems are presented. Chemical thermodynamics is introduced at the upper division level. The phases of matter are discussed. The quantitative treatment of mixtures is developed. The detailed description of chemical equilibrium is elaborated. The measurement and theoretical description of the nonequilibrium properties of chemical systems are presented. Elementary transport properties are introduced. The principles of classical chemical kinetics are developed in great detail. 3 hrs. lec., 1 hr. rec.
Prerequisites: 09-106 and (09-231 or 21-259)

09-347 Advanced Physical Chemistry
Fall: 12 units
09-347 Advanced Physical Chemistry Fall: 12 units A course of study designed to provide the microscopic basis of concepts encountered in the field of chemical engineering. The properties of macroscopic materials are calculated in terms of the microscopic properties of atoms and molecules. Both classical and quantum approaches are employed. The thermodynamic properties are developed in terms of the chemical potentials of the constituent particles. The transport properties are calculated using molecular dynamics and Brownian dynamics. Classical chemical kinetics is fully developed and applied to complex reactions. Rate constants are calculated for simple reactions in gases and solutions. The course enrollment is limited to chemical engineering majors. 4 hrs. lec.
Prerequisites: (06-221 or 06-151) and (06-262 or 06-155) and 09-106 and (33-142 or 33-122 or 33-107 or 33-112)

09-348 Inorganic Chemistry
Spring: 10 units
The focus of this class is understanding the properties of the elements and of the inorganic compounds. The electronic structure of elements is discussed as the basis for the element's organization in the Periodic Table and for their properties. The systematic chemistry of main group elements and of transition metals is presented. The number of inorganic compounds is extremely large and their properties are extremely diverse. Therefore in this course, the presentation of physical and chemical properties of inorganic compounds is based upon the observation of the trends in the respective properties and the relation between these trends and the place of the elements in the Periodic Table. 3 hrs. lec., 1 hr. rec.
Prerequisites: (09-105 or 09-107) and 21-120

09-401 Undergraduate Seminar V
Fall: 1 unit
Students attend seminars on current topics in chemistry. Students are sent a menu of choices for each week of the semester and may select topics of interest. Enrollment is restricted to students majoring in chemistry. 1 hr.

09-402 Undergraduate Seminar VI
Fall and Spring: 3 units
Students enrolled in this course present a 20 - 30 minute oral report on a current topic in chemistry. This may be from the student's research work or a special chemistry topic of general interest. Presentations or papers prepared for other courses are not acceptable for this purpose. Thoroughness in the use of the chemical literature is emphasized. The use of presentation aids such as PowerPoint is required. Other students in the class submit written evaluations of the presentation. Talks are recorded for viewing by the student and instructor as a means of providing individualized feedback about presentation skills. A seminar presentation is required of all chemistry majors. No exceptions possible. Enrollment is limited to students majoring in chemistry. 1 hr.

09-403 Chemistry of Addiction
Fall: 9 units
What makes us need something so much that it eclipses other important aspects of our lives, such as family, friends, work, hobbies, health and wellness? There are many different types of addiction; this course will focus on molecular addictions, specifically those involving members of the opiate class of narcotics. The ongoing epidemic of opiate addiction, arising both from over-prescription of pain killers and recreational use of heroin, has been widely reported and continues to rise at alarming rates, ravaging our urban and rural communities. In this course, we will explore the complicated role of chemistry in this epidemic, including the good (elucidating mechanisms of action, development of clinically useful and safe opiates and non-opiate pain killers) and the bad (design and synthesis of increasingly addictive opiates). We will also discuss ethical questions faced by the pharmaceutical industry that develops, markets and sells opiates, the medical community that prescribes opiates, and the government agencies charged with regulating these activities. Students who complete this course will emerge with a broad understanding and perspective on an issue that is of great scientific and societal importance. 3 hrs. lec.
Prerequisites: 09-218 or 09-220

09-425 Special Topics in Chemistry
All Semesters
This course is intended to provide faculty in the Department of Chemistry with the opportunity to develop and test ideas for new courses that may become part of the menu of department offerings at the undergraduate level. It also allows the department to take advantage of opportunities to offer a class that for any of a variety of reasons may not be offered again. The course content will be described by an appropriate special title and a course description and profile that will be available to students. 09-425 courses are intended for undergraduates.

09-435 Independent Study Chemistry
All Semesters
The course allows students to earn academic credit for concentrated study in a topic area developed in conjunction with and monitored by a faculty member in the Department of Chemistry. These topics are distinct from projects that would rise to the level of undergraduate research either because they are in unrelated areas distinct from the faculty member's research interests or may constitute the investigation and compilation of existing information from a variety of resources and may not be expected to result in the generation of new information as is a reasonable expected outcome in undergraduate research (likely is not publishable).

09-445 Undergraduate Research
Fall and Spring
Properly qualified students may undertake research projects under the direction of members of the faculty, normally 6 to 12 hrs/week. A written, detailed report describing the project and results is required. Course may be taken only with the consent of a faculty research advisor in chemistry or on occasion in another department provided that the project is chemical in nature and with permission of the Director of Undergraduate Studies. The number of units taken generally corresponds to the actual number of hours the student actually spends in the lab doing research during the week. Maximum number of units taken per semester is 18.

09-455 Honors Thesis
Fall and Spring
Students enrolled in the departmental honors program (B.S. with Departmental Honors or combined 4-year B.S./M.S. degree) are required to enroll in this course to complete the honors degree requirements. A thesis written in an acceptable style describing an original research project, and a successful oral defense of the thesis topic before a THesis Committee are required. Limited to students accepted into the honors program. (B.S. Honors candidates normally enroll for 6 units; B.S./M.S. candidates enroll for 15 units.)

09-502 Organic Chemistry of Polymers
Spring: 9 units
A study of the synthesis and reactions of high polymers. Emphasis is on practical polymer preparation and on the fundamental kinetics and mechanisms of polymerization reactions. Topics include: relationship of synthesis and structure, step-growth polymerization, chain-growth polymerization via radical, ionic and coordination intermediates, copolymerization, discussions of specialty polymers and reactions of polymers. 09-509, Physical Chemistry of Macromolecules, is excellent preparation for this course but is not required. 3-6 hrs. lec. (Graduate Course: 12 units, 09-741)
Prerequisites: 09-220 or 09-218

09-507 Nanoparticles
Intermittent: 9 units
This course discusses the chemistry, physics, and biology aspects of several major types of nanoparticles, including metal, semiconductor, magnetic, carbon, and polymer nanostructures. For each type of nanoparticles, we select pedagogical examples (e.g. Au, Ag, CdSe, etc.) and introduce their synthetic methods, physical and chemical properties, self assembly, and various applications. Apart from the nanoparticle materials, other topics to be briefly covered include microscopy and spectroscopy techniques for nanoparticle characterization, and nanolithography techniques for fabricating nano-arrays. The course is primarily descriptive with a focus on understanding major concepts (such as plasmon, exciton, polaron, etc.). The lectures are power point presentation style with sufficient graphical materials to aid students to better understand the course materials. Overall, this course is intended to provide an introduction to the new frontiers of nanoscience and nanotechnology. Students will gain an understanding of the important concepts and research themes of nanoscience and nanotechnology, and develop their abilities to pursue highly disciplinary nanoscience research. The course should be of interest and accessible to advanced undergraduates and graduate students in fields of chemistry, materials science, and biology. 3 hrs. lec.
Prerequisites: (33-107 or 33-112 or 33-122 or 33-142) and 09-106

09-509 Physical Chemistry of Macromolecules
Fall: 9 units
This course develops fundamental principles of polymer science. Emphasis is placed on physio-chemical concepts associated with the macromolecular nature of polymeric materials. Engineering aspects of the physical, mechanical and chemical properties of these materials are discussed in relation to chain microstructure. Topics include an introduction to polymer science and a general discussion of commercially important polymers; molecular weight; condensation and addition synthesis mechanisms with emphasis on molecular weight distribution; solution thermodynamics and molecular conformation; rubber elasticity; and the rheological and mechanical properties of polymeric systems. (This course is also listed as 06-609. Graduate Course: 12 units, 09-715) 3 hrs. lec.
Prerequisites: 09-347 or 09-345

09-510 Chemistry and Sustainability
Spring: 9 units
This course aims to educate students in the foundations of systematic leadership for building a sustainable world. Many sustainability challenges are associated with commercial chemicals and with operational modes of the chemical enterprise. For scientists, effectiveness in solving the technical challenges and redirecting cultural behavior is the defining substance of sustainability leadership. The course aims to challenge students to analyze and understand the root causes of unsustainability, especially in the technological dimension, to imagine a more sustainable world and to begin to define personal leadership missions. Students will be introduced to sustainability ethics as the foundation stone of transformative sustainability leadership, to the Collins ?Sustainability Compass? and ?Code of Sustainability Ethics? and to the Robért/Broman ?Framework for Strategic Sustainable Development (FSSD)?as powerful guiding tools. The Collins ?Bookcase of Green Science Challenges? organizes the technical content. It systematizes the major chemical sustainability challenges of our time: clean synthesis, renewable feed-stocks, safe energy, elemental pollutants, persistent molecular toxicants and endocrine disruptors. Focal areas will be the technical, toxicological and cultural histories of elemental and molecular pollutants and endocrine disruptor (ED) science?EDs represent the single greatest sustainability challenge of everyday chemicals. The graded substance will take the form of take-home work. Students will primarily read key books and articles and will summarize and personally evaluate the material in essay assignments. The course is intended for upper level undergraduates and graduates. There are no other prerequisites. The class is limited to 25 students. The 09-510 assignments are common to both undergraduate and graduate classes offerings. (Graduate course 12 units 09-710) 3 hrs. lec.
Prerequisites: 09-107 or 09-105

09-517 Organotransition Metal Chemistry
Intermittent: 9 units
The first half of this course focuses on the fundamentals of structure and bonding in organotransition metal complexes and how the results can be used to explain, and predict, chemical reactivity. The latter half of the course covers applications, and more specifically, homogeneous catalysts for industrial processes and organic synthesis. (Graduate Course: 12 units, 09-717)
Prerequisite: 09-348

09-518 Bioorganic Chemistry: Nucleic Acids and Carbohydrates
Fall: 9 units
This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of nucleic acids and carbohydrates, and their applications in chemistry, biology and medicine. Later in the course, students will have the opportunity to explore cutting-edge research in this exciting new field that bridges chemistry with biology. Students will be required to keep abreast of the current literature. In addition to standard homework assignments and examinations, students will have the opportunity to work in teams to tackle contemporary problems at the forefront of chemistry and biology. The difference between the 09-518 (9-unit) and 09-718 (12-unit) is that the latter is a graduate level course. Students signed up for 09-718 will be required to turn in an original research proposal at the end of the course, in addition to all the other assignments. (Graduate Course: 12 units, 09-718) 3 hrs. lec.
Prerequisites: (03-151 or 03-121) and (09-218 or 09-220)

09-519 Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry
Spring: 9 units
This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of peptides, proteins and small molecules. Basic concepts of bioorganic chemistry will be presented in the context of the current literature and students will have the opportunity to learn about the experimental methods used in various research labs. An introduction to combinatorial chemistry in the context of drug design and drug discovery will also be presented. Students will be required to keep abreast of the current literature. Homeworks and team projects will be assigned on a regular basis. The homework assignments will require data interpretation and experimental design; and team projects will give students the opportunity to work in teams to tackle contemporary problems at the interface of chemistry and biology. Students enrolled in the graduate level course (09-719) will be required to turn in an original research proposal at the end of the course, in addition to the homework assignments, midterm, and final exam that are required for the undergraduate course. (Graduate Course: 12 units 09-719) 3 hrs. lec.
Prerequisites: (03-121 or 03-151) and (09-220 or 09-218)

09-521 Metals in Biology: Function and Reactivity
Intermittent: 6 units
Metal ions play important roles in many biological processes, including photosynthesis, respiration, global nitrogen cycle, carbon cycle, antibiotics biosynthesis, gene regulation, bio-signal sensing, and DNA/RNA repair, just to name a few. Usually, metal ions are embedded in protein scaffold to form active centers of proteins in order to catalyze a broad array of chemical transformations, which are essential in supporting the biological processes mentioned above. These metal containing proteins, or metalloproteins, account for half of all proteins discovered so far. In this course, the relation between the chemical reactivity and the structure of metalloproteins will be discussed in detail. The main focus is to illustrate the geometric and electronic structure of metal centers and their interactions with the protein environment in governing the chemical reactivity of metalloproteins. The applications of these principles in designing biomimetic/bioinspried inorganic catalysts and in engineering metalloproteins bearing novel chemical reactivity will also be discussed. The basic principles of the frequently utilized physical methods in this research area will also be introduced, which include optical absorption spectroscopy, Infrared (IR) and Raman spectroscopies, Mössbauer spectroscopy, electron paramagnetic resonance (EPR), X-ray absorption and diffraction techniques.
Prerequisites: (09-344 or 09-345 or 09-214 or 09-347) and 09-348

09-522 Kinetics and Mechanisms of Enzymatic Reactions
Intermittent: 9 units
Major attention is devoted to kinetic methods of investigation of mechanisms of homogeneous chemical and enzymatic reactions. A mini course on kinetics and mechanisms of chemical reactions in solution is integrated followed by basics of kinetics of enzymatic reactions. The relationships between electronic structures, catalytic properties, and oxidation reactivity of biologically relevant metal complexes will be provided. Multiple roles of metal complexes in chemical and biochemical oxidations will be presented. Electrochemical and redox properties, electronic structures of metal complexes will be reviewed. Mechanistic pathways of action of hydrolases, kinases, hydrogenases, oxidases, peroxidases, cytochrome P-450, and other metalloenzymes will be described. (Graduate course: 09-722, 12-units) 3 hrs. lec.
Prerequisite: 09-348

09-524 Environmental Chemistry
Spring: 9 units
Environmental pollutants are common consequences of human activities. These chemicals have a wide range of deleterious effects on the environment and people. This course will introduce students to a range of major environmental pollutants, with a particular focus on persistent organic pollutants. We will use chemical principles including thermodynamics, kinetics, photochemistry, organic reaction mechanisms, and structure-activity relationships to understand the environmental fate of major classes of pollutants. The transport of chemicals through the environment and their partitioning between air, water, soil, and people will be described. The major environmental reaction pathways (oxidation, photolysis, hydrolysis, reduction, metabolism) of common pollutants will be explored. This will provide students with the necessary knowledge to predict the chemical fate of environmental pollutants, and improve their understanding of the environmental impacts of their everyday chemical use and exposure. Specific topics include water quality, photochemical smog, organic aerosols, atmospheric chemistry and global climate change, toxicity of pesticides, and heterogeneous and multiphase atmospheric chemistry. The 12-unit course is intended for graduate students that want to explore aspects of the course more deeply. This includes additional requirements including a final term paper and in-class presentation, and additional advanced questions on the homework assignments.
Prerequisites: 09-217 or 09-219

09-525 Transition Metal Chemistry
Intermittent: 9 units
This class covers fundamental concepts in Transition Metal Chemistry, including coordination numbers and stereochemistry, electronic structure, physical properties, and aspects of chemical reactivity of transition elements and their complexes. Point group theory is used to link the geometric and electronic structures of high symmetry coordination compounds. Analysis of the electronic structure of low symmetry coordination complexes is based on the Angular Overlap Model. In choosing coordination complexes that are discussed in class, special emphasis is given to those that are relevant for the fields of research of students enrolled in the class, such as supramolecular chemistry, nanotechnology, and metal-based catalysis. Students learn about the choice and relevance of modern questions posed by researchers in these fields and the modern methods and techniques used to answer the questions. Students learn also in this course how to use the Cambridge Crystallographic Database, a repository of structural data for more than 200,000 compounds, and how to use Mathematica to solve chemical problems. No prior knowledge of this software is required. (Graduate Course: 12 units, 09-725) 3 hrs. lec.
Prerequisite: 09-348

09-529 Introduction to Sustainable Energy Science
Fall: 9 units
This course focuses on the chemistry aspects of sustainable energy science. It introduces the major types of inorganic and molecular materials for various important processes of energy conversion and storage, such as photovoltaics, fuel cells, water splitting, solar fuels, batteries, and CO2 reduction. All the energy processes heavily rely on innovations in materials. This course is intended to offer perspectives on the materials/physical chemistry that are of importance in energy processes, in particular, how the atomic and electronic structures of materials impact the energy harvesting and conversion. In current energy research, intense efforts are focused on developing new strategies for achieving sustainable energy through renewable resources as opposed to the traditional oil/coal/gas compositions. This course offers students an introduction to the current energy research frontiers with a focus on solar energy conversion/storage, electrocatalysis and artificial photosynthesis. The major types of materials to be covered include metals, semiconductors, two-dimensional materials, and hybrid perovskites, etc. The material functions in catalysis, solar cells, fuel cells, batteries, supercapacitors, hydrogen production and storage are also discussed in the course. The lectures are power-point presentation style with sufficient graphical materials to aid students to better understand the course materials. Demo experiments are designed to facilitate student learning.
Prerequisites: (09-105 or 09-107) and (33-151 or 33-141 or 33-121)

09-531 Polymer Science
Fall: 9 units
Polymer science is a vibrant multidisciplinary activity. It uses the methods of chemistry, physics, chemical engineering, materials science and biology to create a coherent picture of the macromolecular world. This course is a survey of this field of endeavor suitable for Senior chemistry majors, or other students with a desire for a broad knowledge of the science and engineering of polymers. It covers a thorough description of the field, the synthetic chemistry of macromolecules, the physical chemistry of macromolecules, and the principles of polymer engineering and processing.
Prerequisites: (09-217 or 09-219) and (09-347 or 09-214 or 09-345)

09-534 Chemical Approaches to Energy Conversion & Storage
Spring: 9 units
Solar energy and electrical energy from renewable resources need to be stored to resolve intermittency issues. Energy can be stored through charge transfer, changes in chemical bonding, or in electric polarization. This course will introduce students to general aspects of energy-storage technologies using these strategies, integrating scientific and engineering perspectives to discuss thermodynamics, mechanisms of energy storage, and fundamental aspects of efficiency, capacity, and power delivery. Then we will explore current and experimental technologies, covering supercapacitors, batteries, and water-splitting catalysts. By the end of the course, students will be able to apply chemical principles to understand energy-storage technologies and gain knowledge of important classes of these systems. Students enrolled in 09-734 (rather than 09-534) will also be required to write a 15-page NSF style proposal. 3 hrs. lec.
Prerequisites: (09-219 or 09-217) and (27-215 or 33-341 or 24-324 or 09-345 or 09-347)

09-535 Applied topics in Macromolecular and Biophysical Techniques
Fall: 9 units
Applications of physical chemistry are widespread. Physical chemical principles are fundamental to the methods used to sequence human genome, obtain high resolution structures of proteins and complex nucleic acids e.g., ribosome, and further provides the framework to predict how molecules fold in 3-dimension, how the different domains interact (inter- and intra-molecular interactions) to perform biological functions. The principles that were discussed in theory in undergraduate physical chemistry classes, will be applied in order to understand the molecular structures and dynamics in nucleic acids and proteins, and to more advanced molecular motors. In the last decade major advances have been made through single-molecule studies that provide finer details of macromolecules in action. This course aims to teach and apply physical chemistry as related to biological problems.
Prerequisites: (09-347 or 09-345 or 09-214) and (03-232 or 03-231 or 03-121)

09-560 Computational Chemistry
Fall: 12 units
Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.
Prerequisites: 09-347 or 09-214 or 09-344 or 09-345

09-561 Computational Chemistry
Spring: 9 units
Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.

09-563 Molecular Modeling and Computational Chemistry
Spring: 9 units
Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.
Prerequisites: 09-345 or 09-347 or 09-344 or 09-214

09-604 Introduction to Chemical Kinetics
Spring: 6 units
Empirical description of the time evolution of chemical reactions. Inductive derivation of kinetic rate laws from actual data. Deductive derivation of kinetic rate laws from proposed mechanisms. Gas phase reactions, catalyzed reactions, enzyme kinetics. Theories of kinetic rate constants for gas phase reactions: unimolecular and bimolecular. Theories of solution phase reactions. Absolute reactions rate theory. Diffusion controlled reactions. Kinetics in highly viscous media. Activation energy and entropy. Volume of activation.

09-611 Chemical Thermodynamics
Fall: 6 units
A focused course on chemical thermodynamics. The basic thermodynamic functions will be introduced and discussed. The formal basis for thermochemistry will be presented. Single component phase equilibrium will be considered. The thermodynamic basis of solutions will be developed and applied to separation methods. The fundamental basis of chemical equilibrium will be developed and applied to a wide variety of reactions. Finally, a few special topics such as self-assembled systems will be presented. This is a graduate level course in chemistry and presumes the appropriate undergraduate preparation.
Prerequisites: 09-345 and 09-231

09-614 Spectroscopy
Intermittent: 6 units
This is a course exclusively in optical methods, both time resolved and steady state. In addition to methodology, spectral interpretation in terms of group theory will be discussed. The time-dependent formalism of quantum mechanics will also be introduced. Molecules in gas phase and condensed phase will be discussed. Frequent use will be made of the current literature. Background consisting of undergraduate physical chemistry is assumed. This course has a prerequisite 09-344, Quantum Chemistry or permission of the instructor.

09-701 Quantum Chemistry I
Fall: 12 units
The main topics to be covered will include exploration of the Schroedinger equation, operators, particle in the box, harmonic oscillator and hydrogen atom, tunneling, Stern-Gerlach experiment and quantum mechanical postulates, time-independent and time-dependent perturbation theory, matrix diagonalization. The student will learn to master the fundamental concepts and techniques of quantum mechanics. The parallel mini course Mathematical Analysis for Chemistry will provide the necessary mathematical background.

09-702 Statistical Mechanics and Dynamics
Intermittent: 12 units
This course will address the application of statistical mechanics to chemical systems. Topics to be discussed include the calculation of thermodynamic functions, phase transitions and chemical equilibrium, calculation of the transport properties of gases and liquids and the elementary theory of chemical kinetics.
Prerequisites: (09-344 or 09-611) and 09-231 and 09-701

09-705 Chemosensors and Biosensors
Intermittent: 12 units
Chemosensors and biosensors rely on "recognition" and "signaling" elements to transduce a molecular-scale binding event into an observable signal. Students in this course will be introduced to current research and technology for detecting chemical and biological analytes in a variety of contexts, including environmental testing, biological probing and medical diagnostics. Recognition elements ranging from small organic molecules to antibodies will be presented, while various detection modes, including fluorescence, gravimetric and colorimetric, that illustrate different signaling elements will be discussed and compared. Issues to be addressed include sensitivity, selectivity and efficiency. Each sensor will be analyzed in terms of the physical chemistry, organic chemistry and/or biochemistry underlying its function. This is a graduate level course that may also be appropriate for upper level undergraduates in chemistry and the biological sciences. The material in 09-518/09-519 or 09-718/09-719 would be appropriate background material for this course. 3 hrs. lec.
Prerequisites: (03-121 or 03-231 or 03-232) and (09-218 or 09-220)

09-710 Chemistry and Sustainability
Spring: 12 units
This course aims to educate students in the foundations of systematic leadership for building a sustainable world. Many sustainability challenges are associated with commercial chemicals and with operational modes of the chemical enterprise. For scientists, effectiveness in solving the technical challenges and redirecting cultural behavior is the defining substance of sustainability leadership. The course aims to challenge students to analyze and understand the root causes of unsustainability, especially in the technological dimension, to imagine a more sustainable world and to begin to define personal leadership missions. Students will be introduced to sustainability ethics as the foundation stone of transformative sustainability leadership, to the Collins ?Sustainability Compass? and ?Code of Sustainability Ethics? and to the Robért/Broman ?Framework for Strategic Sustainable Development (FSSD)?as powerful guiding tools. The Collins ? Bookcase of Green Science Challenges? organizes the technical content. It systematizes the major chemical sustainability challenges of our time: clean synthesis, renewable feed-stocks, safe energy, elemental pollutants, persistent molecular toxicants and endocrine disruptors. Focal areas will be the technical, toxicological and cultural histories of elemental and molecular pollutants and endocrine disruptor (ED) science?EDs represent the single greatest sustainability challenge of everyday chemicals. The graded substance will take the form of take-home work. Students will primarily read key books and articles and will summarize and personally evaluate the material in essay assignments. The course is intended for upper level undergraduates and graduates. There are no other prerequisites. The class is limited to 25 students. The 09-510 assignments are common to both undergraduate and graduate classes offerings and 09-710 students will engage in additional projects. 3 hrs. lec.
Prerequisites: 09-107 or 09-105

09-711 Physical Organic Chemistry
Fall: 12 units
This course introduces students to the study of structure and reactivity of organic compounds from a physical and theoretical standpoint. Students will learn the fundamentals of molecular orbital theory along with some practical applications to aromaticity and anti-aromaticity. Methods are described for the study of reaction mechanisms by means of physical methods such as kinetics, isotope effects, substituent effects, and solvent effects. Important reactive intermediates are described, along with detection methods. This course may be suitable for upper level undergraduates in chemistry with the appropriate background in organic chemistry and physical chemistry. 3 hrs. lec.
Prerequisites: 09-344 and 09-220

09-714 Advanced Organic Chemistry
Spring: 12 units
This course will expose the students to modern methods of organic synthesis including insights into the basis and mechanisms of chemical reactions. Topics include but are not limited to: modern spectroscopic analysis and structure determination, synthetic methods, retrosynthesis, organic reaction mechanisms, and references to separation techniques and some analytical methods. Upon completion of the course students should be able to design reaction schemes using scientific literature sources, evaluate their suitability for use in the lab and develop an aptitude in identifying the use of modern reagents that are more efficient, specific, safer and environmentally friendly. It is assumed that at minimum students will have completed at least two semesters of undergraduate coursework in organic chemistry and suggested that they have completed 09-222 and 09-321, the organic laboratory courses. 3 hrs. lec
Prerequisites: 09-218 or 09-220

09-716 Bioactive Natural Products
Spring: 12 units
This course is aimed at students with an interest in natural products research. Natural products are used as active components in medicinal products, as model compounds for further development into medicinally active drugs, as ingredients in food and for flavor and fragrances, among other very useful and interesting applications. An overview of the structural variety and activity of natural products will be presented along with their isolation and structural determination. Overall, the course will offer an introduction to the work that is customary in natural product research. This course will cover: Strategies to select the plant or marine material for study; main groups of natural products derived from plants; representative natural products derived from marine organisms; preparation of extracts and selection of active fractions, screening strategies; separation and purification of active components; bench-top bioassays and chemical assays and structure elucidation (especially 2D-NMR spectroscopy) Student's performance will be assessed by weekly assignments on the topics discussed in lecture and exams. 3 hrs. lec.
Prerequisites: 09-219 or 09-217

09-720 Physical Inorganic Chemistry
Intermittent: 6 units
This course develops the principles of magnetochemistry and inorganic spectroscopy. Electronic absorption, magnetic circular dichroism, resonance raman, NMR, EPR, Mossbauer, magnetization and x-ray methods will be introduced with application towards the determination of electronic structures of transition metal complexes.
Prerequisites: 09-344 and 09-345 and 09-348

09-721 Metals in Biology: Function and Reactivity
Intermittent: 6 units
Metal ions play important roles in many biological processes, including photosynthesis, respiration, global nitrogen cycle, carbon cycle, antibiotics biosynthesis, gene regulation, bio-signal sensing, and DNA/RNA repair, just to name a few. Usually, metal ions are embedded in protein scaffold to form active centers of proteins in order to catalyze a broad array of chemical transformations, which are essential in supporting the biological processes mentioned above. These metal containing proteins, or metalloproteins, account for half of all proteins discovered so far. In this course, the relation between the chemical reactivity and the structure of metalloproteins will be discussed in detail. The main focus is to illustrate the geometric and electronic structure of metal centers and their interactions with the protein environment in governing the chemical reactivity of metalloproteins. The applications of these principles in designing biomimetic/bioinspried inorganic catalysts and in engineering metalloproteins bearing novel chemical reactivity will also be discussed. The basic principles of the frequently utilized physical methods in this research area will also be introduced, which include optical absorption spectroscopy, Infrared (IR) and Raman spectroscopies, Mössbauer spectroscopy, electron paramagnetic resonance (EPR), X-ray absorption and diffraction techniques.
Prerequisites: (09-347 or 09-214 or 09-344 or 09-345) and 09-348

09-723 Proximal Probe Techniques: New Tools for Nanoscience & Nanotechnology
Intermittent: 12 units
Proximal probe techniques are revolutionizing physical and biological sciences, owing to their ability to explore and manipulate matter at the nanoscale, and to operate in various environments (including liquids). Proximal probe techniques rely on the use of nanoscale probes, positioned and scanned in the immediate vicinity of the material surface. Their development is often viewed as a first step towards nanotechnology, since they demonstrate the feasibility of building purposeful structures one atom or one (macro)molecule at a time. This course is designed for the students of chemistry, biology physics and engineering, who are interested in the fundamentals of proximal probe techniques and in their applications in various areas, converging into a rapidly developing, interdisciplinary field of nanoscience. It will provide physical background of such basic techniques as Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), and Near-Field Scanning Optical Microscopy (NSOM) and of their variants. Throughout the course, the working "virtual AFM" computer model will be assembled in classroom by each student and then used extensively to gain thorough understanding of AFM operation principles. Particular emphasis will be placed on modes of operation facilitating chemical contrast and contrast based on other material properties. (No prior experience with computer programming required). 3 hrs. lec.
Prerequisites: (21-124 or 09-231 or 21-122) and (09-344 or 09-322 or 09-345 or 09-331)

09-736 Transition Metal Catalysis for Organic and Polymer Synthesis
Intermittent: 12 units
Transition metal catalysts are invaluable in small molecule and polymer synthesis. The course will begin with a brief overview of organometallic chemistry and a discussion of fundamental organometallic reactions. Following this, a survey of some selected topics for the formation of small molecules and polymers will be presented. Some topics to be highlighted include: (1) Hydrogenation (2) Palladium Catalyzed Cross-Coupling (3) Epoxidation (4) Olefin Metathesis (5) Olefin Polymerization
Prerequisites: (09-220 or 09-218) and 09-348

09-737 Medicinal Chemistry and Drug Development
Spring: 12 units
Organic chemistry is an intimate part of the drug discovery and design processes in areas that include structure determination (NMR, mass spectrometry), synthesis, and determination of mechanisms of action. Once a promising compound (i.e. a ?lead?) has been identified in the laboratory, it is rarely ready to be used in the clinic. Complications include poor bioavailability, rapid degradation, and off-target effects. Students will learn about lead compound optimization through structural variations, cell-specific targeting and pro-drug strategies. Several examples will be presented to illustrate the role played by organic chemistry in the development of drugs used to treat a range of diseases, including cancer, HIV-AIDS, bacterial infections and heart disease.
Prerequisites: 09-218 or 09-220

09-760 The Molecular Basis of Polymer Mechanics
Spring: 12 units
This course is a graduate level course designed to prepare students for graduate research in polymer science. Based around a laboratory component, students will learn the lab skills needed to synthesize and fully characterize novel polymer materials. The classroom component will teach the theory behind the measurements made in lab, as well as an understanding of the best experiments to learn about the properties of the material. Emphasis will be placed on current literature and technical communication (written and oral). 3 hrs lec; 3 hrs lab

09-803 Chemistry of Gene Expression
Intermittent: 12 units
This course examines the chemical basis of biological reactions required for the propagation of genetic information stored in DNA and the organic chemistry principles behind the structure and function of nucleic acids.Main topics of lectures and class discussion will include the chemical and biochemical syntheses, properties and analyses of natural and modified nucleic acids to investigate cellular processes such as transcription, RNA splicing, other RNA regulation and translation; an introduction to the enzymatic strategies that accelerate these chemical reactions and a comparison of protein enzymes, ribozymes and other nucleic acid based enzymes in contemporary chemistry and biology. Students will learn to critically evaluate current scientific efforts that examine various aspects of chemistry and biological chemistry, the relationship between the structure and function of biomolecular systems, propose experiments to examine biological chemistry research problems and communicate these ideas and participate in scientific discussions and debates. 3 hrs. lec.
Prerequisites: (09-218 or 09-220) and (03-231 or 03-232)

09-860 Special Topics in Computational Chemistry:Machine Learning for Experimentalists
Spring: 6 units
The advent of Big Data has led to major advances in consumer electronics, finance, and medicine. While the associated methods of data mining and machine learning were developed for massive datasets, these tools can be applied in physical science and engineering where the datasets are much smaller but physical laws and engineering principles can be applied to reduce and model the parameter space. This course is designed to introduce students to statistical analysis and modeling of experimental data that enables understanding of complex parameter spaces and makes predictions of future experiments using smaller datasets. Sample applications would cover systems in which patterns are evident but the rules cannot be reduced to simple deterministic equations, such as design of high-strength polymers, analysis of spectroscopic data on complex systems, producing 3D-printed constructs, and developing organic dyes. Course content will focus on introducing techniques useful for experimentalists who have generated small- or medium-sized datasets, including preliminary data analysis using principle component analysis or canonical correlation analysis, linear and nonlinear regressions, multivariate methods, graphical models, Bayesian models, and causal inference. In addition, basic machine-learning algorithms in the form of optimization methods will be explored as well as approaches for improving the graphical representation of data. The course will be composed of two minis. In mini 1, students will learn tools of machine learning through lectures, problem sets, and exams. In mini 2, students will apply these methods to their data in a project-based course that culminates in a written report and an oral presentation. Both courses will make extensive use of Python and R.
Prerequisites: (09-107 or 09-106) and (09-231 or 21-259)

Department of Mathematical Sciences

Thomas Bohman, Department Head

William J. Hrusa, Associate Head

Jason Howell, Director of Undergraduate Studies

Location: Wean Hall 6113
www.math.cmu.edu

Mathematics provides much of the language and quantitative underpinnings of the natural and social sciences, and mathematical scientists have been responsible for the development of many of the most commonly used tools in business management as well as for laying the foundation for computational and computer science. The name of the Department of Mathematical Sciences reflects its tradition of outstanding research and teaching of applicable mathematics relating to these areas. Indeed, the Department contains highly ranked research groups in Applied Mathematics, Discrete Mathematics, Logic, and Mathematical Finance. These research strengths are reflected in the variety of options that the Department provides for its undergraduate majors.

The Department offers a B.S. degree in Mathematical Sciences. Concentrations within the degree include Mathematical Sciences, Operations Research and Statistics, Statistics, Discrete Mathematics and Logic, and Computational and Applied Mathematics.

The Mathematical Sciences concentration is the least structured of our programs, in recognition of the wide variety of interests that can be productively coupled with the study of mathematical sciences. It can be an appropriate choice for students planning for graduate study in mathematics or seeking to design their curriculum to take advantage of the many opportunities for a second major from another department in the University.

The Operations Research and Statistics Concentration prepares students to enter the area of operations research. Mathematicians with a background in operations research are especially valuable in such diverse activities as project planning, production scheduling, market forecasting and finance. Such applications are found in virtually all industrial and governmental settings.

The Statistics Concentration prepares students to contribute to a wide variety of research areas. Applications range from experimental design and data analysis in the physical and social sciences, medicine and engineering, to modeling and forecasting in business and government, to actuarial applications in the financial and insurance industries. This is also a useful second major for students planning for graduate study and research in subject areas requiring a strong statistical background.

The Discrete Mathematics and Logic Concentration provides a background in discrete mathematics, mathematical logic, and theoretical computer science. This concentration prepares the student to do research in these and related fields, or to apply their ideas elsewhere.

Finally, the Computational and Applied Mathematics Concentration provides the background needed to support the computational and mathematical analysis needs of a wide variety of businesses and industries and is well suited to students with an interest in the physical sciences and engineering.

The Department places great emphasis on the advising of students. This is critical if students are to make the most of their years at the University. Students are urged to work carefully with their advisor and other faculty to formulate their degree programs. Study abroad is encouraged, and an interested student should investigate the opportunities available in the Undergraduate Options section of the catalog.

Special Options

The Department offers special opportunities for the exceptionally well-prepared and intellectually ambitious student. These options are available to students from any department in the University.

Matrix Theory and Vector Analysis

For selected Freshmen entering the University, the department offers the Fall/Spring sequence of Matrix Theory (21-242) and Vector Analysis (21-269), which include a rigorous introduction to proofs and abstract mathematics. Typically, a student choosing this sequence has mastered the operational aspects of high school mathematics and now seeks a deeper conceptual understanding.

- Matrix Theory (21-242) is an honors version of Matrices and Linear Transformations (21-241).
- Vector Analysis (21-269) is an honors version of Multidimensional Calculus (21-268).

Admission to Matrix Theory (21-242) is based on a placement test taken at the start of the freshman year. Admission to Vector Analysis (21-269) is based on a student's performance in Matrix Theory (21-242), and on other courses taken in the Fall semester.

Mathematical Studies

The sequence of undergraduate honors courses continues with the Mathematical Studies courses, aimed primarily at sophomores. These highly demanding courses provide excellent preparation for graduate study, with many of the participants taking graduate courses as early as their Junior year. Students will be expected to master material at a high level of abstraction, and to work on very challenging problems. The typical enrollment of about 15 students allows for close contact with the instructors.

- 21-235 Mathematical Studies Analysis I is an honors version of 21-355 Principles of Real Analysis I.
- 21-237 Mathematical Studies Algebra I is an honors version of 21-373 Algebraic Structures.
- 21-236 Mathematical Studies Analysis II is an honors version of 21-356 Principles of Real Analysis II.
- 21-238 Mathematical Studies Algebra II) is an honors version of 21-341 Linear Algebra.

Admission to Mathematical Studies is by invitation, and interested students should apply during the Spring of their freshman year. Applicants are not absolutely required to have taken 21-242 Matrix Theory or 21-269 Vector Analysis, and may be admitted on the basis of exceptionally strong performance in non-honors mathematics courses.

It is possible to take only the Algebra courses or only the Analysis courses. Admission to 21-236 Mathematical Studies Analysis II requires a grade of B or better in 21-235 Mathematical Studies Analysis I, and similarly, admission to 21-238 Mathematical Studies Algebra II requires a grade of B or better in 21-237 Mathematical Studies Algebra I.

Interdisciplinary Programs

Several interdisciplinary options enable a student to combine mathematics with other disciplines.

- The Bachelor of Science and Arts (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/bxaintercollege/#bachelorofscienceandartsdegreeprogram) program allows a student to combine mathematics with study in any of the five schools in the College of Fine Arts.
- The Bachelor of Science in Mathematics and Economics (http://coursecatalog.web.cmu.edu/tepper/undergraduateeconomicsprogram/#bsineconomicsandmathematicalsciences) is a flexible program which allows students to develop depth in both fields of study. Note: for students whose home college is Dietrich College, this major is known as the Bachelor of Science in Economics and Mathematical Sciences.
- Finally, a joint program with the Heinz College of Public Policy and Management and the Tepper School of Business leads to the degree Bachelor of Science in Computational Finance (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#bachelorofscienceincomputationalfinance). (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#bachelorofscienceincomputationalfinance)

Curriculum

For each concentration, we provide a list of the requirements and a suggested schedule that takes prerequisites into account. A Mathematical Sciences, Computer Science, Physics, Statistics Elective refers to any course from the Departments of Mathematical Sciences, Computer Science, Physics, or Statistics and Data Science, respectively, satisfying the following restrictions: a mathematical sciences course must be at the 21-300 level or above or 21-270 or 21-272 or 21-292, a computer science course must be at the 15-200 level or above, a physics course must be at the 33-300 level or above, and a statistics course must be at the 36-300 level or above and have at least 36-225 as a prerequisite.

Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-499 Undergraduate Research Topic and 21-599 Undergraduate Reading and Research for this purpose. At most a total of 9 units of 21-499/21-599 can be applied toward the Depth Elective requirement. This requires permission of both the advisor and the department.

Mathematical Sciences majors are required to complete an introductory computer science course, either 15-110 or 15-112. Students who plan to take further computer science courses must complete 15-112.

An H&SS Elective refers to a course in the Dietrich College of Humanities and Social Sciences requirements as described in the catalog section for the Mellon College of Science. A course listed as an Elective is a free elective with the only restriction that the maximum total of ROTC, STUCO, and Physical Education units that will be accepted for graduation is nine.

For a list of courses required for all MCS students see "First Year for Science Students." (http://coursecatalog.web.cmu.edu/melloncollegeofscience/#firstyearforsciencestudents)

Mathematical Sciences Concentration

This program is the most flexible available to our majors. The flexibility to choose eight electives within the major plus seven humanities courses and seven free electives allows the student to design a program to suit his or her individual needs and interests. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies. The requirements for the Mathematics Degree are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

Courses		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
36-225	Introduction to Probability Theory	9
or 21-325	Probability	
21-259	Calculus in Three Dimensions	9
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-341	Linear Algebra	9
21-355	Principles of Real Analysis I	9
21-356	Principles of Real Analysis II	9
21-373	Algebraic Structures	9
		113

Forty-five units of (required) Mathematical Sciences electives (at the 21-300 level or above or 21-270 or 21-272 or 21-292).

27 Units of (required) Mathematical Sciences (at the 21-300 level or above or 21-270 or 21-272 or 21-292, or Computer Science (at the 15-200 level or above), or Physics (at the 33-300 level or above), or Statistics (must be at the 36-300 level or above and have at least 36-225 as a prerequisite) electives.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Mathematical Sciences Electives for Students Intending Graduate Studies

Students preparing for graduate study in mathematics should consider the following courses as Mathematical Sciences electives, choosing among them according to the desired area of graduate study. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

Courses		Units
21-272	Introduction to Partial Differential Equations	9
21-301	Combinatorics	9
21-360	Differential Geometry of Curves and Surfaces	9
21-371	Functions of a Complex Variable	9
21-374	Field Theory	9
21-441	Number Theory	9
21-465	Topology	9
21-467	Differential Geometry	9
21-470	Selected Topics in Analysis	9
21-476	Introduction to Dynamical Systems	9
21-484	Graph Theory	9
21-602	Introduction to Set Theory I	12
21-603	Model Theory I	12
21-610	Algebra I	12
21-620	Real Analysis	6
21-621	Introduction to Lebesgue Integration	6
21-630	Ordinary Differential Equations	12
21-632	Introduction to Differential Equations	12
21-640	Introduction to Functional Analysis	12
21-651	General Topology	12
21-660	Introduction to Numerical Analysis I	12
21-701	Discrete Mathematics	12
21-720	Measure and Integration	12
21-721	Probability	12
21-723	Advanced Real Analysis	12
21-737	Probabilistic Combinatorics	12
21-738	Extremal Combinatorics	12

Note that courses 21-600 and above carry graduate credit. Courses at the 600 level are designed as transitional courses to graduate study. A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-499 Undergraduate Research Topic and 21-599 Undergraduate Reading and Research for this purpose.

Courses 21-700 and above can be used with the permission of both the advisor and the department.

Suggested Schedule for students without AP credit

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
xx-xxx	Life/Physical Sciences Course	9
		47

Spring		Units
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
21-122	Integration and Approximation	10
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
xx-xxx	Physical/Life Sciences Course	9

xx-xxx	H&SS Elective	9
		48

Sophomore Year

Fall		Units
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-268	Multidimensional Calculus	10
xx-xxx	STEM Course	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		47

Spring		Units
21-261	Introduction to Ordinary Differential Equations	10
21-373	Algebraic Structures	9
xx-xxx	Mathematical Sci, Statistics, or Computer Sci Elective	9
xx-xxx	STEM Course	9
xx-xxx	H&SS Elective	9
		46

Junior Year

Fall		Units
21-355	Principles of Real Analysis I	9
36-225	Introduction to Probability Theory	9
or 21-325	Probability	
xx-xxx	Mathematical Sci, Statistics, or Computer Sci Elective	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		45

Spring		Units
21-341	Linear Algebra	9
21-356	Principles of Real Analysis II	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Cultural/Global Understanding Elective	9
xx-xxx	Free Elective	9
		45

Senior Year

Fall		Units
21-xxx	Mathematical Sciences Elective	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Spring		Units
21-xxx	Mathematical Sciences Elective	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Mathematical Sci, Statistics, or Computer Sci Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree: 360

Suggested Schedule for Students with AP Credit

Freshman Year

Fall		Units
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
xx-xxx	Life/Physical Sciences Course	9
		47

Spring		Units
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-268	Multidimensional Calculus	10
or 21-269	Vector Analysis	
xx-xxx	H&SS Elective	9
		38

Sophomore Year

Fall		Units
36-225	Introduction to Probability Theory	9
or 21-325	Probability	
xx-xxx	Mathematical Sci, Statistics, or Computer Sci Elective	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		36

Spring		Units
21-261	Introduction to Ordinary Differential Equations	10
21-355	Principles of Real Analysis I	9
xx-xxx	STEM Course	9
xx-xxx	H&SS Elective	9
		37

Junior Year

Fall		Units
21-356	Principles of Real Analysis II	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Cultural/Global Understanding Course	9
xx-xxx	Free Elective	9
		36

Spring		Units
21-341	Linear Algebra	9
xx-xxx	Mathematical Sci, Statistics, or Computer Sci Elective	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		45

Senior Year

Fall		Units
21-xxx	Mathematical Sciences Elective	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Spring		Units
21-xxx	Mathematical Sciences Elective	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Mathematical Sci, Statistics, or Computer Sci Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree:	360

Operations Research and Statistics Concentration

An operations research professional employs quantitative and computational skills toward enhancing the function of an organization or process. Students choosing this concentration will develop problem-solving abilities in mathematical and statistical modeling and computer-based simulation in areas such as network design, transportation scheduling, allocation of resources and optimization. In addition to courses in mathematics and statistics, a basic background in economics and accounting is included. Since problems in business and industry are often solved by teams, the curriculum typically includes group projects. Students choosing this concentration may not pursue an additional minor in Statistics in the Dietrich College of Humanities and Social Sciences College. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Graduate Studies.

The requirements for the concentration in Operations Research and Statistics are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

Courses		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	9
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-292	Operations Research I	9
21-369	Numerical Methods	12
21-393	Operations Research II	9
		98

Statistics Courses (required)

Courses		Units
36-225	Introduction to Probability Theory	9
or 21-325	Probability	
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
		45

Economics, Business, and Computer Science Courses (required)

Courses		Units
15-110	Principles of Computing	10
70-122	Introduction to Accounting	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	
		46

Depth Electives (required)

Five depth electives (required), to be chosen from the list below. The course 21-355 is particularly recommended for a student planning to pursue graduate work. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

Courses		Units
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (Undergrad)	
10-605	Machine Learning with Large Datasets	12
15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-270	Introduction to Mathematical Finance	9
21-301	Combinatorics	9
21-341	Linear Algebra	9
21-355	Principles of Real Analysis I	9
21-356	Principles of Real Analysis II	9
21-365	Projects in Applied Mathematics	9
21-366	Topics in Applied Mathematics	9
21-370	Discrete Time Finance	9
21-373	Algebraic Structures	9
21-377	Monte Carlo Simulation for Finance	9
21-378	Mathematics of Fixed Income Markets	9
21-420	Continuous-Time Finance	9
21-484	Graph Theory	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
70-371	Operations Management	9
70-460	Mathematical Models for Consulting	9
70-471	Supply Chain Management	9

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Note that 73-102, 73-103, 73-230, and 73-240 satisfy requirements from the MCS general education core.

Suggested Schedule

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
xx-xxx	Life/Physical Sciences Course	9
		47

Spring		Units
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
21-122	Integration and Approximation	10
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
xx-xxx	Physical/Life Sciences Course	9
xx-xxx	H&SS Elective	9
		48

Sophomore Year

Fall		Units
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-259	Calculus in Three Dimensions	9
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
73-102	Principles of Microeconomics	9
xx-xxx	STEM Course	9
		37

Spring		Units
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-292	Operations Research I	9
70-122	Introduction to Accounting	9
xx-xxx	H&SS Elective	9
xx-xxx	STEM Elective	9
		45

Junior Year

Fall		Units
21-369	Numerical Methods	12
36-225	Introduction to Probability Theory	9
or 21-325	Probability	
73-103	Principles of Macroeconomics	9
xx-xxx	Depth Elective	9
xx-xxx	Free Elective	9
		48

Spring		Units
36-226	Introduction to Statistical Inference	9
36-410	Introduction to Probability Modeling	9
xx-xxx	Depth Elective	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	
xx-xxx	Cultural/Global Understanding Course	9
		45

Senior Year

Fall		Units
21-393	Operations Research II	9
36-401	Modern Regression	9
xx-xxx	Depth Elective	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		45

Spring		Units
36-402	Advanced Methods for Data Analysis	9
xx-xxx	Depth Elective	9
xx-xxx	Depth Elective	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree: 360

Statistics Concentration

Statistics is concerned with the process by which inferences are made from data. Statistical methods are essential to research in a wide variety of scientific disciplines. For example, principles of experimental design that assist chemists in improving their yields also help poultry farmers grow bigger chickens. Similarly, time series analysis is used to better understand radio waves from distant galaxies, hormone levels in the blood, and concentrations of pollutants in the atmosphere. This diversity of application is an exciting aspect of the field, and it is one reason for the current demand for well-trained statisticians.

The courses 36-225 Introduction to Probability Theory and 36-226 Introduction to Statistical Inference taken in the Junior year serve as the basis for all further statistics courses. The course 21-325 is a more mathematical alternative to 36-225.

The Statistics Concentration is jointly administered by the Department of Mathematical Sciences and the Department of Statistics and Data Science. The Department of Statistics and Data Science considers applications for the master's program from undergraduates in the Junior year. Students who are accepted are expected to finish their undergraduate studies, using some electives in the Senior year to take courses recommended by the Department of Statistics and Data Science. This will ensure a strong background to permit completion of the master's program in one year beyond the baccalaureate. Students choosing this concentration may not pursue an additional minor in Statistics in the Dietrich College of Humanities and Social Sciences. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies. The requirements for the Statistics Concentration are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

Courses		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	9
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-292	Operations Research I	9
21-369	Numerical Methods	12
21-393	Operations Research II	9
		98

Statistics Courses (required)

Courses		Units
36-225	Introduction to Probability Theory	9
or 21-325	Probability	
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
		45

Economics and Computer Science Courses (required)

Courses		Units
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	10
73-102	Principles of Microeconomics	9
		31

Depth Electives (required)

Five depth electives, including at least one statistics course, to be chosen from the list below. The course 21-355 Principles of Real Analysis I is particularly recommended for a student planning to pursue graduate work. Exceptions to the elective requirements for each concentration of the B.S.

degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

Courses		Units
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (Undergrad)	
10-605	Machine Learning with Large Datasets	12
15-150	Principles of Functional Programming	10
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-270	Introduction to Mathematical Finance	9
21-341	Linear Algebra	9
21-355	Principles of Real Analysis I	9
21-356	Principles of Real Analysis II	9
21-365	Projects in Applied Mathematics	9
21-366	Topics in Applied Mathematics	9
21-370	Discrete Time Finance	9
21-373	Algebraic Structures	9
21-377	Monte Carlo Simulation for Finance	9
21-378	Mathematics of Fixed Income Markets	9
21-420	Continuous-Time Finance	9
21-484	Graph Theory	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Note that 73-102 satisfies the requirement from the MCS core.

Suggested Schedule

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
xx-xxx	Life/Physical Sciences Course	9
		47

Spring		Units
15-112	Fundamentals of Programming and Computer Science	12
21-122	Integration and Approximation	10
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
xx-xxx	STEM Course	9
xx-xxx	Physical/Life Sciences Course	9
		50

Sophomore Year

Fall		Units
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-259	Calculus in Three Dimensions	9
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
73-102	Principles of Microeconomics	9
xx-xxx	STEM Course	9
xx-xxx	H&SS Elective	9
		46

Spring		Units
15-122	Principles of Imperative Computation	10
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-292	Operations Research I	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		46

Junior Year

Fall		Units
21-369	Numerical Methods	12
36-225	Introduction to Probability Theory	9
or 21-325	Probability	
xx-xxx	Depth Elective	9
xx-xxx	Depth Elective	9
xx-xxx	H&SS Elective	9
		48

Spring		Units
36-226	Introduction to Statistical Inference	9
36-410	Introduction to Probability Modeling	9
xx-xxx	Depth Elective	9
xx-xxx	Cultural/Global Understanding Course	9
xx-xxx	Free Elective	9
		45

Senior Year

Fall		Units
21-393	Operations Research II	9
36-401	Modern Regression	9
xx-xxx	Depth Elective	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		45

Spring		Units
36-402	Advanced Methods for Data Analysis	9
xx-xxx	Depth Elective	9
xx-xxx	Depth Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree:	360

Discrete Mathematics and Logic Concentration

Discrete mathematics is the study of finite and countable structures and algorithms for the manipulation and analysis of such structures, while mathematical logic is the study of axiomatic systems and their mathematical applications. Both are flourishing research areas and have close ties with computer science.

The Discrete Mathematics and Logic Concentration provides a firm background in discrete mathematics and mathematical logic, together with the elements of theoretical computer science. It prepares the student to pursue research in these fields, or to apply their ideas in the many disciplines (ranging from philosophy to hardware verification) where such ideas have proved relevant. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies.

The requirements for the Discrete Mathematics and Logic Concentration are:

Mathematical Sciences and Computer Science Courses (required)

The alternative course 21-242 is particularly recommended for a student planning to pursue graduate work. Students who plan to pursue graduate study in mathematical logic are strongly advised to take 21-300 Basic Logic.

Courses		Units
15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-300	Basic Logic	9
or 15-317	Constructive Logic	
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-301	Combinatorics	9
21-341	Linear Algebra	9
21-355	Principles of Real Analysis I	9
21-373	Algebraic Structures	9
		127

Computer Science electives (required)

Any two courses at the 300 level or above. The following are specifically suggested:

15-312	Foundations of Programming Languages	12
15-451	Algorithm Design and Analysis	12
15-453	Formal Languages, Automata, and Computability	9

Students pursuing this concentration who minor in Computer Science must take two additional Computer Science courses at the 300 level or above to avoid excessive double counting.

Mathematical Sciences Electives (required)

Seven courses from lists 1 and 2 below, including at least three chosen from list 1. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

List 1 (Discrete Mathematics and Logic Electives)

Courses		Units
15-359	Probability and Computing	12
21-325	Probability	9
21-329	Set Theory	9
21-374	Field Theory	9
21-400	Intermediate Logic	9
21-441	Number Theory	9
21-484	Graph Theory	9
21-602	Introduction to Set Theory I	12
21-603	Model Theory I	12
21-610	Algebra I	12
21-701	Discrete Mathematics	12
80-405	Game Theory	9
80-411	Proof Theory	9
80-413	Category Theory	9

List 2 (General Mathematics Electives)

Courses		Units
21-259	Calculus in Three Dimensions	9-10
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-270	Introduction to Mathematical Finance	9
21-272	Introduction to Partial Differential Equations	9
21-292	Operations Research I	9
21-356	Principles of Real Analysis II	9
21-366	Topics in Applied Mathematics	9
21-369	Numerical Methods	12
21-370	Discrete Time Finance	9
21-371	Functions of a Complex Variable	9
21-393	Operations Research II	9
21-420	Continuous-Time Finance	9
21-470	Selected Topics in Analysis	9
21-476	Introduction to Dynamical Systems	9
21-499	Undergraduate Research Topic	9

Any graduate course in mathematics at the 600 and 700 level not included in List 1.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Suggested Schedule

Freshman Year

Fall		Units
15-112	Fundamentals of Programming and Computer Science	12
21-120	Differential and Integral Calculus	10
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
xx-xxx	Life/Physical Sciences Course	9
		49

Spring		Units
15-122	Principles of Imperative Computation	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
xx-xxx	Physical/Life Sciences Course	9
		49

Sophomore Year

Fall		Units
15-150	Principles of Functional Programming	10
21-201	Undergraduate Colloquium	1
21-268	Multidimensional Calculus	10
or 21-269	Vector Analysis	
21-301	Combinatorics	9
21-373	Algebraic Structures	9
xx-xxx	H&SS Elective	9
		48

Spring		Units
15-210	Parallel and Sequential Data Structures and Algorithms	12
xx-xxx	Discrete Math/Logic Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	STEM Course	9
xx-xxx	H&SS Elective	9
		48

Junior Year

Fall		Units
15-xxx	Computer Science Elective	9
21-300	Basic Logic	9
or 15-317	Constructive Logic	

21-355	Principles of Real Analysis I	9
xx-xxx	H&SS Elective	9
xx-xxx	STEM Course	9
		45

Spring		Units
15-xxx	Computer Science Elective	9
21-341	Linear Algebra	9
xx-xxx	H&SS Elective	9
xx-xxx	Cultural/Global Understanding Course	9
xx-xxx	Free Elective	9
		45

Senior Year

Fall		Units
xx-xxx	Discrete Math/Logic Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Spring		Units
xx-xxx	Discrete Math/Logic Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree: 360

Computational and Applied Mathematics Concentration

This concentration is designed to prepare students for careers in business or industry which require significant analytical, computational and problem solving skills. It also prepares students with interest in computational and applied mathematics for graduate school.

The students in this concentration develop skills to choose the right framework to quantify or model a problem, analyze it, simulate and in general use appropriate techniques for carrying the effort through to an effective solution. The free electives allow the student to develop an interest in a related area by completing a minor in another department, such as Engineering Studies, Economics, Information Systems or Business Administration. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies.

The requirements for the Computational and Applied Mathematics Concentration are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

Courses		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	9
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
36-225	Introduction to Probability Theory	9
or 21-325	Probability	
21-355	Principles of Real Analysis I	9
21-369	Numerical Methods	12
21-469	Computational Introduction to Partial Differential Equations	9
		107

Students must take three courses from the list below. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

Depth Electives

Courses		Units
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (Undergrad)	
21-270	Introduction to Mathematical Finance	9
21-292	Operations Research I	9
21-344	Numerical Linear Algebra	9
21-380	Introduction to Mathematical Modeling	9
21-435	Applied Harmonic Analysis	9

Computer Science Courses (required)

Courses		Units
15-122	Principles of Imperative Computation	10

Mathematics Electives (required)

Students must take 27 units either from the three remaining courses in List 1 or from the list below:

Courses		Units
21-341	Linear Algebra	9
21-356	Principles of Real Analysis II	9
21-365	Projects in Applied Mathematics	9
21-366	Topics in Applied Mathematics	9
21-370	Discrete Time Finance	9
21-371	Functions of a Complex Variable	9
21-373	Algebraic Structures	9
21-377	Monte Carlo Simulation for Finance	9
21-378	Mathematics of Fixed Income Markets	9
21-393	Operations Research II	9
21-420	Continuous-Time Finance	9
21-467	Differential Geometry	9
21-470	Selected Topics in Analysis	9
21-476	Introduction to Dynamical Systems	9
21-484	Graph Theory	9
21-620	Real Analysis	6
21-621	Introduction to Lebesgue Integration	6
21-630	Ordinary Differential Equations	12
21-632	Introduction to Differential Equations	12
21-640	Introduction to Functional Analysis	12
21-651	General Topology	12
21-660	Introduction to Numerical Analysis I	12
21-690	Methods of Optimization	12
21-720	Measure and Integration	12
21-721	Probability	12
21-723	Advanced Real Analysis	12
21-724	Sobolev Spaces	12
21-732	Partial Differential Equations I	12
21-832	Partial Differential Equations II	12

Students must take 9 additional units of Mathematical Sciences (at the 21-300 level or above or 21-270 or 21-272 or 21-292), or Computer Science (at the 15-200 level or above), or Physics (at the 33-300 level or above), or Statistics (must be at the 36-300 level or above and have at least 36-225 as a prerequisite) electives.

21-366 Topics in Applied Mathematics and 21-470 Selected Topics in Analysis have content that varies from year to year. These courses can be taken more than once (with permission).

Note that courses 21-600 and above carry graduate credit. 600-level courses are designed as transitional courses to graduate study.

A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-499 Undergraduate Research Topic and 21-599 Undergraduate Reading and Research for this purpose.

Courses 21-700 and above can be used with the permission of both the advisor and the department.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units).

Students not in MCS are required to take 15-110 Principles of Computing (10 units).

Suggested Schedule

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
21-126	Introduction to Mathematical Software	3
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
xx-xxx	Life/Physical Sciences Course	9
		47

Spring		Units
21-122	Integration and Approximation	10
21-228	Discrete Mathematics	9
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
xx-xxx	Physical/Life Sciences Course	9
xx-xxx	H&SS Elective	9
		47

Sophomore Year

Fall		Units
15-112	Fundamentals of Programming and Computer Science	12
21-201	Undergraduate Colloquium	1
21-268	Multidimensional Calculus	10
or 21-269	Vector Analysis	
xx-xxx	STEM Course	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		50

Spring		Units
15-122	Principles of Imperative Computation	10
21-261	Introduction to Ordinary Differential Equations	10
21-355	Principles of Real Analysis I	9
xx-xxx	STEM Course	9
xx-xxx	H&SS Elective	9
		47

Junior Year

Fall		Units
21-320	Symbolic Programming Methods	9
21-325	Probability	9
21-356	Principles of Real Analysis II	9
xx-xxx	H&SS Elective	9
xx-xxx	Free Elective	9
		45

Spring		Units
xx-xxx	Mathematics Elective	9
xx-xxx	Depth Elective	9
21-369	Numerical Methods	12
xx-xxx	Cultural/Global Understanding Elective	9
xx-xxx	Free Elective	9
		48

Senior Year

Fall		Units
xx-xxx	Mathematics Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Spring		Units
xx-xxx	Mathematics Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree: 360

Double Major Requirements

All degrees offered by the Department are available as a second major to students majoring in other departments. Interested students should contact the Department for further information and guidance. In general the requirements for a second major include all the required courses except the MCS core and free electives.

The Minor in Mathematical Sciences

The Minor includes six courses. 21-127 Concepts of Mathematics is a prerequisite for 21-228 and recommended for 21-241 . The minimum preparation required for 21-355 Principles of Real Analysis I is 21-122 and 21-127 or equivalent courses.

21-127	Concepts of Mathematics	10
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-355	Principles of Real Analysis I	9
21-3xx	Mathematical Sciences Elective	
21-3xx	Mathematical Sciences Elective	

To avoid excessive double counting, the two Mathematical Sciences Electives may not also count toward the student's major.

The Minor in Discrete Mathematics and Logic

This minor develops the fundamentals of discrete mathematics and logic necessary to understand the mathematical foundations of many computer related disciplines. Required courses are:

21-228	Discrete Mathematics [1]	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-300	Basic Logic	9
or 15-317	Constructive Logic	
21-301	Combinatorics	9

[1] 21-127 Concepts of Mathematics is a prerequisite for 21-228.

Three of the following (at least one from each group):

Logic		
21-329	Set Theory	9
21-400	Intermediate Logic	9

21-602	Introduction to Set Theory I	12
21-603	Model Theory I	12
21-700	Mathematical Logic II	12

Algebra and Discrete Mathematics

21-341	Linear Algebra	9
21-373	Algebraic Structures	9
21-374	Field Theory	9
21-441	Number Theory	9
21-484	Graph Theory	9
21-610	Algebra I	12
21-701	Discrete Mathematics	12

The Honors Degree Program

This demanding program qualifies the student for an additional degree, the Master of Science in Mathematical Sciences. Admission to the Honors Degree Program is selective and interested students should apply for admission during their junior year. In the application process, the Department will hold to the same high standards which apply to admission to any graduate program. Applicants are not absolutely required to have taken the Mathematical Studies courses and may be admitted on the basis of exceptionally strong performance in non-honors mathematics courses or of accomplishments in research. Applicants are expected to have completed the Mathematical Studies sequences in Algebra and Analysis or 21-355/21-356 and 21-373/ 21-341 prior to application.

In order to complete the Honors Degree Program, students must complete five mathematics graduate courses with grades of B- or better and write an honors thesis. At the time of admission, students will declare a timetable on which they plan to take the graduate courses, do the research required for the thesis, and write up their work: this timetable can naturally be adjusted as required. At most one of these five graduate courses may be applied towards the student's bachelor degree program.

At least three graduate courses must come from the list of Basic Examinations courses found at www.cmu.edu/math/grad/phd/requirements.html.

Currently these are listed as:

- General Topology (21-651)
- Functional Analysis (21-640)
- Measure and Integration (21-720)
- Probability (21-721)
- Discrete Mathematics (21-701)
- Probabilistic Combinatorics (21-737)
- Set Theory (21-602)
- Algebra (21-610)
- Model Theory (21-603)
- Differential Equations (21-632)

By special permission of the department, one graduate course with sufficient mathematical content offered in another department may be counted. The honors thesis may either be research-based or expository: expository theses must be at a high mathematical level, at least that of a second-year graduate course. Students should plan on finding a thesis advisor by the end of their junior year. Students are required to take the Masters Degree Reading and Research (21-901) course during their senior year, subject to the following conditions:

1. Students must complete a minimum of 15 units of 21-901 to earn the MS degree.
2. Students who have not defended their thesis by the Add Course Deadline during each of their last two semesters must register for a minimum of 3 units of 21-901 for that semester.
3. Students may not overload more than 66 units while taking 21-901.

The Master of Science degree in Mathematical Sciences may be earned together with a Bachelor of Science from another department.

Faculty

PETER B. ANDREWS, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1963–

JEREMY AVIGAD, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 1996–

ALBERT A. BLANK, Emeritus – Ph.D., New York University; Carnegie Mellon, 1969–

MANUEL BLUM, University Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1999–

THOMAS BOHMAN, Professor – Ph.D., Rutgers University; Carnegie Mellon, 1998–

DEBORAH BRANDON, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1991–

BORIS BUKH, Associate Professor – Ph.D., Princeton University; Carnegie Mellon, 2012–

CLINTON CONLEY, Associate Professor – Ph.D., University of California Los Angeles; Carnegie Mellon, 2014–

GERARD CORNUEJOLS, University Professor – Ph.D., Cornell University; Carnegie Mellon, 1978–

JAMES CUMMINGS, Professor – Ph.D., Cambridge University; Carnegie Mellon, 1996–

HASAN DEMIRKOPARAN, Associate Teaching Professor – Ph.D., Michigan State University; Carnegie Mellon, 2005–

JOANNA ELLIS-MONAGHAN, Shelly Visiting Professor – Ph.D., University of North Carolina, Chapel Hill; Carnegie Mellon, 2019–

TIMOTHY FLAHERTY, Associate Teaching Professor – Ph.D., University of Pittsburgh,; Carnegie Mellon, 1999–

IRENE M. FONSECA, University Professor – Ph.D., University of Minnesota; Carnegie Mellon, 1987–

FLORIAN FRICK, Assistant Professor – Ph.D., Technical University of Berlin; Carnegie Mellon, 2018–

ALAN M. FRIEZE, University Professor – Ph.D., University of London; Carnegie Mellon, 1987–

IRINA GHEORGHICIUC, Associate Teaching Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 2007–

RAMI GROSSBERG, Professor – Ph.D., Hebrew University of Jerusalem; Carnegie Mellon, 1988–

YU GU, Assistant Professor – Ph.D., Columbia University; Carnegie Mellon, 2017–

MORTON E. GURTIN, Emeritus – Ph.D., Brown University; Carnegie Mellon, 1966–

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JASON HOWELL, Associate Teaching Professor – Ph.D., Clemson University; Carnegie Mellon, 2017–

WILLIAM J. HRUSA, Professor – Ph.D., Brown University; Carnegie Mellon, 1982–

GAUTAM IYER, Professor – Ph.D., University of Chicago; Carnegie Mellon, 2009–

GREGORY JOHNSON, Associate Teaching Professor – Ph.D., University of Maryland; Carnegie Mellon, 2009–

NIRAJ KHARE, Visiting Assistant Professor – Ph.D., Ohio State University; Carnegie Mellon, 2014–

DAVID KINDERLEHRER, Professor – Ph.D., University of California at Berkeley; Carnegie Mellon, 1990–

DMITRY KRAMKOV, Professor – Ph.D., Steklov Mathematical Institute; Carnegie Mellon, 2000–

MARTIN LARSSON, Associate Professor – Ph.D., Cornell University; Carnegie Mellon, 2019–

JOHN P. LEHOCZKY, Professor – Ph.D., Stanford University; Carnegie Mellon, 1969–

GIOVANNI LEONI, Professor – Ph.D., University of Minnestota; Carnegie Mellon, 2002–

PO-SHEN LOH, Associate Professor – Ph.D., Princeton University; Carnegie Mellon, 2009–

JOHN MACKEY, Teaching Professor – Ph.D., University of Hawaii; Carnegie Mellon, 2003–

DANIELA MIHAI, Associate Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2007–

JOHANNES MUHLE-KARBE, Associate Professor – PhD, Technical University of Munich; Carnegie Mellon, 2017–

FERNANDO NERANGA, Shelly Visiting Assistant Professor – Ph.D., University of South Florida; Carnegie Mellon, 2019–

ROY A. NICOLAIDES, Emeritus – Ph.D., University of London; Carnegie Mellon, 1984–

DAVID OFFNER, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–

MARION L. OLIVER, Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004–

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WESLEY PEGDEN, Associate Professor – Ph.D., Rutgers University; Carnegie Mellon, 2013–

ROBERT L. PEGO, Professor – Ph.D., University of California at Berkeley; Carnegie Mellon, 2004–

AGOSTON PISZTORA, Associate Professor – Ph.D., ETH Zurich,; Carnegie Mellon, 1996–

HAYDEN SCHAEFFER, Associate Professor – Ph.D., University of California at Los Angeles; Carnegie Mellon, 2015–

JOHN W. SCHAEFFER, Professor – Ph.D., Indiana University; Carnegie Mellon, 1983–

ERNEST SCHIMMERLING, Professor – Ph.D., University of California at Los Angeles; Carnegie Mellon, 1998–

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ROBERT F. SEKERKA, University Professor – Ph.D., Harvard University; Carnegie Mellon, 1969–

STEVEN E. SHREVE, University Professor – Ph.D., University of Illinois; Carnegie Mellon, 1980–

DEJAN SLEPCEV, Professor – Ph.D., University of Texas at Austin; Carnegie Mellon, 2006–

RICHARD STATMAN, Professor – Ph.D., Stanford University; Carnegie Mellon, 1984–

SHLOMO TA'ASAN, Professor – Ph.D., Weizmann Institute; Carnegie Mellon, 1994–

LUC TARTAR, University Professor of Mathematics Emeritus – Ph.D., University of Paris; Carnegie Mellon, 1987–

IAN TICE, Associate Professor – Ph.D., New York University; Carnegie Mellon, 2012–

TOMASZ TKOCZ, Assistant Professor – Ph.D., University of Warwick; Carnegie Mellon, 2017–

RUSSELL C. WALKER, Emeritus – D.A., Carnegie Mellon University ; Carnegie Mellon, 1984–

NOEL S. WALKINGTON, Professor – Ph.D., University of Texas at Austin; Carnegie Mellon, 1989–

FRANZISKA WEBER, Assistant Professor – Ph.D., University of Oslo; Carnegie Mellon, 2018–

WILLIAM O. WILLIAMS, Emeritus – Ph.D., Brown University; Carnegie Mellon, 1966–

ZELEALEM YILMA, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2015–

Department of Mathematical Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

21-101 Freshman Mathematics Seminar
Intermittent: 3 units
This course is offered in the Fall semester for first semester Freshmen interested in majoring in mathematics. Topics vary from year to year. Recent topics have included Fermat's last theorem, finite difference equations, convexity, and fractals. 3 hrs. lec.

21-105 Pre-Calculus
Summer: 9 units
Review of basic concepts, logarithms, functions and graphs, inequalities, polynomial functions, complex numbers, and trigonometric functions and identities. Special summer program only. 3 hrs lec., 1 hr.rec.

21-111 Differential Calculus
Fall and Spring: 10 units
Review of basic algebra, functions, limits, derivatives of algebraic, exponential and logarithmic functions, curve sketching, maximum-minimum problems. Successful completion of 21-111 and 21-112 entitles a student to enroll in any mathematics course for which 21-120 is a prerequisite. 3 hrs. lec., 2 hrs. rec.

21-112 Integral Calculus
Fall and Spring: 10 units
Definite and indefinite integrals, and hyperbolic functions; applications of integration, integration by substitution and by parts. Successful completion of 21-111 and 21-112 entitles a student to enroll in any mathematics course for which 21-120 is a prerequisite. 3 hrs. lec., 2 hrs. rec.
Prerequisite: 21-111

21-115 Basic Differential Calculus
Summer: 5 units
Functions, limits, derivatives, curve sketching, Mean Value Theorem, trigonometric functions, related rates, linear and quadratic approximations, maximum-minimum problems. Special summer program only.

21-120 Differential and Integral Calculus
All Semesters: 10 units
Functions, limits, derivatives, logarithmic, exponential, and trigonometric functions, inverse functions; L'Hospital's Rule, curve sketching, Mean Value Theorem, related rates, linear and quadratic approximations, maximum-minimum problems, inverse functions, definite and indefinite integrals, and hyperbolic functions; applications of integration, integration by substitution and by parts. 3 hrs lec., 2 hrs. rec.

21-122 Integration and Approximation
All Semesters: 10 units
Integration by trigonometric substitution and partial fractions; arclength; improper integrals; Simpson's and Trapezoidal Rules for numerical integration; separable differential equations, Newton's method, Euler's method, Taylor's Theorem including a discussion of the remainder, sequences, series, power series. Parametric curves, polar coordinates, vectors, dot product. 3 hrs lec., 2 hrs. rec.
Prerequisites: 21-112 or 21-120

21-124 Calculus II for Biologists and Chemists
Spring: 10 units
This is intended as a second calculus course for biology and chemistry majors. It uses a variety of computational techniques based around the use of MATLAB or a similar system. Topics to be covered include: Integration: techniques and numerical integration. Ordinary differential equations: techniques for solving ODEs and numerical methods. Modeling with ODEs (e.g., infection, population models). Linear algebra: matrices, complex numbers, eigenvalues, eigenvectors. Systems of ordinary differential equations (if time allows: stability of differential systems). Probability: discrete and continuum probability, conditional probability and independence, limit theorems, important distributions, probabilistic models. 3 hrs. lec., 2 hrs. rec. Prerequisite: 21-112 or 21-120.
Prerequisites: 21-112 or 21-120

21-126 Introduction to Mathematical Software
Intermittent: 3 units
This course provides an introduction to the use of several software packages, which are useful to mathematics students. Among the packages are Maple and Mathematica for symbolic computing, TeX and LaTeX for mathematical documents, and Matlab for numerical computing. The course will also introduce the mathematical facilities built into spreadsheets such as Excel. The aim of the course is to provide the student with some basic skills in the use of this software without attempting complete coverage. A deeper knowledge of the software will be easy to obtain after completing this course. There are no prerequisites for the course, other than basic computer literacy and a knowledge of elementary mathematics. It is suggested that the course should be taken during the first two years of undergraduate studies.

21-127 Concepts of Mathematics
All Semesters: 10 units
This course introduces the basic concepts, ideas and tools involved in doing mathematics. As such, its main focus is on presenting informal logic, and the methods of mathematical proof. These subjects are closely related to the application of mathematics in many areas, particularly computer science. Topics discussed include a basic introduction to elementary number theory, induction, the algebra of sets, relations, equivalence relations, congruences, partitions, and functions, including injections, surjections, and bijections. A basic introduction to the real numbers, rational and irrational numbers. Supremum and infimum of a set. 3 hrs. lec., 2 hrs. rec.

21-128 Mathematical Concepts and Proofs
Fall: 12 units
This course is intended for MCS first-semester students who are interested in pursuing a major in mathematical sciences. The course introduces the basic concepts, ideas and tools involved in doing mathematics. As such, its main focus in on presenting informal logic, and the methods of mathematical proof. These subjects are closely related to the application of mathematics in many areas, particularly computer science. Topics discussed include a basic introduction to elementary number theory, induction, the algebra of sets, relations, equivalence relations, congruences, partitions, and functions, including injections, surjections, and bijections. A basic introduction to the real numbers, rational and irrational numbers. Supremum and infimum of a set. This course is a superset of 21-127, with additional out of class time devoted to proofs and additional topics in math. 3 hrs. lec., 2 hrs. rec.

21-201 Undergraduate Colloquium
Fall and Spring: 1 unit
All mathematics majors meet for one hour each week to hear discussions on current research by faculty or students, presentations on mathematics from mathematicians outside academia, and expository talks on selected mathematical topics not part of the usual curricula. Also will include topics of special interest to undergraduates such as preparation for graduate school.

21-228 Discrete Mathematics
Fall and Spring: 9 units
The techniques of discrete mathematics arise in every application of mathematics, which is not purely continuous, for example in computer science, economics, and general problems of optimization. This course introduces two of the fundamental areas of discrete mathematics: enumeration and graph theory. The introduction to enumeration includes permutations, combinations, and topics such as discrete probability, combinatorial distributions, recurrence relations, generating functions, Ramsey's Theorem, and the principle of inclusion and exclusion. The introduction to graph theory includes topics such as paths, walks, connectivity, Eulerian and Hamilton cycles, planar graphs, Euler's Theorem, graph coloring, matchings, networks, and trees. 3 hrs. lec, 1 hr. rec.
Prerequisites: 15-151 or 21-127 or 21-128

21-235 Mathematical Studies Analysis I
Fall: 12 units
An honors version of 21-355 for students of greater aptitude and motivation. Topics to be covered include: The Real Number System: sups and infs, completeness, integers and rational numbers. Metric spaces, normed spaces, inner product spaces and their specialization to the Euclidean space. Topological properties of metric spaces (open sets, closed sets, density, compactness, Heine-Borel Theorem). Sequences and convergence; completeness. Baire Category Theorem. Real sequences: limsup and liminf, subsequences, monotonic sequences, Bolzano-Weierstrass Theorem. Real series (criteria for convergence). Continuity, limits of functions, attainment of extrema, Intermediate Value Theorem, uniform continuity. Differentiation of functions of one variable: Chain Rule, local extrema, Mean-Value Theorems, L'Ho'pital's Rule, Taylor's Theorem. Riemann Integration: Partitions, upper and lower integrals, sufficient conditions for integrability, Fundamental Theorem of Calculus. 3 hrs. lec.
Prerequisites: (21-128 or 21-127) and 21-269

21-236 Mathematical Studies Analysis II
Spring: 12 units
An honors version of 21-356 for students of greater aptitude and motivation. Topics to be covered include: Vector differential calculus: differentiability, partial derivatives, directional derivatives, gradients, Jacobians, the chain rule, implicit function theorem, inverse function theorem. Local extrema, constrained problems (Lagrange multipliers). Integration of differential forms: Manifolds, Differential forms (properties, differentiation, change of variables), partition of unity, integration, volume form, area form, Stokes' theorem. Sequences of Functions: Pointwise convergence, uniform convergence, Arzela-Ascoli, Weierstrass approximation theorem. Series of functions: Power series, Fourier series, orthonormal bases. 3 hrs. lec.
Prerequisites: 21-242 and 21-235 Min. grade B

21-237 Mathematical Studies Algebra I
Fall: 12 units
An honors version of 21-373 Algebraic structures for students of greater aptitude and motivation. Abstract algebra is the study of algebraic systems by the axiomatic method, and it is one of the core areas of modern mathematics. This course is a rigorous and fast-paced introduction to the basic objects in abstract algebra. Topics to be covered include: Homomorphisms. Subgroups, cosets, Lagrange's theorem. Conjugation. Normal subgroups, quotient groups, first isomorphism theorem. Automorphisms, the automorphism group, characteristic subgroups. Group actions, Cauchy's Theorem, Sylow's theorem. Normalisers and centralisers, class equation, finite p-groups. Dihedral and alternating groups. The second and third isomorphism theorems. Simple groups, statement of Jordan-Holder theorem, semidirect product of groups. Subrings, ideals, quotient rings, first isomorphism theorem. Polynomial rings. Zorn's Lemma. Prime and maximal ideals, prime and irreducible elements. PIDs and UFDs. Noetherian domains. Hilbert Basis Theorem. Gauss' lemma. Eisenstein criterion. Field of fractions of an integral domain. k a field implies k[x] a PID, R a UFD implies R[x] a UFD. Finite fields and applications. 3 hrs. lec.
Prerequisites: (21-127 or 21-128 or 15-151) and 21-269

21-238 Mathematical Studies Algebra II
Spring: 12 units
An honors version of 21-341 Linear Algebra for students of greater aptitude and motivation. Linear algebra is a crucial tool in pure and applied mathematics. This course aims to introduce the main ideas at a high level of rigour and generality. The course starts with the study of (potentially) infinite-dimensional vector spaces over an arbitrary field, continues with the theory of modules (where the role of the field is now played by an arbitrary ring), and concludes with the development of real and complex inner product spaces. Topics to be covered include: Review of fields. Review of Zorn's Lemma. Vector spaces (possibly in finite dimensional) over an arbitrary field. Independent sets, bases, existence of a basis, exchange lemma, dimension. Linear transformations, dual space. Multilinear maps, tensor product, exterior power, determinant of a transformation. Eigenvalues, eigenvectors, characteristic and minimal polynomial of a transformation, Cayley-Hamilton theorem. Review of commutative rings. R-modules. Sums and quotients of modules. Free modules. Structure theorem for fg modules over a PID and applications (Jordan and rational canonical form, structure theory of fg abelian groups). Review of real and complex numbers. Real and complex inner product spaces. Orthonormal sets, orthonormal bases, Gram-Schmidt. Examples: F^n and l^2(F) for F = R; C. Operators: Symmetric/Hermitian and Orthogonal/Unitary operators. Spectral theorem. Quadratic forms. Singular value decomposition. Possible additional topics (time permitting): applications to combinatorics, category theory, representations of finite groups, normed spaces. 3 hrs. lec.
Prerequisites: 21-242 and 21-237 Min. grade B

21-240 Matrix Algebra with Applications
Fall and Spring: 10 units
Vectors and matrices, the solution of linear systems of equations, vector spaces and subspaces, orthogonality, determinants, real and complex eigenvalues and eigenvectors, linear transformations. The course is intended for students in Economics, Statistics, Information Systems, and it will focus on topics relevant to these fields. 3 hrs. lec., 1 hr. rec.

21-241 Matrices and Linear Transformations
All Semesters: 10 units
A first course in linear algebra intended for scientists, engineers, mathematicians and computer scientists. Students will be required to write some straightforward proofs. Topics to be covered: complex numbers, real and complex vectors and matrices, rowspace and columnspace of a matrix, rank and nullity, solving linear systems by row reduction of a matrix, inverse matrices and determinants, change of basis, linear transformations, inner product of vectors, orthonormal bases and the Gram-Schmidt process, eigenvectors and eigenvalues, diagonalization of a matrix, symmetric and orthogonal matrices. 21-127 is strongly recommended. 3 hrs. lec., 1 hr. rec

21-242 Matrix Theory
Fall: 10 units
An honors version of 21-241 (Matrix Algebra and Linear Transformations) for students of greater aptitude and motivation. More emphasis will be placed on writing proofs. Topics to be covered: complex numbers, real and complex vectors and matrices, rowspace and columnspace of a matrix, rank and nullity, solving linear systems by row reduction of a matrix, inverse matrices and determinants, change of basis, linear transformations, inner product of vectors, orthonormal bases and the Gram-Schmidt process, eigenvectors and eigenvalues, diagonalization of a matrix, symmetric and orthogonal matrices, hermitian and unitary matrices, quadratic forms. 3 hrs. lec., 1 hr. rec.

21-256 Multivariate Analysis
Fall and Spring: 9 units
This course is designed for students in Economics or Business Administration. Matrix algebra: vectors, matrices, systems of equations, dot product, cross product, lines and planes. Optimization: partial derivatives, the chain rule, gradient, unconstrained optimization, constrained optimization (Lagrange multipliers and the Kuhn-Tucker Theorem). Improper integrals. Multiple integration: iterated integrals, probability applications, triple integrals, change of variables. 3 hrs lec., 1 hr rec.
Prerequisites: 21-112 or 21-120

21-257 Models and Methods for Optimization
Intermittent: 9 units
Introduces basic methods of operations research and is intended primarily for Business Administration and Economics majors. Review of linear systems; linear programming, including the simplex algorithm, duality, and sensitivity analysis; the transportation problem; the critical path method; the knapsack problem, traveling salesman problem, and an introduction to set covering models. 3 hrs. lec., 1 hr. rec.
Prerequisites: 21-256 or 21-242 or 21-241 or 21-240 or 18-202 or 06-262

21-259 Calculus in Three Dimensions
All Semesters: 9 units
Vectors, lines, planes, quadratic surfaces, polar, cylindrical and spherical coordinates, partial derivatives, directional derivatives, gradient, divergence, curl, chain rule, maximum-minimum problems, multiple integrals, parametric surfaces and curves, line integrals, surface integrals, Green-Gauss theorems. 3 hrs. lec., 1 hr. rec.
Prerequisite: 21-122

21-260 Differential Equations
All Semesters: 9 units
Ordinary differential equations: first and second order equations, applications, Laplace transforms; partial differential equations: partial derivatives, separation of variables, Fourier series; systems of ordinary differential equations; applications. 21-259 or 21-268 or 21-269 are recommended. 3 hrs. lec., 1 hr. rec.
Prerequisite: 21-122

21-261 Introduction to Ordinary Differential Equations
Spring: 10 units
A first course in ordinary differential equations intended primarily for math majors and for those students interested in a more conceptual treatment of the subject. One of the goals of this course is to prepare students for upper level courses on differential equations, mathematical analysis and applied mathematics. Students will be required to write rigorous arguments. Topics to be covered: Ordinary differential equations: first and second order equations, applications, Laplace transform, systems of linear ordinary differential equations; systems of nonlinear ordinary differential equations, equilibria and stability, applications. Note: courses 21-259, or 21-268, or 21-269 are recommended. 21-128 or 15-151 can replace 21-127 as a corequisite. 3 hrs. lec., 1 hr. rec.
Prerequisite: 21-122

21-268 Multidimensional Calculus
Fall and Spring: 10 units
A serious introduction to multidimensional calculus that makes use of matrices and linear transformation. Results will be stated carefully and rigorously. Students will be expected to write some proofs; however, some of the deeper results will be presented without proofs. Topics to be covered include: functions of several variables, regions and domains, limits and continuity, partial derivatives, linearization and Jacobian matrices, chain rules, inverse and implicit functions, geometric applications, higher derivatives, Taylor's theorem, optimization, vector fields, multiple integrals and change of variables, Leibnitz's rule, line integrals, Green's theorem, path independence and connectedness, conservative vector fields, surfaces and orientability, surface integrals, divergence theorem and Stokes's theorem. 3 hrs. lec.
Prerequisites: 21-122 and (21-241 or 21-242)

21-269 Vector Analysis
Spring: 10 units
An honors version of 21-268 for students of greater aptitude and motivation. More emphasis will be placed on writing proofs. Topics to be covered include: basic geometry and topology of Euclidean space, curves in space, arclength, curvature and torsion, functions on Euclidean spaces, limits and continuity, partial derivatives, gradients and linearization, chain rules, inverse and implicit function theorems, geometric applications, higher derivatives, Taylor's theorem, optimization, vector fields, multiple integrals and change of variables, Leibnitz's rule, conservative and solenoidal vector fields, divergence and curl, surfaces and orientability, surface integrals, Gauss-Green theorems and Stokes's theorem. A grade of B or better in 21-242 is required. 3 hrs. lec.
Prerequisites: 21-122 and 21-242 Min. grade B

21-270 Introduction to Mathematical Finance
Spring: 9 units
This is a first course for those considering majoring or minoring in Computational Finance. The theme of this course is pricing derivative securities by replication. The simplest case of this idea, static hedging, is used to discuss net present value of a non-random cash flow, internal rate of return, and put-call option parity. Pricing by replication is then considered in a one-period random model. Risk-neutral probability measures, the Fundamental Theorems of Asset Pricing, and an introduction to expected utility maximization and mean-variance analysis are presented in this model. Finally, replication is studied in a multi-period binomial model. Within this model, the replicating strategies for European and American options are determined. 3 hrs. lec.
Prerequisites: 21-112 or 21-120

21-272 Introduction to Partial Differential Equations
Spring: 9 units
A Partial Differential Equation (PDE for short) is a differential equation involving derivatives with respect to more than one variable. These arise in numerous applications from various disciplines. A prototypical example is the heat equation, governing the evolution of temperature in a conductor. This course will serve as a first introduction to PDE's, and will focus on the most important model equations. It will cover both analytical methods (e.g. separation of variables, Green's functions), numerical methods (e.g. finite elements) and the use of a computer to approximate and visualize solutions. Time permitting, it will touch upon the mathematical ideas behind phenomena observed in nature (e.g. speed of wave propagation, and/or shocks in traffic flow).
Prerequisites: (21-269 or 21-259 or 21-268) and (21-260 or 33-231 or 21-261)

21-292 Operations Research I
Spring: 9 units
Operations research offers a scientific approach to decision making, most commonly involving the allocation of scarce resources. This course develops some of the fundamental methods used. Linear programming: the simplex method and its linear algebra foundations, duality, post-optimality and sensitivity analysis; the transportation problem; the critical path method; non-linear programming methods. 3 hrs. lec., 1 hr. rec.
Prerequisites: 21-122 and (21-240 or 21-241 or 21-242) and (15-251 or 21-228)

21-295 Putnam Seminar
Fall: 3 units
A problem solving seminar designed to prepare students to participate in the annual William Lowell Putnam Mathematical Competition. Students solve and present their solutions to problems posed.

21-296 Millennium Problems Seminar
Intermittent: 3 units
This seminar course will discuss some of the most important unsolved problems of mathematics (as deemed in 2000 by an international committee of mathematicians): The Riemann Hypothesis; Yang-Mills Theory and the Mass Gap Hypothesis; the P. vs. NP Problem; smoothness of solutions of the Navier-Stokes Equations; the Hodge Conjecture; the Birch and Swinnerton-Dyer Conjecture. If the time allows, the Poincare conjecture will also be discussed. 1 hr. lec.

21-300 Basic Logic
Fall: 9 units
Propositional and predicate logic: Syntax, proof theory and semantics up to completeness theorem, Lowenheim Skolem theorems, and applications of the compactness theorem. 3 hrs. lec.
Prerequisites: 15-251 or 21-228 or 21-373

21-301 Combinatorics
Fall and Spring: 9 units
A major part of the course concentrates on algebraic methods, which are relevant in the study of error correcting codes, and other areas. Topics covered in depth include permutations and combinations, generating functions, recurrence relations, the principle of inclusion and exclusion, and the Fibonacci sequence and the harmonic series. Additional topics may include existence proofs, partitions, finite calculus, generating combinatorial objects, Polya theory, codes, probabilistic methods. 3 hrs. lec
Prerequisites: 21-122 and (21-228 or 15-251)

21-302 Lambda Calculus
Intermittent: 9 units
An introductory course in classical lambda calculus, with an emphasis on syntax. The course will describe many research problems which are suitable topics for senior theses or master's theses. Topics will include: Basic properties of reduction and conversion; Reduction and conversion strategies; Calculability and representation of data types; Elementary theory of Ershov numberings; Bohm's theorem, easy terms, and other exotic combinations; Solvability of functional equations (unification); Combinatorics and bases; Simple and algebraic types; Labelled reduction and intersection types; Extensionality and the omega rule.
Prerequisites: 80-310 or 15-150 or 21-300

21-320 Symbolic Programming Methods
Intermittent: 9 units
The objective of this course is to learn to program in Maple, a powerful symbolic mathematics package available on many platforms at Carnegie Mellon. After learning what Maple can do with the commands provided with the package, students will learn to develop their own Maple functions to accomplish extended mathematical computations. Grades in the course will be based mostly on project work. Projects may come from any relevant field and may be graphical, numerical, or symbolic or all three. The course will involve online demonstrations in most classes. 3 hrs. lec.
Prerequisites: (15-151 or 21-127 or 21-128) and 21-122

21-325 Probability
Fall and Spring: 9 units
This course focuses on the understanding of basic concepts in probability theory and illustrates how these concepts can be applied to develop and analyze a variety of models arising in computational biology, finance, engineering and computer science. The firm grounding in the fundamentals is aimed at providing students the flexibility to build and analyze models from diverse applications as well as preparing the interested student for advanced work in these areas. The course will cover core concepts such as probability spaces, random variables, random vectors, multivariate densities, distributions, expectations, sampling and simulation; independence, conditioning, conditional distributions and expectations; limit theorems such as the strong law of large numbers and the central limit theorem; as well as additional topics such as large deviations, random walks and Markov chains, as time permits. 3 hrs. lec.
Prerequisites: 21-268 or 21-269 or 21-259

21-329 Set Theory
Spring: 9 units
Set theory was invented about 110 years ago by George Cantor as an instrument to understand infinite objects and to compare different sizes of infinite sets. Since then set theory has come to play an important role in several branches of modern mathematics, and serves as a foundation of mathematics. Contents: Basic properties of natural numbers, countable and uncountable sets, construction of the real numbers, some basic facts about the topology of the real line, cardinal numbers and cardinal arithmetic, the continuum hypothesis, well ordered sets, ordinal numbers and transfinite induction, the axiom of choice, Zorn's lemma. Optional topics if time permits: Infinitary combinatorics, filters and large cardinals, Borel and analytic sets of reals. 3 hrs. lec.
Prerequisites: 21-128 or 21-127 or 15-151

21-341 Linear Algebra
Fall and Spring: 9 units
21-341 Linear Algebra. A mathematically rigorous treatment of Linear Algebra over an arbitrary field. Topics studied will include abstract vector spaces, linear transformations, determinants, eigenvalues, eigenvectors, inner products, invariant subspaces, canonical forms, the spectral theorem and the singular value decomposition. 21-373 recommended. 3 hrs. lec.
Prerequisites: (21-241 and 21-373) or 21-242

21-344 Numerical Linear Algebra
Spring: 9 units
An introduction to algorithms pertaining to matrices and large linear systems of equations. Direct methods for large sparse problems including graph data structures, maximum matchings, row and column orderings, and pivoting strategies. Iterative methods including Conjugate Gradient and GMRES, with a discussion of preconditioning strategies. Additional topics include: computation of eigenvalues and eigenvectors, condition numbers, the QR and singular value decompositions, least-squares systems. 3 hrs. lec.
Prerequisites: 15-112 and (21-242 or 21-241 or 21-240) and (21-269 or 21-268 or 21-259)

21-350 History of Mathematics
Intermittent: 9 units
Mathematics has a long and interesting history, and there is much insight into both mathematics and history to be gained from its study. The emphasis here will be on learning the mathematics with the added value of appreciating it in historical context. Selected topics may range from early number systems, the development of geometry, the emergence of the ideas of analysis, through to the origins of modern set theory. 3 hrs. lec.

21-355 Principles of Real Analysis I
Fall and Spring: 9 units
This course provides a rigorous and proof-based treatment of functions of one real variable. The Real Number System: Field and order axioms, sups and infs, completeness, integers and rational numbers. Real Sequences: Limits, cluster points, limsup and liminf, subsequences, monotonic sequences, Cauchy's criterion, Bolzano-Weierstrass Theorem. Topology of the Real Line: Open sets, closed sets, density, compactness, Heine-Borel Theorem. Continuity: attainment of extrema, Intermediate Value Theorem, uniform continuity. Differentiation: Chain Rule, local extrema, Mean-Value Theorems, L'Hospital's Rule, Taylor's Theorem. Riemann Integration: Partitions, upper and lower integrals, sufficient conditions for integrability, Fundamental Theorem of Calculus. Sequences of Functions: Pointwise convergence, uniform convergence, interchanging the order of limits. The course presumes some mathematical sophistication including the ability to recognize, read, and write proofs. 3 hrs lec.
Prerequisites: (21-127 or 21-128 or 15-151) and 21-122

21-356 Principles of Real Analysis II
Fall and Spring: 9 units
This course provides a rigorous and proof-based treatment of functions of several real variables. Topology in metric spaces, specialization to finite dimensional normed linear spaces. Vector differential calculus: continuity and the total derivative, partial derivatives, directional derivatives, gradients, Jacobians, the chain rule, implicit function theorem. Vector integral calculus: double and triple integrals, arclength and surface area, line integrals, Green's Theorem, surface integrals, Divergence and Stokes Theorems. If time permits: trigonometric series, Fourier series for orthonormal bases, minimization of square error. The course presumes some mathematical sophistication including the ability to recognize, read, and write proofs. 21-268 or 21-269 are strongly recommended rather than 21-259. 3 hrs lec.
Prerequisites: (21-259 or 21-269 or 21-268) and 21-241 and 21-355

21-360 Differential Geometry of Curves and Surfaces
Intermittent: 9 units
The course is a rigorous introduction to the differential and integral calculus of curves and surfaces. Topics to be covered include: Parameterized and regular curves Frenet equations canonical coordinate system, local canonical forms, global properties of plane curves Regular surfaces, differential functions on surfaces, the tangent plane and differential of a map, orientation of surfaces, characterization of compact orientable surfaces, classification of compact surfaces The geometry of the Gauss map, isometries and conformal maps, parallel transport, geodesics, the Gauss-Bonnet theorem and applications. More topics may be covered, as time allows. Students should be prepared to write proofs and perform computations. 21-356 or 21-236 are recommended. 3 hrs. lec.
Prerequisites: 21-269 or 21-268

21-365 Projects in Applied Mathematics
Intermittent: 9 units
This course provides students with an opportunity to solve problems posed by area companies. It is also designed to provide experience working as part of a team to solve problems for a client. The background needed might include linear programming, simulation, data analysis, scheduling, numerical techniques, etc.

21-366 Topics in Applied Mathematics
Intermittent: 9 units
Typical of courses that might be offered from time to time are game theory, non-linear optimization, and dynamic programming. Prerequisites will depend on the content of the course. 3 hrs. lec.

21-369 Numerical Methods
Fall and Spring: 12 units
This course provides an introduction to the use of computers to solve scientific problems. Methods for the computational solution of linear algebra systems, nonlinear equations, the interpolation and approximation of functions, differentiation and integration, and ordinary differential equations. Analysis of roundoff and discretization errors and programming techniques. 21-268 or 21-269 are recommended rather than 21-259. 3 hrs. lec.
Prerequisites: (15-110 or 15-112) and (21-269 or 21-259 or 21-268) and (21-242 or 21-241 or 21-240) and (21-260 or 33-231 or 21-261)

21-370 Discrete Time Finance
Fall: 9 units
This course introduces the Black-Scholes option pricing formula, shows how the binomial model provides a discretization of this formula, and uses this connection to fit the binomial model to data. It then sets the stage for Continuous-Time Finance by discussing in the binomial model the mathematical technology of filtrations, martingales, Markov processes and risk-neutral measures. Additional topics are American options, expected utility maximization, the Fundamental Theorems of Asset Pricing in a multi-period setting, and term structure modeling, including the Heath-Jarrow-Morton model. Students in 21-370 are expected to read and write proofs. 3 hrs lec.
Prerequisites: (70-492 or 21-270) and (21-259 or 21-269 or 21-268 or 21-256)

21-371 Functions of a Complex Variable
Fall: 9 units
This course provides an introduction to one of the basic topics of both pure and applied mathematics and is suitable for those with both practical and theoretical interests. Algebra and geometry of complex numbers; complex differentiation and integration. Cauchy's theorem and applications; conformal mapping; applications. 21-268 or 21-269 are recommended rather than 21-259. 3 hrs. lec.
Prerequisites: 21-235 or 21-355

21-372 Partial Differential Equations and Fourier Analysis
Intermittent: 9 units
This course provides an introduction to partial differential equations and is recommended for majors in mathematics, physical science, or engineering. Boundary value problems on an interval, Fourier series, uniform convergence, the heat, wave, and potential equations on bounded domains, general theory of eigenfunction expansion, the Fourier integral applied to problems on unbounded domains, introduction to numerical methods. 21-268 and 21-269 are recommended rather than 21-259; and 21-261 is recommended rather than 21-260. 3 hrs. lec.
Prerequisites: (21-259 or 21-269 or 21-268) and (21-260 or 21-261)

21-373 Algebraic Structures
Fall and Spring: 9 units
Groups: Homomorphisms. Subgroups, cosets, Lagrange's theorem. Conjugation. Normal subgroups, quotient groups, first isomorphism theorem. Group actions, Cauchy's Theorem. Dihedral and alternating groups. The second and third isomorphism theorems. Rings: Subrings, ideals, quotient rings, first isomorphism theorem. Polynomial rings. Prime and maximal ideals, prime and irreducible elements. PIDs and UFDs. Noetherian domains. Gauss' lemma. Eisenstein criterion. Fields: Field of fractions of an integral domain. Finite fields. Applications to coding theory, cryptography, number theory. 3 hrs lec.
Prerequisites: (21-127 or 15-151 or 21-128) and (21-242 or 21-241)

21-374 Field Theory
Spring: 9 units
The purpose of this course is to provide a successor to Algebraic Structures, with an emphasis on applications of groups and rings within algebra to some major classical problems. These include constructions with a ruler and compass, and the solvability or unsolvability of equations by radicals. It also offers an opportunity to see group theory and basic ring theory "in action", and introduces several powerful number theoretic techniques. The basic ideas and methods required to study finite fields will also be introduced. These ideas have recently been applied in a number of areas of theoretical computer science including primality testing and cryptography. 3 hrs. lec.
Prerequisite: 21-373

21-377 Monte Carlo Simulation for Finance
Intermittent: 9 units
first course in Monte Carlo simulation, with applications to Mathematical Finance. Students will put into practice many of the theoretical ideas introduced in Continuous Time Finance. Topics to be covered: random variable/stochastic process generation; options pricing; variance reduction; Markov chain Monte Carlo Methods.
Prerequisites: 21-325 Min. grade B or 21-420

21-378 Mathematics of Fixed Income Markets
Fall: 9 units
A first course in fixed income. Students will be introduced to the most common securities traded in fixed income markets and the valuation methods used to price them. Topics covered include discount factors; interest rates basics; pricing of coupon bonds; identifying the yield to maturity, as well as bond sensitivities to interest rates; term structure modeling; forward and swap rates; fixed income derivatives (including mortgage backed securities) and their valuation through backwards induction; fixed income indexes and return attribution. For a co-requisite, 36-225 can be accepted as an alternative for 21-325.
Prerequisite: 21-270 Min. grade B

21-380 Introduction to Mathematical Modeling
Intermittent: 9 units
This course shall examine mathematical models, which may be used to describe natural phenomena. Examples, which have been studied include: continuum description of highway traffic, discrete velocity models of a monotonic gas, chemotactic behavior in biological systems, European options pricing, and cellular-automata. Systems such as the first four are described by partial differential equations; the last involves discrete-time and discrete-phase dynamical systems, which have been used to successfully represent both physical and biological systems. The course will develop these models and then examine the behavior of the underlying systems, both analytically and numerically. The mathematical tools required will be developed in the course.
Prerequisites: (21-241 or 21-242) and (21-260 or 21-261)

21-393 Operations Research II
Fall: 9 units
Building on an understanding of Linear Programming developed in 21-292 Operations Research I, this course introduces more advanced topics. Integer programming, including cutting planes and branch and bound. Dynamic programming. An introduction to Combinatorial Optimization including optimal spanning trees, shortest paths, the assignment problem and max-flow/min-cut. The traveling salesman problem and NP-completeness. An important goal of this course is for the student to gain experience with the process of working in a group to apply operations research methods to solve a problem. A portion of the course is devoted to a group project based upon case studies and the methods presented. 36-410 recommended. 3 hrs. lec.
Prerequisites: (15-251 or 21-228) and 21-292

21-400 Intermediate Logic
Intermittent: 9 units
The course builds on the proof theory and model theory of first-order logic covered in 21-300. These are applied in 21-400 to Peano Arithmetic and its standard model, the natural numbers. The main results are the incompleteness, undefinability and undecidability theorems of Godel, Tarski, Church and others. Leading up to these, it is explained how logic is formalized within arithmetic, how this leads to the phenomenon of self-reference, and what it means for the axioms of a theory to be computably enumerable. Related aspects of computability theory are included to the extent that time permits.
Prerequisite: 21-300

21-420 Continuous-Time Finance
Spring: 9 units
This course begins with Brownian motion, stochastic integration,and Ito's formula from stochastic calculus. This theory is used to develop the Black-Scholes option pricing formula and the Black-Scholes partial differential equation. Additional topics may include models of credit risk, simulation, and expected utility maximization. 3 hrs lec.
Prerequisites: (21-260 or 18-202) and 21-370 and (36-218 or 21-325 or 36-225 or 36-217)

21-435 Applied Harmonic Analysis
Intermittent: 9 units
This course serves as a broad introduction to harmonic analysis and its applications, particularly in 1-dimensional signal processing and in image processing, for undergraduate students in mathematics, engineering, and the applied sciences. Topics include: Discrete Fourier transform and fast Fourier transform; Fourier series and the Fourier transform; Hilbert spaces and applications; Shannon sampling theorem, bandlimited functions, uncertainty principle; Wavelets and multi-resolution analysis; Applications in image processing.
Prerequisites: (21-355 or 21-235) and (21-241 or 21-242)

21-441 Number Theory
Fall: 9 units
Number theory deals with the integers, the most basic structures of mathematics. It is one of the most ancient, beautiful, and well-studied branches of mathematics, and has recently found surprising new applications in communications and cryptography. Course contents: Structure of the integers, greatest common divisiors, prime factorization. Modular arithmetic, Fermat's Theorem, Chinese Remainder Theorem. Number theoretic functions, e.g. Euler's function, Mobius functions, and identities. Diophantine equations, Pell's Equation, continued fractions. Modular polynomial equations, quadratic reciprocity. 3 hrs. lec.
Prerequisites: (21-242 or 21-241) and 21-373

21-465 Topology
Intermittent: 9 units
Metric spaces. Topological spaces. Separation axioms. Open, closed and compact sets. Continuous functions. Product spaces, subspaces, quotient spaces. Connectedness and path-connectedness. Homotopy. Fundamental group of a pointed space. Simply connected spaces. Winding number, the fundamental group of the circle. Functorial property of the fundamental group. Brouwer fixed point theorem. Covering spaces. van Kampen's theorem. 2-manifolds. Triangulations. Euler characteristic. Surgery, classification of compact 2-manifolds. 3 hrs lec.
Prerequisites: 21-373 and 21-355

21-467 Differential Geometry
Intermittent: 9 units
This course will provide a thorough and rigorous introduction to differential geometry on manifolds. Contents: Differentiable manifolds; tangent spaces; vector fields and n-forms; integral curves; cotangent vectors; tensors; Riemannian metrics; connection; parallel transport; geodesics and convex neighborhoods; sectional, Ricci, scalar curvatures; tensors on Riemannian manifolds; Lie groups; transformation groups.
Prerequisites: 21-356 and 21-373

21-469 Computational Introduction to Partial Differential Equations
Intermittent: 9 units
A Partial Differential Equation (PDE for short) is a differential equation involving derivatives with respect to more than one variable. These arise in numerous applications from various disciplines. Most PDEs do not have explicit solutions, and hence computational methods are essential for understanding the underlying phenomena. This course will serve as a first introduction to PDEs and their numerical approximation, and will focus on a variety of mathematical models. It will cover both analytical methods, numerical methods (e.g. finite differences) and the use of a computer to approximate and visualize solutions. The mathematical ideas behind phenomena observed in nature will be studied at the theoretical level and in numerical simulations (e.g. speed of wave propagation, and/or shocks in traffic flow). Topics will include: Derivation of PDEs from physical principles, analytical and computational tools for the transport equation and the Poisson equation, Fourier analysis, analytical and numerical techniques for the solution of parabolic equations and if time permits, the wave equation.
Prerequisites: (21-241 or 21-240 or 21-242) and (21-268 or 21-259 or 21-269) and (21-261 or 21-260 or 33-231) and (15-110 or 15-112)

21-470 Selected Topics in Analysis
Intermittent: 9 units
Typical of courses, which are offered from time to time are finite difference equations, calculus of variations, and applied control theory. The prerequisites will depend on the content of the course. 3 hrs. lec.
Prerequisites: 21-259 and 21-260 and 21-241

21-476 Introduction to Dynamical Systems
Intermittent: 9 units
This course is an introduction to differentiable dynamical systems. The material includes basic properties of dynamical systems, including the existence and uniqueness theory, continuation, singular points, orbits, and their classification. The Poincare'-Bendixson theorem and typical applications, like Lienard equations and Lotka-Volterra are also covered. An introduction to chaos as time permits. 3 hrs. lec.
Prerequisites: (21-242 or 21-241) and 21-261

21-484 Graph Theory
Spring: 9 units
Graph theory uses basic concepts to approach a diversity of problems and nontrivial applications in operations research, computer science and other disciplines. It is one of the very few mathematical areas where one is always close to interesting unsolved problems. Topics include graphs and subgraphs, trees, connectivity, Euler tours and Hamilton cycles, matchings, graph colorings, planar graphs and Euler's Formula, directed graphs, network flows, counting arguments, and graph algorithms. 3 hrs. lec.
Prerequisites: (21-228 or 15-251) and (21-242 or 21-241)

21-499 Undergraduate Research Topic
Intermittent: 9 units
This course affords undergraduates to pursue elementary research topics in the area of expertise of the instructor. The prerequisites will depend on the content of the course.

21-590 Practicum
All Semesters
Students in this course gain experience with the application of mathematical models to business and/or industrial problems during an internship. The internship is set up by the student in consultation with a faculty member. The students must also have a mentor at the firm providing the internship, who together with the faculty member develops a description of the goals of the internship. The internship must include the opportunity to learn about problems which have mathematical content.

21-599 Undergraduate Reading and Research
Fall and Spring
Individual reading courses or projects in mathematics and its applications. Prerequisites and units to be negotiated with individual instructors.

21-600 Mathematical Logic I
Intermittent: 12 units
The study of formal logical systems, which model the reasoning of mathematics, scientific disciplines, and everyday discourse. Propositional Calculus and First-order Logic. Syntax, axiomatic treatment, derived rules of inference, proof techniques, computer-assisted formal proofs, normal forms, consistency, independence, semantics, soundness, completeness, Lowenheim-Skolem Theorem, compactness, equality. 3 hrs. lec.
Prerequisites: 21-228 Min. grade B or 21-373 Min. grade B or 21-484 Min. grade B

21-602 Introduction to Set Theory I
Fall: 12 units
First order definability and the Zermelo-Fraenkel axioms; cardinal arithmetic, ordered sets, well-ordered sets (axiom of choice), transfinite induction, the filter of closed unbounded sets (Fodor, Ulm and Solovay's theorems), Delta systems, basic results in partition calculus (e.g., Ramsey's Theorem and the Erdos-Rado Theorem); small to medium large cardinals; applications to general topology (e.g., Alexandroff's conjecture), and the basic ideas of descriptive set theory. The independence of Suslin conjecture from the usual axioms. Godel's axiom of constructibility. Time permitting, the Galvin-Hajnal-Shelah inequality will be proved. 3 hrs. lec.

21-603 Model Theory I
Intermittent: 12 units
Similarity types, structures; downward Lowenheim Skolem theorem; construction of models from constants, Henkin's omitting types theory, prime models; elementary chains of models, basic two cardinal theorems, saturated models, basic results on countable models including Ryll-Nardzewski's theorem; indiscernible sequences, Ehrenfeucht-Mostowski models; introduction to stability, rank functions, primary models, and a proof of Morley's catagoricity theorem; basic facts about infinitary languages, computation of Hanf-Morley numbers.

21-604 Introduction to Recursion Theory
Intermittent: 12 units
Models of computation, computable functions, solvable and unsolvable problems, reducibilities among problems, recursive and recursively enumerable sets, the recursion theorem, Post's problem and the Friedberg-Muchnik theorem, general degrees and r.e. degrees, the arithmetical hierarchy, the hyper-arithmetical hierarchy, the analytical hierarchy, higher type recursion. 3 hrs. lec.

21-610 Algebra I
Intermittent: 12 units
The structure of finitely generated abelian groups, the Sylow theorems, nilpotent and solvable groups, simplicity of alternating and projective special linear groups, free groups, the Neilsen-Schreier theorem. Vector spaces over division rings, field extensions, the fundamental Galois correspondence, algebraic closure. The Jacobson radical and the structure of semisimple rings. Time permitting, one of the following topics will be included: Wedderburn's theorem on finite division rings, Frobenius' Theorem. Prerequisite: Familiarity with the content of an undergraduate course on groups and rings. 3 hrs. lec.

21-620 Real Analysis
Fall: 6 units
A review of one-dimensional, undergraduate analysis, including a rigorous treatment of the following topics in the context of real numbers: sequences, compactness, continuity, differentiation, Riemann integration. (Mini-course. Normally combined with 21-621.) 3 hrs. lec.

21-621 Introduction to Lebesgue Integration
Fall: 6 units
Construction of Lebesgue measure and the Lebesgue integral on the real line. Fatou's Lemma, the monotone convergence theorem, the dominated convergence theorem. (Mini-course. Normally combined with 21-620.) 3 hrs. lec.

21-630 Ordinary Differential Equations
Intermittent: 12 units
Basic concepts covered are existence and uniqueness of solutions, continuation of solutions, continuous dependence, and stability. For autonomous systems, topics included are: orbits, limit sets, Liapunov's direct method, and Poincar-Bendixson theory. For linear systems, topics included are: fundamental solutions, variation of constants, stability, matrix exponential solutions, and saddle points. Time permitting, one or more of the following topics will be covered: differential inequalities, boundary-value problems and Sturm-Liouville theory, Floquet theory.

21-632 Introduction to Differential Equations
Fall: 12 units
This course serves as a broad introduction to Ordinary and Partial Differential Equations for beginning graduate students and advanced undergraduate students in mathematics, engineering, and the applied sciences. Mathematical sophistication in real analysis at the level of 21-355/356 is assumed. Topics include: essentials of Ordinary Differential Equations, origins of Partial Differential Equations, the study of model problems including the Poisson and Laplace equations, the heat equation, the transport equation, and the wave equation. 3 hrs. lec.

21-640 Introduction to Functional Analysis
Spring: 12 units
Linear spaces: Hilbert spaces, Banach spaces, topological vector spaces. Hilbert spaces: geometry, projections, Riesz Representation Theorem, bilinear and quadratic forms, orthonormal sets and Fourier series. Banach spaces: continuity of linear mappings, Hahn-Banach Theorem, uniform boundedness, open-mapping theorem. Closed operators, closed graph theorem. Dual spaces: weak and weak-star topologies (Banach-Alaoglu Theorem), reflexivity. Space of bounded continuous functions and its dual. Linear operators and adjoints: basic properties, null spaces and ranges. Compact operators. Sequences of bounded linear operators: weak, strong and uniform convergence. Introduction to spectral theory: Notions of spectrum and resolvent set of bounded operators, spectral theory of compact operators. Time permitting: Fredholm Alternative. Time permitting: Stone-Weierstrass Theorem.
Prerequisites: 21-651 and (21-621 or 21-720)

21-651 General Topology
Fall: 12 units
Metric spaces: continuity, compactness, Arzela-Ascoli Theorem, completeness and completion, Baire Category Theorem. General topological spaces: bases and subbases, products, quotients, subspaces, continuity, topologies generated by sets of functions, homeomorphisms. Convergence: nets, filters, and the inadequacy of sequences. Separation: Hausdorff spaces, regular spaces, completely regular spaces, normal spaces, Urysohn's Lemma, Tietze's Extension Theorem. Connectedness. Countability conditions: first and second countability, separability, Lindelof property. Compactness: Tychonoff's Theorem, local compactness, one-point compactification. 3 hrs. lec.

21-660 Introduction to Numerical Analysis I
Spring: 12 units
Finite precision arithmetic, interpolation, spline approximation, numerical integration, numerical solution of linear and nonlinear systems of equations, optimization in finite dimensional spaces. 3 hrs. lec.
Prerequisite: 21-632

21-690 Methods of Optimization
Fall: 12 units
An introduction to the theory and algorithms of linear and nonlinear programming with an emphasis on modern computational considerations. The simplex method and its variants, duality theory and sensitivity analysis. Large-scale linear programming. Optimality conditions for unconstrained nonlinear optimization. Newton's method, line searches, trust regions and convergence rates. Constrained problems, feasible-point methods, penalty and barrier methods, interior-point methods.

21-700 Mathematical Logic II
Intermittent: 12 units
Higher-order logic (type theory). Syntax, Lambda-notation, Axioms of Description and Choice, computer-assisted formal proofs, semantics, soundness, standard and non-standard models, completeness, compactness, formalization of mathematics, definability of natural numbers, representability of recursive functions, Church's Thesis. Godel's Incompleteness Theorems, undecidability, undefinability.
Prerequisites: 21-300 or 21-600

Course Website: http://gtps.math.cmu.edu/description-700.txt

21-701 Discrete Mathematics
Fall: 12 units
Combinatorial analysis, graph theory with applications to problems in computational complexity, networks, and other areas.

21-720 Measure and Integration
Fall: 12 units
The Lebesgue integral, absolute continuity, signed measures and the Radon-Nikodym Theorem, Lp spaces and the Riesz Representation Theorem, product measures and Fubini's Theorem.

21-721 Probability
Spring: 12 units
Probability spaces, random variables, expectation, independence, Borel-Cantelli lemmas. Kernels and product spaces, existence of probability measures on infinite product spaces, Kolmogorov's zero-one law. Weak and strong laws of large numbers, ergodic theorems, stationary sequences. Conditional expectation: characterization, construction and properties. Relation to kernels, conditional distribution, density. Filtration, adapted and predictable processes, martingales, stopping times, upcrossing inequality and martingale convergence theorems, backward martingales, optional stopping, maximal inequalities. Various applications of martingales: branching processes, Polya's urn, generalized Borel-Cantelli, Levy's 0-1 law, martingale method, strong law of large numbers, etc. Weak convergence of probability measures, characteristic functions of random variables, weak convergence in terms of characteristic functions. Central limit theorem, Poisson convergence, Poisson process. Large deviations, rate functions, Cramer's Theorem.
Prerequisite: 21-720

21-723 Advanced Real Analysis
Spring: 12 units
This course is a sequel to 21-720 (Measure and Integration). It is meant to introduce students to a number of important advanced topics in analysis.Topics include: distributions, Fourier series and transform, Sobolev spaces, Bochner integration, basics of interpolation theory, integral transforms. 3 hrs. lec.Prerequisites: 21-720 Corequisites: 21-640
Prerequisite: 21-720

21-724 Sobolev Spaces
Intermittent: 12 units
Weak derivatives, Sobolev spaces of integer order, embedding theorems, interpolation inequalities, traces.

21-732 Partial Differential Equations I
Fall: 12 units
An introduction to the modern theory of partial differential equations. Including functional analytic techniques. Topics vary slightly from year to year, but generally include existence, uniqueness and regularity for linear elliptic boundary value problems and an introduction to the theory of evolution equations.

21-737 Probabilistic Combinatorics
Intermittent: 12 units
This course covers the probabilistic method for combinatorics in detail and introduces randomized algorithms and the theory of random graphs. Methods covered include the second moment method, the Rödl nibble, the Lovász local lemma, correlation inequalities, martingale's and tight concentration, Janson's inequality, branching processes, coupling and the differential equations method for discrete random processes. Objects studied include the configuration model for random regular graphs, Markov chains, the phase transition in the Erdős-Rényi random graph, and the Barabási-Albert preferential attachment model.

21-738 Extremal Combinatorics
Intermittent: 12 units
Classical problems and results in extremal combinatorics including the Turán and Zarankiewicz problems, the Erdős-Stone theorem and the Erdos-Simonovits stability theorem. Extremal set theory including the Erdős-Rado sunflower lemma and variations, VC-dimension, and Kneser's conjecture. The Szemeredi regularity lemma. Algebraic methods including finite field constructions and eigenvalues and expansion properties of graphs. Shannon capacity of graphs. Chromatic number of Rn and Borsuk's conjecture. Graph decomposition including Graham-Pollack and Baranyai's theorem.

21-832 Partial Differential Equations II
Intermittent: 12 units
Elliptic boundary value problems, Green's theorem calculations, integral equation methods, variational formulations and Galerkin's method, regularity theory, parabolic problems and semigroups.

21-901 Masters Degree Research
All Semesters
Missing Course Description - please contact the teaching department.

Department of Physics

Scott Dodelson, Head
Location: Wean Hall 7325

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Location: Wean Hall 7303

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Physics, one of the basic sciences, has its origin in the irrepressible human curiosity to explore and understand the natural world. This fundamental urge to discover has led to the detailed understanding of a remarkable variety of physical phenomena. Our knowledge now encompasses the large-scale movement of galaxies, the minute motions within atoms and nuclei, and the complex structure of the assemblies of molecules that make life possible. The spectacular expansion of our comprehension of the physical world forms an impressive part of the intellectual and cultural heritage of our times. The opportunity to add to this heritage is an important source of motivation for young physicists. The application of discoveries in physics to the solution of complex modern technological problems offers a vast field in which physicists make decisive contributions. The interplay of pure and applied physics has always been fruitful and today ensures many rewarding career opportunities for physics students. The deep understanding of the physical world developed by physics majors prepares them for successin a wide variety of careers well beyond physics, from medicine to all the sciences and engineering.

Carnegie Mellon's undergraduate curriculum in physics has been carefully designed to provide a firm knowledge of the basic principles of physics, an appreciation of a wide range of physical problems of current interest, and the capacity to formulate and solve new problems. In addition to classwork and problem solving, the curriculum includes studying physical phenomena in the laboratory. Physics students are strongly encouraged to go beyond the formal theoretical and experimental course work and become involved in research projects under the guidance of individual faculty members.

Students may choose from a variety of degree options. The objectives and requirements for each of these options are described below. Each allows considerable latitude in the choice of electives:

- B.S. in Physics (p. 603)
- B.A. in Physics (p. 605)
- B.S. in Physics with Tracks in: (p. 606)
  - Applied Physics
  - Astrophysics
  - Biological Physics
  - Chemical Physics
  - Computational Physics
- Minor in Physics (http://coursecatalog.web.cmu.edu/melloncollegeofscience/departmentofphysics/#minorinphysicstext)

Students pursuing a B.S. in Physics, with any track, will take all courses from the Physics, Mathematics, and Technical Core lists, and take an appropriate selection of courses from the Technical, Non-Technical, Physics Breadth, and Qualifying Physics Elective lists. These lists are detailed below.

- Physics Core (p. 603)
- Mathematics Core (p. 603)
- Technical Core (p. 603)
- Technical Electives (p. 606)
- Non-Technical Elective (p. 538)
- Physics Breadth Electives (p. 606)
- Qualifying Physics Electives (p. 606)
- Recommended Electives for Graduate School (p. 606)
- Physics Graduate Courses (p. 606)

Through the judicious choice of elective courses, a double major program combining physics and another discipline can be readily achieved. A minor in physics is also offered for those students who major in other disciplines. The student, with the help of their faculty advisors, can easily build a program that aims at specific career objectives.

- Physics as an Additional Major (http://coursecatalog.web.cmu.edu/melloncollegeofscience/departmentofphysics/#doublemajordualdegreetext)
- Physics as a Dual Degree (http://coursecatalog.web.cmu.edu/melloncollegeofscience/departmentofphysics/#doublemajordualdegreetext)
- Minor in Physics (http://coursecatalog.web.cmu.edu/melloncollegeofscience/departmentofphysics/#minorinphysicstext)

The Department maintains an active and wide-ranging program of advising. Beyond aiding in academic planning, the Assistant Head of Undergraduate Affairs can also assist students in finding research work during the academic year, technical jobs and internships for the summer, as well as planning and executing the necessary steps for gaining employment or continuing their studies beyond the bachelor's degree. Whether students follow a standard curriculum or not, they should consult their academic advisor at least once every semester.

- Sample Schedule for a B.S. in Physics (p. 603)

B.S. in Physics

B.S. degree candidates can choose studies in not only a wide variety of intermediate and advanced topics in physics but also a range of material in other science or engineering fields. The B.S. degree provides a solid foundation for students wishing to go on to graduate work in physics or any of a large number of fields in pure or applied science or engineering, for which a sound grasp of physics and mathematics is essential. This program also provides excellent preparation for careers in teaching, for work in industrial or governmental research and development, or for other employment in business or industry with a significant scientific component.

Degree Requirements

Physics Core:

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

		Units
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-104	Experimental Physics	9
33-201	Physics Sophomore Colloquium I	2
33-211	Physics III: Modern Essentials	10
33-231	Physical Analysis	10
33-202	Physics Sophomore Colloquium II	2
33-228	Electronics I	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
33-301	Physics Upperclass Colloquium I	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-341	Thermal Physics I	10
33-302	Physics Upperclass Colloquium II	1
33-340	Modern Physics Laboratory	10
Total Physics Core Units		129

Mathematics Core:

All physics majors take these calculus courses from the Department of Mathematics to support their studies in physics.

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	9
Total Mathematics Core Units		29

Technical Core:

All students in the Mellon College of Science take courses in the Life Sciences, Physical Sciences, and Mathematics, Statistics, or Computer Science to gain the technical breadth necessary for interdisciplinary work. The following three courses have been selected specifically for physics majors to give them the technical breadth they need.

		Units
03-121	Modern Biology [1]	9
09-105	Introduction to Modern Chemistry I [2]	10
15-110	Principles of Computing [3]	10-12
or 15-112	Fundamentals of Programming and Computer Science	
Total Technical Core Units		29-31

[1] If 03-121 is satisfied through placement credit, students should refer to the Mellon College of Science's Life Sciences list to fulfill technical breadth requirement A.

[2] If 09-105 is satisfied through placement credit, students should refer to the Mellon College of Science's Physical Sciences list to fulfill technical breadth requirement B.

[3] If 15-112 is satisfied through placement credit, students should refer to the Mellon College of Science's STEM Course list to fulfill technical breadth requirement D.

Technical Electives:

Physics majors can choose to increase the breadth or depth of their studies through their choices of Technical Electives. Students may choose these electives individually or may take a pre-set selection of technical electives known as a "track" to focus on a specific subfield of physics. **The five available tracks are detailed below.**

		Units
33-xxx	Physics Breadth Elective	9-12
33-xxx	Three Qualifying Physics Electives	27-37
21-2xx	Mathematics Elective	9-10
xx-xxx	Three STEM Electives [4]	27-36
Total Technical Electives Units		72-95

[4] STEM electives are any courses in MCS (including Physics), SCS, Statistics, CIT, and others explicitly approved by the Assistant Head for Undergraduate Affairs.

Non-Technical Electives:

The Mellon College of Science requires that all students take a variety of non-technical courses to strengthen their understanding of both themselves and the world at large.

		Units
99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-230	ENGAGE in Wellness: Looking Inward	1
38-330	ENGAGE in Wellness: Looking Outward	1
38-430	ENGAGE in Wellness: Looking Forward	1
38-302-38-303	Science and Society - Professional Development and Life Skills	6
or 70-246	Innovation & Entrepreneurial Mindset	
xx-xxx	Cultural/Global Understanding Elective [5]	9
xx-xxx	Four Non-Technical Electives [6]	36
Total Non-Technical Units		75

[5] Refer to the Mellon College of Science's Cultural/Global Understanding list for courses that will fulfill this requirement. Placement credit may not be used.

[6] Refer to the Mellon College of Science's Arts, Humanities, and Social Sciences section for courses that will fulfill the non-technical electives requirement. Up to 18 units may be fulfilled through placement credit.

Free Electives:

All students must complete a minimum of 360 units to earn a bachelor's degree in the Mellon College of Science. Students are welcome to take more than the minimum 360 units required.

		Units
xx-xxx	Free Electives [7]	1-26
Total Free Elective Units		1-26

[7] A maximum of 9 units of physical education and/or military science and/or STUCO courses may be taken as free electives.

Sample Schedule (No Track)

BEGINNING FALL 2015 AND BEYOND

First Year

Fall		Units
99-101	Computing @ Carnegie Mellon	3
38-101	EUREKA!: Discovery and Its Impact	6
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
21-120	Differential and Integral Calculus	10
xx-xxx	MCS/Physics Technical Core Requirement 1 of 3	9-12
76-101	Interpretation and Argument	9
or 76-100	Reading and Writing in an Academic Context	
First-Year Fall Units		49-52

Spring		Units
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-104	Experimental Physics	9
21-122	Integration and Approximation	10
xx-xxx	MCS/Physics Technical Core Requirement 2 of 3	9-12
76-101	Interpretation and Argument xx-xxx::Non-Technical elective 1 of 4	9
First-Year Spring Units		49-52

Sophomore Year

Fall		Units
33-201	Physics Sophomore Colloquium I	2
33-211	Physics III: Modern Essentials	10
33-231	Physical Analysis	10
21-259	Calculus in Three Dimensions	9
xx-xxx	MCS/Physics Technical Core Requirement 3 of 3	9-12
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
xx-xxx	Cultural/Global Understanding Elective	9-12
Sophomore Fall Units		52-58

Spring		Units
38-230	ENGAGE in Wellness: Looking Inward	1
33-202	Physics Sophomore Colloquium II	2
33-228	Electronics I	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
xx-xxx	Technical Elective 1 of 8	9-12
Sophomore Spring Units		42-45

Junior Year

Fall		Units
38-330	ENGAGE in Wellness: Looking Outward	1
33-301	Physics Upperclass Colloquium I	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-341	Thermal Physics I	10
xx-xxx	Technical Elective 2 of 8	9-12
Junior Fall Units		41-44

Spring		Units
38-302-38-303	Science and Society - Professional Development and Life Skills	6
or 70-246	Innovation & Entrepreneurial Mindset	
33-302	Physics Upperclass Colloquium II	1
33-340	Modern Physics Laboratory	10
xx-xxx	Technical Elective 3 of 8	9-12
xx-xxx	Technical Elective 4 of 8	9-12

xx-xxx	Non-Technical Elective 2 of 4	9-12
Junior Spring Units		44-53

Senior Year

Fall		Units
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Technical Elective 5 of 8	9-12
xx-xxx	Technical Elective 6 of 8	9-12
xx-xxx	Non-Technical Elective 3 of 4	9-12
xx-xxx	Free Elective	9-12
xx-xxx	Free Elective	9-12
Senior Fall Units		46-61

Spring		Units
xx-xxx	Technical Elective 7 of 8	9-12
xx-xxx	Technical Elective 8 of 8	9-12
xx-xxx	Non-Technical Elective 4 of 4	9-12
xx-xxx	Free Elective	9-12
Senior Spring Units		36-48

B.A. in Physics

The Bachelor of Arts degree in Physics offers a flexible program that allows students to combine the study of Physics with the opportunity to do intensive work in substantive areas such as liberal arts, teaching, business or law. With 82 units of free electives, it is feasible for students to obtain, for example, a double major with a department in the Dietrich College of Humanities and Social Sciences, the College of Fine Arts, or the Tepper School of Business. It is expected that students will focus their elective courses in a well-defined academic area. Students must meet with the Assistant Head for Undergraduate Affairs and construct an approved plan of study.

The requirements for the B.A. degree are the same as for the B.S. degree, except that 6 of the Physics, Mathematics and Technical Electives in the B.S. program become Free Electives in the BA program. These requirements are listed below.

Degree Requirements

Physics Core:

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

		Units
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-104	Experimental Physics	9
33-201	Physics Sophomore Colloquium I	2
33-211	Physics III: Modern Essentials	10
33-231	Physical Analysis	10
33-202	Physics Sophomore Colloquium II	2
33-228	Electronics I	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
33-301	Physics Upperclass Colloquium I	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-341	Thermal Physics I	10
33-302	Physics Upperclass Colloquium II	1
33-340	Modern Physics Laboratory	10
Total Physics Core Units		129

Mathematics Core:

All Physics Majors take these courses from the Department of Mathematics to support their studies in Physics.

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	9
Total Mathematics Core Units		29

Technical Core:

All students in the Mellon College of Science take courses in the Life Sciences, Physical Sciences, and Mathematics, Statistics, or Computer Science to gain the technical breadth necessary for interdisciplinary work. These three courses have been selected specifically for Physics Majors to give them the technical breadth they need

		Units
03-121	Modern Biology [8]	9
09-105	Introduction to Modern Chemistry I [9]	10
15-112	Fundamentals of Programming and Computer Science [10]	10-12
or 15-110	Principles of Computing	
Total Technical Core Units		29-31

[8] If 03-121 is satisfied through placement credit, students should refer to the Mellon College of Science's Life Sciences list to fulfill technical breadth requirement A.

[9] If 09-105 is satisfied through placement credit, students should refer to the Mellon College of Science's Physical Sciences list to fulfill technical breadth requirement B.

[10] If 15-112 is satisfied through placement credit, students should refer to the Mellon College of Science's STEM Course list to fulfill technical breadth requirement D.

Technical Electives:

While students pursuing a B.S. in Physics are required to take a minimum of 8 Physics, Mathematics, and STEM electives, students pursuing a B.A. in Physics need only take a minimum of 2 Qualifying Physics Electives.

		Units
33-xxx	Two Qualifying Physics Electives	18-24
Total Technical Electives		18-24

Non-Technical Electives:

The Mellon College of Science requires that all students take a variety of non-technical courses to strengthen their understanding of both themselves and the world at large. The precise requirements are different for those entering before and after the Fall of 2015.

		Units
99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-230	ENGAGE in Wellness: Looking Inward	1
38-330	ENGAGE in Wellness: Looking Outward	1
38-302-38-303	Science and Society - Professional Development and Life Skills	6
or 70-246	Innovation & Entrepreneurial Mindset	
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Cultural/Global Understanding Elective [11]	9
xx-xxx	Four Non-Technical Electives [12]	36
Total Non-Technical Elective Units		75

[11] Refer to the Mellon College of Science's Cultural/Global Understanding list for courses that will fulfill this requirement. Placement credit may not be used.

[12] Refer to the Mellon College of Science's Arts, Humanities, and Social Sciences section for courses that will fulfill the non-technical electives requirement. Up to 18 units may be fulfilled through placement credit.

Free Electives:

All students must complete a minimum of 360 units to earn a bachelor's degree in the Mellon College of Science. Students are welcome to take more than the minimum 360 units required. The B.A. in Physics replaces 6 Technical Electives with Free Electives, compared to the B.S. in Physics.

		Units
xx-xxx	Free Electives [13]	72-80
Tota Free Electives		72-80

[13] A maximum of 9 units of physical education and/or military science and/or StuCo courses may be taken as free electives.

Physics Electives

Physics Breadth Electives

Students pursuing a B.S. in Physics must take at least one course from the Physics Breadth Elective list to gain experience in a subfield of physics. Some tracks have this course prescribed, while others allow free choice from this list. All of these courses may also be taken as Qualifying Physics Electives, but they may not fulfill both requirements simultaneously. Certain courses are offered only in alternate years, as indicated.

		Units
33-224	Stars, Galaxies and the Universe	9
33-353	Intermediate Optics (Alt. Fall - F20, F22)	12
33-355	Nanoscience and Nanotechnology (Alt. Fall - F19, F21)	9
33-441	Introduction to BioPhysics	10
33-444	Introduction to Nuclear and Particle Physics	9
33-448	Introduction to Solid State Physics	9
33-466	Extragalactic Astrophysics and Cosmology	9
33-467	Astrophysics of Stars and the Galaxy	9
33-650	General Relativity	9

Total Physics Breadth Elective Units 9-12

Qualifying Physics Electives

Students pursuing a B.S. in Physics must take at least three courses totaling at least 27 units from the Qualifying Physics Elective list, not including the 100-level courses. Some tracks have these courses prescribed, while others allow free choice from this list, allowing students to choose between broad and in-depth study. Students pursuing a B.A. in Physics must take at least two courses totaling at least 18 units from this list. Students pursuing a Minor in Physics must take at least three courses totaling at least 27 units from this list or non-prescribed courses from the Physics Core list. While all courses on the Physics Breadth Elective list are also on the Qualifying Physics Elective list, a course may not fulfill both requirements simultaneously. Certain courses are offered only in alternate years, as indicated.

33-114	Physics of Musical Sound (B.A. and Minor only) [14]	9
33-120	Science and Science Fiction (B.A. and Minor only) [14]	9
33-224	Stars, Galaxies and the Universe	9
33-241	Introduction to Computational Physics	9
33-332	Physical Mechanics II	10
33-339	Intermediate Electricity and Magnetism II	10
33-342	Thermal Physics II	10
33-350	Undergraduate Research [15]	Var.
33-353	Intermediate Optics (Alt. Fall - F18, F20)	12
33-355	Nanoscience and Nanotechnology (Alt. Fall - F17, F19)	9
33-398	Special Topics	9
33-441	Introduction to BioPhysics	10
33-444	Introduction to Nuclear and Particle Physics	9
33-445	Advanced Quantum Physics I	9
33-446	Advanced Quantum Physics II	9
33-448	Introduction to Solid State Physics	9
33-451	Senior Research [15]	Var.
33-456	Advanced Computational Physics	9
33-466	Extragalactic Astrophysics and Cosmology	9
33-467	Astrophysics of Stars and the Galaxy	9
33-499	Supervised Reading [15]	Var.
33-650	General Relativity	9
33-7xx	Physics Graduate Level Courses (see list below)	

Total Qualifying Physics Electives Units 27-37

[14] Only one of these two courses (33-114 and 33-120) may be used for the B.A.

[15] Only one of these three courses (33-350, 33-451, and 33-499) of at least 9 units may be used as a Qualifying Physics Elective. Any exceptions must be approved by the Assistant Head for Undergraduate Affairs.

Qualifying Physics Electives Recommended for Graduate School

Students planning to undertake graduate studies in physics are strongly advised to take the following courses, which count as Qualifying Physics Electives and STEM Electives.

		Units
33-332	Physical Mechanics II	10
33-339	Intermediate Electricity and Magnetism II	10
33-445	Advanced Quantum Physics I	9
33-446	Advanced Quantum Physics II	9

Qualifying Physics Electives Recommended for Graduate School in Physics

Physics Graduate Courses

These courses are intended for graduate students in physics, but may be taken by advanced undergraduates as Qualifying Physics or STEM Electives.

		Units
33-755	Quantum Mechanics I	12
33-756	Quantum Mechanics II	12
33-759	Introduction to Mathematical Physics I	12
33-761	Classical Electrodynamics I	12
33-762	Classical Electrodynamics II	12
33-765	Statistical Mechanics	12
33-767	Biophysics: From Basic Concepts to Current Research	12
33-769	Quantum Mechanics III: Many Body and Relativistic Systems	12
33-770	Field Theory I	12
33-771	Field Theory II	12
33-777	Introductory Astrophysics	12
33-779	Introduction to Nuclear and Particle Physics	12
33-780	Nuclear and Particle Physics II	12
33-783	Solid State Physics	12

Physics Graduate Course Units Optional

Tracks for B.S. in Physics

Students seeking a B.S. in Physics may choose from 5 different Physics tracks, or opt to pursue no track. Each of these tracks fulfills the Technical Electives of the B.S. in Physics. The available tracks are:

- Applied Physics
- Astrophysics
- Biological Physics
- Chemical Physics
- Computational Physics

The track descriptions and requirements are listed below.

No Track

Physics students wanting maximum freedom can opt not to select a track. The required Technical Electives are those described in the B.S. in Physics section above, and are reprinted below.

		Units
33-xxx	Physics Breadth Elective	9-12
33-xxx	Three Qualifying Physics Electives	27-37
21-2xx	Mathematics Elective	9-10
xx-xxx	Three STEM Electives [16]	27-36
Total Technical Elective Units		72-95

[16] STEM electives are any courses in MCS (including Physics), SCS, Statistics, CIT, and others explicitly approved by the Assistant Head for Undergraduate Affairs.

Applied Track

The B.S. in Physics/Applied Physics Track is designed primarily for students who want to prepare for a career path that takes advantage of the diverse and expanding opportunities for employment in industrial and government laboratories with a B.S. degree. The program provides a solid foundation in the concepts of physics, as well as giving the student the experience and understanding of the application of these concepts. The track is intended to enhance computing and laboratory skills, and to introduce the application of physics to those subjects of particular interest to the student. Since the possible subject areas for study are so varied, the track will be tailored to each student's needs within the framework described below.

		Units
33-448	Introduction to Solid State Physics	9
xx-xxx	Computational Science Course [17]	9-12
21-2xx	Four Applied Physics/Laboratory Electives [17]	36-48
33-350	Undergraduate Research [15]	9-15
or 33-451	Senior Research	
21-2xx	Mathematics Elective	9-10
Total Applied Track Elective Units		72-94

[17] The elective courses and research topic are decided after consultation with, and approval by, the Assistant Head for Undergraduate Affairs.

Astrophysics Track

The B.S. in Physics/Astrophysics Track provides an option for those Physics majors who either want to specialize in this subfield or plan careers in astronomy or astrophysics. Career paths may include postgraduate training in astronomy or astrophysics or proceeding directly to jobs in these fields. The program provides a thorough foundation in the core physics program with electives concentrating in astrophysics.

		Units
33-224	Stars, Galaxies and the Universe	9
33-466	Extragalactic Astrophysics and Cosmology	9
33-467	Astrophysics of Stars and the Galaxy	9
33-350	Undergraduate Research [18]	9-15
or 33-451	Senior Research	
21-2xx	Mathematics Elective	9-10
xx-xxx	Three STEM Electives	27-36
Total Astrophysics Track Elective Units		72-88

[18] The research topic must be approved by the Assistant Head for Undergraduate Affairs.

Biological Physics Track

The B.S. in Physics/Biological Physics Track combines a rigorous foundation in undergraduate physics with courses in Biological Physics and Chemistry. It is particularly suitable for students preparing for post-baccalaureate careers in the expanding areas of biological and medical physics or for graduate study in biophysics. The program is sufficiently flexible that it can be readily adapted to the requirements of individual students. The student will first meet with the Assistant Head for Undergraduate Affairs to discuss interests and career goals and then choose electives that fulfill the requirements of the track.

The Biological Physics Track is excellent preparation for Medical School. All courses suggested for medical school applicants can be completed within this track. Students interested in both the Biological Physics Track and the pre-medical program should consult with both the Assistant Head for Undergraduate Affairs in the Physics Department and the Director of the Health Professions Program for help in planning their programs.

Program optimized for Biological Physical studies:

		Units
33-441	Introduction to BioPhysics	9-10
or 03-439	Introduction to Biophysics	
33-xxx	One Qualifying Physics Elective	9-12
21-2xx	Mathematics Elective	9-10
03-231	Honors Biochemistry	9
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
03-xxx	Two Biological Sciences Electives [19]	18
Total Biological Physics Track Elective Units		72-77

[19] The elective courses in Biological Sciences are decided after consultation with, and approval by, the Assistant Head for Undergraduate Affairs.

Program optimized for Medical School preparation:

		Units
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-202	Physiology	9
03-124	Modern Biology Laboratory	9
or 03-206	Biomedical Engineering Laboratory	
or 03-343	Experimental Techniques in Molecular Biology	
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
or 09-221	Laboratory I: Introduction to Chemical Analysis	
09-207	Techniques in Quantitative Analysis	9
or 09-221	Laboratory I: Introduction to Chemical Analysis	
09-217	Organic Chemistry I	9
or 09-219	Modern Organic Chemistry	
09-218	Organic Chemistry II	9
or 09-220	Modern Organic Chemistry II	
09-208	Techniques for Organic Synthesis and Analysis	9
or 09-222	Laboratory II: Organic Synthesis and Analysis	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
33-122	Physics II for Biological Sciences and Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	
33-100	Basic Experimental Physics	6
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
21-111	Differential Calculus	10
or 21-120	Differential and Integral Calculus	
21-112	Integral Calculus (A semester of statistics may substitute for a semester of calculus at many medical schools.) [14]	10
or 21-122	Integration and Approximation	
or 21-124	Calculus II for Biologists and Chemists	
36-200	Reasoning with Data	9
or 36-202	Statistics & Data Science Methods	
or 36-247	Statistics for Lab Sciences	
76-101	Interpretation and Argument	9
76-xxx	English II Elective	9
85-xxx	Psychology Elective (Intro to Psychology, Social Psychology)	9
xx-xxx	Intro to Sociology (not offered at CMU)	9
Total Biological Physics Track Elective Units		184

Chemical Physics Track

The B.S. in Physics/Chemical Physics Track is designed for students wishing to have a strong grounding in physics along with a specialization in physical chemistry and/or chemical physics. It is particularly suitable for those students planning on graduate studies in physics with an emphasis on chemical physics or chemistry. The program is sufficiently flexible that it can be readily adapted to the requirements of individual students. The student will first meet with the Assistant Head for Undergraduate Affairs to discuss interests and career goals and then choose electives that fulfill the requirements of the track.

		Units
33-xxx	One Physics Breadth Elective	9-12
21-2xx	Mathematics Elective	9-10
09-106	Modern Chemistry II	10
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9

09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-xxx	Three Chemistry Electives [20]	27
Total Chemical Physics Track Elective Units		73-77

[20] The elective courses in Chemistry are decided after consultation with, and approval by, the Assistant Head for Undergraduate Affairs.

Computational Physics Track

The B.S. in Physics/Computational Physics Track is intended to fill the increasing demand for physics graduates who are skilled in computational and numerical techniques which are used in the analysis of physical problems and in subjects ranging from control and real-time programming to software engineering and compiler and operating systems design. The degree provides the student with a rigorous grounding in physics as well as in the foundations and practice of computer use as applied to scientific problems. Work is done on machines ranging from high-level workstations through supercomputers.

		Units
33-241	Introduction to Computational Physics	9
33-456	Advanced Computational Physics	9
33-xxx	One Physics Breadth Elective	9-12
33-xxx	One Qualifying Physics Elective	9-12
21-127	Concepts of Mathematics	10
21-369	Numerical Methods	12
15-122	Principles of Imperative Computation [21]	10
15-150	Principles of Functional Programming [21]	10
Total Computational Physics Track Elective Units		78-84

[21] The student must check with the Assistant Head for Undergraduate Affairs to confirm that these are the latest required Computer Science courses for this track.

Additional Major or Dual Degree in Physics

Physics may be taken as an additional major (also known as a “double major”) or as a second degree, with another department granting the primary degree. The rules of the Physics Department for these two options are distinct, as discussed below.

Additional Major

In order to receive an Additional Major in Physics, with another department granting the primary degree — with a B.S. or B.A., alone or with any track — all requirements of the Physics degree and the particular physics track, as listed in the previous sections, must be fulfilled except:

- No STEM Electives are required
- No Non-Technical Electives are required
- 03-121 Modern Biology is not required
- 09-105 Introduction to Modern Chemistry I is not required
- No Free Electives are required

The full requirements are described below:

Physics Core:

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

		Units
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-104	Experimental Physics	9
33-201	Physics Sophomore Colloquium I	2
33-211	Physics III: Modern Essentials	10
33-231	Physical Analysis	10
33-202	Physics Sophomore Colloquium II	2
33-228	Electronics I	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
33-301	Physics Upperclass Colloquium I	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-341	Thermal Physics I	10
33-302	Physics Upperclass Colloquium II	1
33-340	Modern Physics Laboratory	10
Total Physics Core Units		129

Mathematics Core:

All physics majors take these calculus courses from the Department of Mathematics to support their studies in physics.

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	9
Total Mathematics Core Units		29

Technical Core for an Additional Major:

Students pursuing an additional major in physics do not need to fulfill the full Technical Core required by the Mellon College of Science, but are still required to take either 15-110 or 15-112 (or an equivalent course as pre-approved by the Associate Dean of the Mellon College of Science).

		Units
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
Total Technical Core Units		10-12

Technical Electives for an Additional Major:

Students pursuing an additional major in physics must take the Physics Electives and Mathematics Elective required of physics as the primary major, but do not need to take the STEM electives. Students may choose these electives individually, but are encouraged to consider the Physics Tracks (p. 606) described in the B.S. in Physics section as sets of courses that are designed to support specific career goals.

		Units
33-xxx	Physics Breadth Elective	9-12
33-xxx	3 Qualifying Physics Electives	27-37
21-2xx	Mathematics Elective	9-10
Total Technical Electives		45-59

Dual Degree

In order to receive a Dual Degree in another subject and Physics, all requirements of the Physics degree must be fulfilled. Students may choose to complete the B.A. or the B.S. in Physics, with or without a track. Students must complete both the technical and non-technical requirements, and should consult with the Assistant Head for Undergraduate Affairs for questions about double counting. The number of units required is 90 more than the total units required by the department requiring the fewer total units. Since Physics requires 360 units, the lowest possible minimum for a Dual Degree with Physics is 450 units.

Minor in Physics

The Minor in Physics is designed to provide a solid foundation in physics at the introductory level, followed by elective courses which will familiarize the student with areas of modern physics, and the concepts and techniques employed therein. The physics minor requires seven courses of at least 9 units each, of which four are required and three are electives.

The Minor is open to all students in the university, but students with non-calculus-based majors should be aware of the mathematics requirements for many physics courses (21-120, 21-122, and 21-259).

		Units
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
or 33-151	Matter and Interactions I	
33-122	Physics II for Biological Sciences and Chemistry Students	12
or 33-142	Physics II for Engineering and Physics Students	

or 33-152	Matter and Interactions II	
33-104	Experimental Physics	9
33-211	Physics III: Modern Essentials	10
33-xxx	Three Qualifying Physics Electives or Physics Core Electives [22]	27-37
Total Physics Minor Units		70-80

[22] The physics electives are decided after consultation with, and approval by, the Assistant Head for Undergraduate Affairs. Students may take courses from the Qualifying Physics List or additional courses from the Physics Core list, such as Quantum Physics or Electronics I.

Faculty

JOHN ALISON, Assistant Professor of Physics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2018–

DAVID ANDERSON, Assistant Teaching Professor of Physics – Ph.D., University of York (UK) ; Carnegie Mellon, 2008–

SHILADITYA BANERJEE, Assistant Professor of Physics – Ph.D., Syracuse University; Carnegie Mellon, 2020–

ROY A. BRIERE, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1999–

HAEL COLLINS, Assistant Teaching Professor of Physics – Ph.D., Harvard University; Carnegie Mellon, 2019–

RUPERT CROFT, Professor of Physics – Ph.D., Oxford University; Carnegie Mellon, 2001–

MARKUS DESERNO, Professor of Physics – Ph. D., University of Mainz, Germany; Carnegie Mellon, 2007–

TIZIANA DI MATTEO, Professor of Physics – Ph.D., University of Cambridge; Carnegie Mellon, 2004–

SCOTT DODELSON, Professor of Physics; Head, Department of Physics – Ph.D., Columbia University; Carnegie Mellon, 2017–

ULRIKE ENDESFELDER, Associate Professor of Physics – Ph.D., Bielefeld University; Carnegie Mellon, 2020–

RANDALL M. FEENSTRA, Professor of Physics – Ph.D., California Institute of Technology; Carnegie Mellon, 1995–

STEPHEN GAROFF, Professor of Physics – Ph.D., Harvard University; Carnegie Mellon, 1988–

KUNAL GHOSH, Teaching Professor of Physics, Assistant Head for Undergraduate Affairs, Department of Physics – Ph.D., Iowa State University; Carnegie Mellon, 2001–

FREDERICK J. GILMAN, Buhl Professor of Physics – Ph.D., Princeton University; Carnegie Mellon, 1995–

FRANK HEINRICH, Research Associate of Physics – Ph.D., University of Leipzig; Carnegie Mellon, 2008–

BENJAMIN HUNT, Assistant Professor of Physics – Ph.D., Cornell University; Carnegie Mellon, 2009–

TINA KAHNIASHVILI, Research Associate Professor of Physics – Ph.D., Russian Academy of Sciences; Carnegie Mellon, 2010–

JYOTI KATOCH, Assistant Professor or Physics – Ph.D., University of Central Florida; Carnegie Mellon, 2018–

SERGEY KOPOSOV, Assistant Professor of Physics – Ph.D., University of Heidelberg; Carnegie Mellon, 2016-–

MATHIAS LOSCHE, Professor of Physics – Ph.D., Technical University of Munich; Carnegie Mellon, 2005–

BARRY B. LUOKKALA, Teaching Professor of Physics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1980–

SARA A. MAJETICH, Professor of Physics – Ph.D., University of Georgia; Carnegie Mellon, 1990–

RACHEL MANDELBAUM, Associate Professor in Physics – Ph.D., Princeton University; Carnegie Mellon, 2012–

CURTIS A. MEYER, Professor of Physics; Associate Dean, Mellon College of Science – Ph.D., University of California, Berkeley; Carnegie Mellon, 1993–

COLIN J. MORNINGSTAR, Professor of Physics – Ph.D., University of Toronto; Carnegie Mellon, 2000–

DIANA PARNO, Assistant Professor of Physics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

MANFRED PAULINI, Professor of Physics; Associate Dean, Mellon College of Science – Ph.D., University of Erlangen, Germany; Carnegie Mellon, 2000–

RICCARDO PENCO, Assistant Professor of Physics – Ph.D., Syracuse University; Carnegie Mellon, 2018–

JEFFREY B. PETERSON, Professor of Physics – Ph.D., University of California, Berkeley; Carnegie Mellon, 1993–

BRIAN P. QUINN, Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1988–

IRA Z. ROTHSTEIN, Professor of Physics – Ph.D., University of Maryland at College Park; Carnegie Mellon, 1997–

REINHARD A. SCHUMACHER, Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1987–

SIMRANJEET SINGH, Research Assistant Professor of Physics – Ph.D., University of Central Florida; Carnegie Mellon, 2018–

HY TRAC, Associate Professor of Physics – Ph.D., University of Toronto; Carnegie Mellon, 2010–

MATTHEW WALKER, Assistant Professor of Physics – Ph.D., University of Michigan; Carnegie Mellon, 2013–

MICHAEL WIDOM, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1985–

DI XIAO, Associate Professor of Physics – Ph.D., University of Texas, Austin; Carnegie Mellon, 2012–

Emeriti Faculty

LUC BERGER, Professor of Physics, Emeritus – Ph.D., University of Lausanne, Switzerland; Carnegie Mellon, 1960–

ARNOLD ENGLER, Professor of Physics, Emeritus – Ph.D., University of Berne, Switzerland; Carnegie Mellon, 1962–

THOMAS A. FERGUSON, Professor of Physics, Emeritus – Ph.D., University of California at Los Angeles; Carnegie Mellon; Carnegie Mellon, 1985–

JOHN G. FETKOVICH, Professor of Physics, Emeritus – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1959–

GREGG B. FRANKLIN, Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1984–

RICHARD GRIFFITHS, Professor of Physics, Emeritus – Ph.D., University of Leicester, U.K.; Carnegie Mellon, 1996–

ROBERT GRIFFITHS, University Professor of Physics, Emeritus – Ph.D, Stanford University; Carnegie Mellon, 1962–

RICHARD F. HOLMAN, Professor of Physics, Emeritus – Ph.D., John Hopkins University; Carnegie Mellon; Carnegie Mellon, 1987–

LEONARD S. KISSLINGER, Professor of Physics, Emeritus – Ph.D., Indiana University; Carnegie Mellon, 1969–

GEORGE KLEIN, Associate Teaching Professor of Physics – Ph.D., New York University; Carnegie Mellon, 1993–

ROBERT W. KRAEMER, Professor of Physics, Emeritus – Ph.D., Johns Hopkins University; Carnegie Mellon, 1965–

MICHAEL J. LEVINE, Professor of Physics, Emeritus – Ph.D., California Institute of Technology; Carnegie Mellon, 1968–

LING-FONG LI, Professor of Physics, Emeritus – Ph.D., University of Pennsylvania; Carnegie Mellon, 1974–

JOHN F. NAGLE, Professor of Physics, Emeritus – Ph.D., Yale University; Carnegie Mellon, 1967–

JAMES S. RUSS, Professor of Physics, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1967–

ROBERT T. SCHUMACHER, Professor of Physics, Emeritus – Ph.D., University of Illinois; Carnegie Mellon, 1957–

ROBERT F. SEKERKA, University Professor of Physics and Mathematics, Emeritus – Ph.D., Harvard ; Carnegie Mellon, 1969–

ROBERT M. SUTER, Professor of Physics, Emeritus – Ph.D., Clark University; Carnegie Mellon, 1981–

ROBERT H. SWENDSEN, Professor of Physics, Emeritus – Ph.D., University of Pennsylvania; Carnegie Mellon, 1984–

STEPHANIE TRISTRAM-NAGLE, Research Professor of Physics, Emerita – Ph.D., University of California, Berkeley; Carnegie Mellon, 1986–

NED S. VANDER VEN, Professor of Physics, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1961–

HELMUT VOGEL, Professor of Physics, Emeritus – Ph.D. , University of Erlangen-Nuremberg; Carnegie Mellon, 1983–

Joint Appointments and Courtesy Appointments

SHELLEY ANNA, Professor of Chemical Engineering – Ph.D., Harvard University; Carnegie Mellon, 2003–

AXEL BRANDENBURG, Adjunct Professor of Physics – Ph.D., University of Helsinki; Carnegie Mellon, 2018–

SHIRLEY HO, Adjunct Associate Professor of Physics – Ph.D., Princeton University; Carnegie Mellon, 2012–

MOHAMMAD F. ISLAM, Associate Research Professor of Materials Science & Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2005–

NOA MAROM, Assistant Professor of Material Science and Engineering – Ph.D., Weizmann of Science; Carnegie Mellon, 2016–

MICHAEL E. MCHENRY, Professor of Materials Science and Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–

ANTHONY D. ROLLETT, Professor of Materials Science & Engineering – Ph.D., Drexel University; Carnegie Mellon, 1995–

MAREK SKOWRONSKI, Professor of Material Science and Engineering – Ph.D., Warsaw University; Carnegie Mellon, 1988–

VENKAT VISWANATHAN, Assistant Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2014–

JIAN-GANG ZHU, Professor of Electrical and Computer Engineering – Ph.D., University of California San Diego; Carnegie Mellon, 1997–

Department of Physics Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

33-100 Basic Experimental Physics
All Semesters: 6 units
This course provides students with a basic introduction to experimental physics. The content of the course and the particular experiments to be carried out are chosen to be especially useful for students who intend to work in the health sciences. Specific topics will range from mechanics to nuclear and atomic physics. This course is specifically geared toward pre-health students.

33-101 First Year Seminar
Fall
Various seminars are offered that introduce first-year students to current topics of modern physics. These are mini courses that meet for half a semester. In the past, seminar topics have included: Science and Science Fiction, Astrophysics, Black Holes, Cosmology and Supernovae, Elementary Particles, and The Building Blocks of Matter. These seminars are open only to MCS first year students.

33-104 Experimental Physics
All Semesters: 9 units
This course provides first year students and sophomores with an introduction to the methods of experimental physics. Particular emphasis is placed on three aspects of experimentation: laboratory technique, including both the execution and the documentation of an experiment; data analysis, including the treatment of statistical and systematic errors and computer-aided analysis of experimental data; and written communication of experimental procedures and results. The concepts and skills for measurement and data analysis are acquired gradually through a series of experiments covering a range of topics from mechanics to nuclear and atomic physics.

33-106 Physics I for Engineering Students
Fall and Spring: 12 units
This is a first semester, calculus-based introductory physics course. Basic principles of mechanics and thermodynamics are developed. Topics include vectors, displacement, velocity, acceleration, force, equilibrium, mass, Newton's laws, gravitation, work, energy, momentum, impulse, temperature, heat, equations of state, thermodynamic processes, heat engines, refrigerators, first and second laws of thermodynamics, and the kinetic theory of gases.

33-107 Physics II for Engineering Students
Fall and Spring: 12 units
This is the second half of a two-semester calculus-based introductory physics sequence for engineering students. The course covers waves, including standing and travelling waves, superposition, beats, reflection, interference, electricity, including electrostatics and electric fields, Gauss' law, electric potential, and simple circuits, magnetism, including magnetic forces, magnetic fields, induction and electromagnetic radiation.
Prerequisites: 33-106 and 21-120

33-111 Physics I for Science Students
Fall and Spring: 12 units
This calculus based course combines the basic principles of mechanics with some quantum physics and relativity to explain nature on both a microscopic and macroscopic scale. The course will build models to describe the universe based on a small number of fundamental physics principles. Some simple computer modeling will be done to develop insight into the solving of problems using Newton's laws. Topics covered will include vectors, momentum, force, gravitation, oscillations, energy, quantum physics, center of mass motion, angular momentum, statistical physics, and the laws of thermodynamics. No computer experience is needed.

33-112 Physics II for Science Students
Fall and Spring: 12 units
This is the second semester course that follows 33-111. Electricity and magnetism is developed, including the following topics: Coulomb's law, polarization, electric field, electric potential, DC circuits, magnetic field and force, magnetic induction, and the origins of electromagnetic waves.
Prerequisites: 33-111 and 21-120

33-114 Physics of Musical Sound
Spring: 9 units
An introduction to the physics and psychophysics of musical sound. Elementary physics of vibrating systems. Propagation of sound: traveling waves, reflection, and diffraction. Addition of waves: interference and beats. Anatomy of the ear and the perception of sound: loudness, pitch, and timbre. Standing waves and natural modes. Qualitative description of general periodic systems by Fourier analysis: the harmonic series and complex musical tones. The acoustics of musical instruments including percussion instruments, such as drums, bars, and struck and plucked strings; and instruments exhibiting self-sustained oscillations, including bowed strings, blown pipes, reeds, brasses, and singing. Intervals and consonance, musical scales, tuning and temperament. Basic room and auditorium acoustics. There are no formal prerequisites, but an ability to read music and having some previous musical experience will be very useful.

33-115 Physics for Future Presidents
Fall: 9 units
Countless topics of social and political importance are intimately related to science in general and physics in particular. Examples include energy production, global warming, radioactivity, terrorism, and space travel. This course aims to provide key bits of knowledge based on which such issues can be discussed in a meaningful way, i.e., on the level of arguments and not just vague beliefs. We will cover an unusually wide range of topics, including energy, heat, gravity, atoms, radioactivity, chain reactions, electricity, magnetism, waves, light, weather, and climate. No calculus or algebra will be required. The course is open for all students at CMU.

33-120 Science and Science Fiction
Summer: 9 units
We will view and critique the science content in a selection of science fiction films, spanning more than 100 years of cinematic history, and from sci-fi TV shows from the past 50+ years. Guided by selected readings from current scientific literature, and aided by order-of-magnitude estimates and careful calculations, we will ponder whether the films are showing things which may fall into one of the following categories: Science fiction at the time of production, but currently possible, due to recent breakthroughs. Possible, in principle, but beyond our current technology. Impossible by any science we know. Topics to be covered include the future of the technological society, the physics of Star Trek, the nature of space and time, extraterrestrial intelligence, robotics and artificial intelligence, biotechnology and more. Success of this course will depend upon class participation. Students will be expected to contribute to discussion of assigned readings and problems, and to give brief presentations in class on assigned films.

33-121 Physics I for Science Students
Fall and Spring: 12 units
This calculus-based course combines the basic principles of mechanics with some quantum physics and relativity to explain nature on both a microscopic and macroscopic scale. The course will build models to describe the universe based on a small number of fundamental physics principles. Some simple computer modeling will be done to develop insight into the solving of problems using Newton's laws. Topics covered will include vectors, momentum, force, gravitation, oscillations, energy, quantum physics, center of mass motion, rotation, angular momentum, statistical physics, and the laws of thermodynamics. No computer experience is needed. Examples illustrating basic principles being presented will be taken from physics, chemistry, and biology.

33-122 Physics II for Biological Sciences and Chemistry Students
Fall and Spring: 9 units
This is the second course in the introductory physics sequence for chemistry and biological science majors. The course will consist of eight portions covering (1) electrostatics and dynamics, (2) electrical circuits, (3) magnetism, (4) waves, (5) optics, (6) diffusive motion, and (7) hydrostatic forces and flow. Emphasis will be put on the application of the underlying physical principles in the study of biology and chemistry.
Prerequisites: (21-120 and 33-121) or 33-151 or 33-141 or (21-120 and 33-111) or 33-131 or 33-106

33-124 Introduction to Astronomy
Fall: 9 units
Astronomy continues to enjoy a golden age of exploration and discovery. This course presents a broad view of astronomy, straightforwardly descriptive and without any complex mathematics. The goal of the course is to encourage non-technical students to become scientifically literate and to appreciate new developments in the world of science, especially in the rapidly developing field of astronomy. Subjects covered include the solar system, stars, galaxies and the universe as a whole. The student should develop an appreciation of the ever-changing universe and our place within it. Computer laboratory exercises will be used to gain practical experience in astronomical techniques. In addition, small telescopes will be used to study the sky. This course is specifically geared toward non-science/engineering majors.

33-126 Astronomy Lab
Fall: 3 units
This course is the laboratory source in science and astronomy. It overviews the scientific method, teaches how to obtain knowledge from data and to develop physics-based models of natural phenomena, trains how to use astronomical instruments (telescope) to make observations and to explain these observations qualitatively, and explains how to apply of the state-of-the art professional software to study our universe. Astronomy is one of the oldest fields of science with at least 3000 years of recorded history. On the astronomy side, major topics of this laboratory course include an overview of the Solar system and the Universe. The goals of the laboratory course are to expand the student?s understanding of the motions of objects through the sky, to use astronomical techniques, such as telescope and simulated observations, and to obtain, analyze, and interpret data.

33-131 Matter and Interaction I
Fall: 12 units
A more challenging alternative to 33-111, Physics for Science Students I. Students with particularly strong physics backgrounds may volunteer for this course. Modeling of physical systems, including 3D computer modeling, with emphasis on atomic-level description and analysis of matter and its interactions. Momentum, numerical integration of Newton's laws, ball-and-spring model of solids, harmonic oscillator, energy, energy quantization, mass-energy equivalence, multiparticle systems, collisions, angular momentum including quantized angular momentum, kinetic theory of gases, statistical mechanics (temperature, entropy, and specific heat of the Einstein solid, Boltzmann factor).

33-132 Matter and Interactions II
Spring: 12 units
A more challenging alternative to 33-112, Physics for Science Students II. Emphasis on atomic-level description and analysis of matter and its electric and magnetic interactions. Coulomb's law, polarization, electric field, plasmas, field of charge distributions, microscopic analysis of resistor and capacitor circuits, potential, macroscopic analysis of circuits, Gauss' law, magnetic field, atomic model of magnetism, Ampere's law, magnetic force, relativistic issues, magnetic induction with emphasis on non-Coulomb electric field, Maxwell's equations, electromagnetic radiation including its production and its effects on matter, re-radiation, interference. Computer modeling and visualization; desktop experiments.
Prerequisites: 21-120 and 33-131

33-141 Physics I for Engineering Students
Fall and Spring: 12 units
This is a first semester, calculus-based introductory physics course. Basic principles of mechanics and thermodynamics are developed. Topics include vectors, displacement, velocity, acceleration, force, equilibrium, mass, Newton's laws, gravitation, work, energy, momentum, impulse, torque and angular momentum, temperature, heat, equations of state, thermodynamic processes, heat engines, refrigerators, first and second laws of thermodynamics, and the kinetic theory of gases.

33-142 Physics II for Engineering and Physics Students
Fall and Spring: 12 units
This is the second half of a two-semester calculus-based introductory physics sequence for engineering and physics students. Two fifths of the course covers electricity, including electrostatics and electric fields, Gauss' law, electric potential, and simple circuits. Two fifths cover magnetism, including magnetic forces, magnetic fields, induction and electromagnetic radiation. One fifth of the course covers mechanical waves (including standing and traveling waves, superposition, and beats) and electromagnetic waves (including mode of propagation, speed, and other properties).
Prerequisites: 33-106 or 33-141 or (21-120 and 33-111) or 33-131 or 33-151 or (21-120 and 33-121)

33-151 Matter and Interactions I
Fall: 12 units
For students with a strong physics background who are interested using calculus-based mechanics to learn about topics such as dark matter, particle physics, and quantum phenomena, Matter and Interactions I provides an excellent alternative to Physics for Science Students. This course places great emphasis on constructing and using physical models, with a special focus on computer modeling to solve problems. Throughout the course, both traditional analytics techniques and scientific computing will be used to solve mechanical problems going from planetary systems, spring-based systems and nuclear scattering. Topics covered include Newton's Laws, microscopic models of solids, energy, energy quantization, mass-energy equivalence, multi particle systems, collisions, angular momentum including quantized angular momentum, kinetic theory of gases and statistical mechanics. Students are encouraged to do an optional research project that will be presented at a departmental poster session at the end of the semester.
Prerequisite: 21-120

33-152 Matter and Interactions II
Spring: 12 units
A more challenging alternative to 33-142, Physics II for Engineering and Physics Students. There is an emphasis on atomic-level description and analysis of matter and its electric and magnetic interactions. Topics include: Coulomb's law, polarization, electric field, plasmas, field of charge distributions, microscopic analysis of resistor and capacitor circuits, potential, macroscopic analysis of circuits, Gauss' law, magnetic field, atomic model of magnetism, Ampere's law, magnetic force, relativistic issues, magnetic induction with emphasis on non-Coulomb electric field, Maxwell's equations, electromagnetic radiation including its production and its effects on matter, re-radiation, interference. There will also be computer modeling, visualization and desktop experiments.
Prerequisites: (33-151 and 21-122) or (33-131 and 21-122)

33-201 Physics Sophomore Colloquium I
Fall: 2 units
This course (together with 33-202) is designed to give students an overview of the field of Physics and to help students make knowledgeable choices in both their academic and professional careers. We discuss several of the sub-fields of Physics in order to give students an understanding of the types of activities, from research to industrial applications, in each. Over the two semesters, we typically discuss six subfields in some detail with the goal of providing a minimal literacy in the relevant concepts and language. The course consists of one classroom lecture per week plus one hour per week of reading and/or problem solving.

33-202 Physics Sophomore Colloquium II
Spring: 2 units
Continuation of 33-201.

33-211 Physics III: Modern Essentials
Fall and Spring: 10 units
Physics III is primarily for third-semester students of physics, including all physics majors, but is open to any qualified student who wants an introduction to the physics of the 20th century. The course will have a strong component of Special Relativity, dealing with kinematics and dynamics, but not electricity and magnetism. (See 33-213 description.) It will introduce students to a conceptual theory, which is mathematically simple but (initially) non-intuitive. The course also provides a broad exposure to quantum phenomena and early quantum theory without getting overly mathematical. It leads into the more formal Quantum Physics course (33-234).
Prerequisites: 33-122 or 33-112 or 33-132 or 33-152 or 33-142 or 33-107

33-213 Mini-Course in Special Relativity
Fall and Spring: 4 units
This course spans the first six weeks of 33-211, Physics III: Modern Essentials. It treats the Mechanics aspects of Special Relativity, including topics such as simultaneity, the Lorentz transformation, time dilation, length contraction, space-time geometry, resolving some famous puzzles, and the momentum, mass, and energy relations. The Electricity and Magnetism portions of the subject are deferred until the junior/senior courses in E&M (33-338/33-339).
Prerequisites: 33-152 or 33-122 or 33-142 or 33-112 or 33-132 or 33-107

33-224 Stars, Galaxies and the Universe
Fall: 9 units
The study of astronomy has blossomed over the past few decades as a result of new ground-based and space-based telescopes, and with the advantage of fast computers for analysis of the huge quantities of data. As our astronomical horizon expands, we are still able to use the laws of physics to make sense of it all. This course is for students who want to understand the basic concepts in astronomy and what drives astronomical objects and the universe. The course emphasizes the application of a few physical principles to a variety of astronomical settings, from stars to galaxies to the structure and evolution of the universe. Introductory classical physics is required, but modern physics will be introduced as needed in the course. The course is intended for science and engineering majors as well as students in other disciplines with good technical backgrounds. Computer lab exercises will be used to gain practical experience in astronomical techniques. In addition, small telescopes are available for personal sign-out for those who would like to use them, and outdoor observing sessions will be organized as weather permits.
Prerequisites: 33-121 or 33-106 or 33-131 or 33-111 or 33-141 or 33-151

33-225 Quantum Physics and Structure of Matter
Fall: 9 units
This course introduces the basic theory used to describe the microscopic world of electrons, atoms, and photons. The duality between wave-like and particle-like phenomena is introduced along with the deBroglie relations which link them. We develop a wave description appropriate for quanta which are partially localized and discuss the interpretation of these wavefunctions. The wave equation of quantum mechanics is developed and applied to the hydrogen atom from which we extrapolate the structure of the Periodic Table. Other materials-related applications are developed, for example, Boltzmann and quantum statistics and properties of electrons in crystals. This course is intended primarily for non-physics majors who have not taken 33-211.
Prerequisites: 33-107 or 33-132 or 33-112 or 33-142 or 33-122 or 33-152

33-228 Electronics I
Spring: 10 units
An introductory laboratory and lecture course with emphasis on elementary circuit analysis, design, and testing. We start by introducing basic circuit elements and study the responses of combinations to DC and AC excitations. We then take up transistors and learn about biasing and the behavior of amplifier circuits. The many uses of operational amplifiers are examined and analyzed; general features of feedback systems are introduced in this context. Complex functions are used to analyze all of the above linear systems. Finally, we examine and build some simple digital integrated circuits.
Prerequisites: 33-122 or 33-142 or 33-107 or 33-132 or 33-112 or 33-152

33-231 Physical Analysis
Fall: 10 units
This course aims to develop analytical skills and mathematical modeling skills across a broad spectrum of physical phenomena, stressing analogies in behavior of a wide variety of systems. Specific topics include dimensional analysis and scaling in physical phenomena, exponential growth and decay, the harmonic oscillator with damping and driving forces, linear approximations of nonlinear systems, coupled oscillators, and wave motion. Necessary mathematical techniques, including differential equations, complex exponential functions, matrix algebra, and elementary Fourier series, are introduced as needed.
Prerequisites: 21-122 and (33-152 or 33-142 or 33-112 or 33-132 or 33-107 or 33-122)

33-232 Mathematical Methods of Physics
Spring: 10 units
This course introduces, in the context of physical systems, a variety of mathematical tools and techniques that will be needed for later courses in the physics curriculum. Topics will include, linear algebra, vector calculus with physical application, Fourier series and integrals, partial differential equations and boundary value problems. The techniques taught here are useful in more advanced courses such as Physical Mechanics, Electricity and Magnetism, and Advanced Quantum Physics.
Prerequisite: 33-231

33-234 Quantum Physics
Spring: 10 units
An introduction to the fundamental principles and applications of quantum physics. A brief review of the experimental basis for quantization motivates the development of the Schrodinger wave equation. Several unbound and bound problems are treated in one dimension. The properties of angular momentum are developed and applied to central potentials in three dimensions. The one electron atom is then treated. Properties of collections of indistinguishable particles are developed allowing an understanding of the structure of the Periodic Table of elements. A variety of mathematical tools are introduced as needed.
Prerequisite: 33-211

33-241 Introduction to Computational Physics
Fall: 9 units
This undergraduate course will provide an introduction to the numerical methods and computational algorithms used to solve a variety of problems in physics. In introductory physics courses, you are able to derive analytical solutions for simpler problems and often with simplifying assumptions. Have you wondered if a numerical solution can be obtained for a more complex problem that has no closed-form analytical solution? Computational physics provides a modern and powerful approach to compliment classical approaches to problem solving. Today's and tomorrow's scientists must be computationally fluent to be competitive and successful. In this course, you will learn to formulate problems by applying physical principles, select and apply numerical methods, develop and apply computational algorithms, solve physical problems analytically and numerically, and visualize quantitative results using plotting software
Prerequisites: 15-112 and 21-122 and 33-104 and (33-142 or 33-122 or 33-132 or 33-152 or 33-107 or 33-112)

33-301 Physics Upperclass Colloquium I
Fall: 1 unit
Upperclass Physics majors meet together for 1 hour a week to hear discussions on current physics research from faculty, undergraduate and graduate students, and outside speakers. Other topics of interest such as application to graduate school, areas of industrial research and job opportunities are also be presented.

33-302 Physics Upperclass Colloquium II
Spring: 1 unit
Continuation of 33-301.

33-331 Physical Mechanics I
Fall: 10 units
Fundamental concepts of classical mechanics. Conservation laws, momentum, energy, angular momentum, Lagrange's and Hamilton's equations, motion under a central force, scattering, cross section, and systems of particles.
Prerequisites: 21-259 and 33-232

33-332 Physical Mechanics II
Spring: 10 units
This is the second semester of a two-semester course on classical mechanics. The course will use the tools developed in 33-331 to examine motion in non-inertial reference frames; in particular, rotating frames. This then leads to the development of general rigid body motion, Euler's Equations. Finally, the course will cover coupled oscillations with particular emphasis on normal modes.
Prerequisite: 33-331

33-338 Intermediate Electricity and Magnetism I
Fall: 10 units
This course includes the basic concepts of electro- and magnetostatics. In electrostatics, topics include the electric field and potential for typical configurations, work and energy considerations, the method of images and solutions of Laplace's Equation, multipole expansions, and electrostatics in the presence of matter. In magnetostatics, the magnetic field and vector potential, magnetostatics in the presence of matter, properties of dia-, para- and ferromagnetic materials are developed.
Prerequisites: 21-259 and 33-232

33-339 Intermediate Electricity and Magnetism II
Spring: 10 units
This course focuses on electro- and magnetodynamics. Topics include Faraday's Law of induction, electromagnetic field momentum and energy, Maxwell's equations and electromagnetic waves including plane waves, waves in non-conducting and conducting media, reflection and refraction of waves, and guided waves. Electromagnetic radiation theory includes generation and characteristics of electric and magnetic dipole radiation. The Special Theory of Relativity is applied to electrodynamics: electric and magnetic fields in different reference frames, Lorentz transformations, four-vectors, invariants, and applications to particle mechanics.
Prerequisite: 33-338

33-340 Modern Physics Laboratory
Spring: 10 units
Emphasis is on hands-on experience observing important physical phenomena in the lab, advancing the student's experimental skills, developing sophisticated data analysis techniques, writing thorough reports, and improving verbal communication through several oral progress reports given during the semester and a comprehensive oral report on one experiment. Students perform three experiments which are drawn from the areas of atomic, condensed matter, classical, and nuclear and particle physics. Those currently available are the following: Zeeman effect, light scattering, optical pumping, thermal lensing, Raman scattering, chaos, magnetic susceptibility, nuclear magnetic resonance, electron spin resonance, X-ray diffraction, Mössbauer effect, neutron activation of radioactive nuclides, Compton scattering, and cosmic ray muons.
Prerequisites: 33-234 and (33-331 or 33-338 or 33-341)

33-341 Thermal Physics I
Fall: 10 units
The three laws of classical thermodynamics, which deal with the existence of state functions for energy and entropy and the entropy at the absolute zero of temperature, are developed along phenomenological lines. Elementary statistical mechanics is then introduced via the canonical ensemble to understand the interpretation of entropy in terms of probability and to calculate some thermodynamic quantities from simple models. These laws are applied to deduce relationships among heat capacities and other measureable quantities and then are generalized to open systems and their various auxiliary thermodynamic potentials; transformations between potentials are developed. Criteria for equilibrium of multicomponent systems are developed and applied to phase transformations and chemical reactions. Models of solutions are obtained by using statistical mechanics and are applied to deduce simple phase diagrams for ideal and regular solutions. The concept of thermodynamic stability is then introduced and illustrated in the context of phase transformations.
Prerequisites: 33-232 and 33-234

33-342 Thermal Physics II
Spring: 10 units
This course begins with a more systematic development of formal probability theory, with emphasis on generating functions, probability density functions and asymptotic approximations. Examples are taken from games of chance, geometric probabilities and radioactive decay. The connections between the ensembles of statistical mechanics (microcanonical, canonical and grand canonical) with the various thermodynamic potentials is developed for single component and multicomponent systems. Fermi-Dirac and Bose-Einstein statistics are reviewed. These principles are then applied to applications such as electronic specific heats, Einstein condensation, chemical reactions, phase transformations, mean field theories, binary phase diagrams, paramagnetism, ferromagnetism, defects, semiconductors and fluctuation phenomena.
Prerequisite: 33-341

33-350 Undergraduate Research
Fall and Spring
The student undertakes a project of interest under the supervision of a faculty member. May include research done in a research lab, extending the capabilities of a teaching lab, or a theoretical or computational physics project. The student experiences the less structured atmosphere of a research program where there is much room for independent initiative. A list of research projects is available. The student must contact the Assistant Head for the Undergraduate Affairs before registering so that student project pairings can be set. Reports on results are required at end of semester.

33-353 Intermediate Optics
Fall: 12 units
Offer alternative years. Geometrical optics: reflection and refraction, mirrors, prisms, lenses, apertures and stops, simple optical instruments, fiber optics. Scalar wave optics: wave properties of light, interference, coherence, interferometry, Huygens-Fresnel principle, Fraunhofer diffraction, resolution of optical instruments, Fourier optics, Fresnel diffraction. Laser beam optics: Gaussian beams. Vector wave optics: electromagnetic waves at dielectric interfaces, polarized light. The course will use complex exponential representations of electromagnetic waves.
Prerequisites: 33-132 or 33-112 or 33-142 or 33-152 or 33-122 or 33-107

33-355 Nanoscience and Nanotechnology
Fall: 9 units
Offered alternative years. This course will explore the underlying science behind nanotechnology, the tools used to create and characterize nanostructures, and potential applications of such devices. Material will be presented on a level intended for upper-level science and engineering students. The course will start with a brief review of the physical principles of electric fields and forces, the nature of chemical bonds, the interaction of light with matter, and elastic deformation of solids. Characterization using electron microscopy, scanning probe methods, and spectroscopic techniques will then be described in detail. Fabrication using top-down and bottom-up methods will be discussed, contrasting these approaches and providing examples of each. Nanotechnology methods will be compared with those used in the modern micro-electronics industry. Finally, examples of nanoscale components and systems will be described, including quantum dots, self-assembled monolayers, molecular computing, and others. Stand-alone laboratory exercises will be included as an important element of the course. These will focus on the use of scanning probe methods to study the nm-scale structure and atomic forces involved in various nanostructures. Students will sign up for these laboratory sessions and perform the exercises under the supervision of a teaching assistant. In addition to the prerequisites, students should have taken a prior laboratory course in a science or engineering department and should have some familiarity with differential equations at an elementary level.
Prerequisites: 33-132 or 33-107 or 33-122 or 33-152 or 33-142 or 33-112

33-398 Special Topics
Fall: 9 units
The description of most all physical systems relies on the concept of a manifold. In addition to the space-time manifold, which plays the role of the stage upon which the dynamics plays out, many systems involve target spaces which are manifolds. These target spaces are typically Lie Groups. A classic example of such a system is the rigid rotator, where every configuration of the system is a point on the manifold which defines the group of rotations. The purpose of this class will be to learn the basics of differential geometry and apply these ideas to physical systems. Topics will include Hamiltonian dynamics, fluid mechanics as well as gauge theories. Requirements: Knowledge of Linear Algebra. No prior knowledge of group theory will be expected.
Prerequisites: (21-260 or 33-231) and 21-341

33-441 Introduction to BioPhysics
Fall: 10 units
This intermediate level course is primarily offered to Physics and Biology undergrads (junior/senior) and provides a modern view of molecular and cellular biology as seen from the perspective of physics, and quantified through the analytical tools of physics. This course will not review experimental biophysical techniques (which are covered, e.g., in 03-871). Rather, physicists will learn what sets "bio" apart from the remainder of the Physics world and how the apparent dilemma that the existence of life represents to classical thermodynamics is reconciled. They also will learn the nomenclature used in molecular biology. In turn, biologists will obtain (a glimpse of) what quantitative tools can achieve beyond the mere collecting and archiving of facts in a universe of observations: By devising models, non-obvious quantitative predictions are derived which can be experimentally tested and may lead to threads that connect vastly different, apparently unrelated phenomena. One major goal is then to merge the two areas, physics an biology, in a unified perspective.
Prerequisites: (03-151 or 03-121) and (33-132 or 33-122 or 33-112 or 33-152 or 33-142 or 33-107)

33-444 Introduction to Nuclear and Particle Physics
Spring: 9 units
Description of our understanding of nuclei, elementary particles, and quarks, with equal emphasis on the nuclear and particle aspects of sub-atomic matter. We discuss the physics of accelerators, and how particle interactions with matter lead to various kinds of detector instrumentation. Then we discuss methods for measuring sub-atomic structure, symmetries and conservation laws, and the electromagnetic, weak, and strong interactions. We examine the quark model of the mesons and baryons, as well as several models of the atomic nucleus.
Prerequisites: 33-234 and 33-338

33-445 Advanced Quantum Physics I
Fall: 9 units
Mathematics of quantum theory, linear algebra and Hilbert spaces; review of classical mechanics; problems with classical mechanics; postulates of quantum theory; one dimensional applications; the harmonic oscillator; uncertainty relations; systems with N degrees of freedom, multi-particle states, identical particles; approximation methods.
Prerequisite: 33-234

33-446 Advanced Quantum Physics II
Spring: 9 units
Classical symmetries; quantum symmetries; rotations and angular momentum; spin; addition of angular momentum; the hydrogen atom; quantum "paradoxes" and Bell's theorem; applications.
Prerequisite: 33-445

33-448 Introduction to Solid State Physics
Spring: 9 units
This course gives a quantitative description of crystal lattices, common crystal structures obtained by adding a basis of atoms to the lattice, and the definition and properties of the reciprocal lattice. Diffraction measurements are studied as tools to quantify crystal lattices, including Bragg's law and structure factors. Diffraction from amorphous substances and liquids is also introduced. The various types of atomic bonding, e.g., Van der Waals, metallic, ionic, covalent and hydrogen are surveyed. Binding energies of some crystalline structures are calculated. Models of crystal binding are generalized to include dynamics, first for classical lattice vibrations and then for quantized lattice vibrations known as phonons. These concepts are used to calculate the heat capacities of insulating crystals, to introduce the concept of density of states, and to discuss phonon scattering.
The band theory of solids is developed, starting with the free electron model of a metal and culminating with the properties of conductors and semiconductors. Magnetic phenomena such as paramagnetism and the mean field theory of ferromagnetism are covered to the extent that time permits.
Prerequisites: 33-341 and (33-225 or 33-234)

33-451 Senior Research
Fall and Spring
Open to all senior physics majors. May include research done in a research lab, extending the capabilities of a teaching lab, or a theoretical or computational physics project. The student experiences the less structured atmosphere of a research program where there is much room for independent initiative. Modern Physics Laboratory, 33-340, should precede this course, though it is not required. A list of research projects is available. The student must contact a faculty member and/or the Assistant Head for the Undergraduate Affairs before registering so that student project pairings can be set. Reports on results are required at end of semester.

33-456 Advanced Computational Physics
Spring: 9 units
This course extends the study of the topics of 33-241 emphasizing practical numerical, symbolic and data-driven computational techniques as applied to a selection of currently active research areas. It is taught by faculty and staff actively engaged in a variety of areas of computational science. Numerical methods may include SVD decomposition, chi-squared minimization, and Fast Fourier Transforms and Monte Carlo simulation of experiments. Applications may include data analysis, eigenvalue problems and others depending on the research activities of the instructors. The students will be expected to become proficient in a specific programming language and to gain the ability to move to other languages and algorithms as their future computationally intensive efforts may require.
Prerequisite: 33-241

33-466 Extragalactic Astrophysics and Cosmology
Spring: 9 units
Starting from the expanding universe of galaxies, this course lays out the structure of the universe from the Local Group of galaxies to the largest structures observed. The observational pinnacle of the Big Bang theory, the microwave background radiation, is shown to provide us with many clues to conditions in the early universe and to the parameters which control the expansion and fate of the universe. Current theories for the development of galaxies and clusters of galaxies are outlined in terms of our current understanding of dark matter. Observational cosmology continues to enjoy a golden era of discovery and the latest observational results will be interpreted in terms of the basic cosmological parameters.
Prerequisites: 33-224 and 33-234

33-467 Astrophysics of Stars and the Galaxy
Fall: 9 units
The physics of stars is introduced from first principles, leading from star formation to nuclear fusion to late stellar evolution and the end points of stars: white dwarfs, neutron stars and black holes. The theory of stellar structure and evolution is elegant and impressively powerful, bringing together all branches of physics to predict the life cycles of the stars. The basic physical processes in the interstellar medium will also be described, and the role of multi-wavelength astronomy will be used to illustrate our understanding of the structure of the Milky Way Galaxy, from the massive black hole at the center to the halo of dark matter which emcompasses it.
Prerequisites: 33-224 and 33-234

33-499 Supervised Reading
Fall and Spring
The student explores a certain area of advanced physics under the supervision of a faculty member. The student must contact a faculty member and the Assistant Head for Undergraduate Affairs before registering.

33-650 General Relativity
Fall: 9 units
General Relativity is the classical theory of gravity. It is widely recognized as a beautiful theory - equating gravity and the geometry of spacetime leads to a profound conceptual change in the way we regard the universe. The predictions of the theory are relevant to systems as varied as high precision measurements of the earth's gravitational field or the strongly curved space-times around black holes. In this course, we will gradually develop an understanding of the geometries which are the solutions of the Einstein equation, with an emphasis on their relevance to physical situations. We will motivate the theory step by step and eventually introduce the Einstein equation itself. Typical Textbook(s): "Gravity, An Introduction to Einstein's General Relativity" by James Hartle.
Prerequisites: 33-211 and 33-339

33-658 Quantum Computation and Quantum Information Theory
Spring: 10 units
This course, taught in collaboration with the Computer Science Department, provides an overview of recent developments in quantum computation and quantum information theory. The topics include: an introduction to quantum mechanics, quantum channels, both ideal and noisy, quantum cryptography, an introduction to computational complexity, Shor's factorization algorithm, Grover's search algorithm, and proposals for the physical realization of quantum devices, such as correlated photons, ions in traps, and nuclear magnetic resonance. The course includes a weekly seminar. Typical Textbook(s): "Quantum Computation and Quantum Information" by Nielsen and Chuang.

33-755 Quantum Mechanics I
Fall: 12 units
This course introduces fundamental concepts of quantum mechanics. Applications are made to quantum computing, the harmonic oscillator, the hydrogen atom, electron spin and addition of angular momentum. 3hrs. lecture. Typical Text: Cohen-Tannoudji Quantum Mechanics, volume 1.
Prerequisite: 33-446

33-756 Quantum Mechanics II
Spring: 12 units
This course focuses on qualitative and approximation methods in quantum mechanics, including time-independent and time-dependent perturbation theory, scattering and semiclassical methods. Applications are made to atomic, molecular and solid matter. Systems of identical particles are treated including many electron atoms and the Fermi gas. Prerequisite: 33-755, Quantum Mechanics I; 33-759 Theoretical Physics. 3 hrs. lecture. Typical Text: Cohen-Tannoudji Quantum Mechanics, volume 2.

33-758 Quantum Computation and Quantum Information Theory
Spring: 12 units
This course, taught in collaboration with the Computer Science Department, provides an overview of recent developments in quantum computation and quantum information theory. The topics include: an introduction to quantum mechanics, quantum channels, both ideal and noisy, quantum cryptography, an introduction to computational complexity, Shor's factorization algorithm, Grover's search algorithm, and proposals for the physical realization of quantum devices, such as correlated photons, ions in traps, and nuclear magnetic resonance. The textbook is Nielsen and Chuang, Quantum Computation and Quantum Information. 3 hrs. lecture plus weekly seminar. A 10 unit version of the course, 33-658, does not include the seminar.

33-759 Introduction to Mathematical Physics I
Fall: 12 units
This course is an introduction to methods of mathematical analysis used in solving physical problems. Emphasis is placed both upon the generality of the methods, through a variety of sample problems, and upon their underlying principles. Topics normally covered include matrix algebra (normal modes, diagonalization, symmetry properties), complex variables and analytic functions, differential equations (Laplace's equation and separation of variables, special functions and their analytic properties), orthogonal systems of functions. 3 hrs. lecture and recitation. Typical Text: G. Arfken, Mathematical Methods for Physicists.

33-761 Classical Electrodynamics I
Fall: 12 units
This course deals with the static and dynamic properties of the electromagnetic field as described by Maxwell's equations. Among the topics emphasized are solutions of Laplace's, Poisson's and wave equations, effects of boundaries, Green's functions, multipole expansions, emission and propagation of electromagnetic radiation and the response of dielectrics, metals, magnetizable bodies to fields. 3 hrs. lecture. Typical Text: Jackson, Classical Electrodynamics, 2nd Ed.
Prerequisite: 33-339

33-762 Classical Electrodynamics II
Spring: 12 units
The applications of electromagnetic theory to various physical systems is the main emphasis of this course. The topics discussed include the theory of wave guides, scattering of electromagnetic waves, index of refraction, special relativity and foundation of optics. 3 hrs. lecture. Typical Text: Jackson, Classical Electrodynamics. 2nd Ed.

33-765 Statistical Mechanics
Spring: 12 units
This course develops the methods of statistical mechanics and uses them to calculate observable properties of systems in thermodynamic equilibrium. Topics treated include the principles of classical thermodynamics, canonical and grand canonical ensembles for classical and quantum mechanical systems, partition functions and statistical thermodynamics, fluctuations, ideal gases of quanta, atoms and polyatomic molecules, degeneracy of Fermi and Bose gases, chemical equilibrium, ideal paramagnetics and introduction to simple interacting systems. 3 hrs. lecture, 1 hr. recitation. Typical Texts: Reif, Statistical and Thermal Physics; Pathria, Statistical Mechanics.

33-767 Biophysics: From Basic Concepts to Current Research
Spring: 12 units
This course mixes lectures and student presentations on advanced topis in Biological Physics. In the course, students will gain a deep appreciation of the fact that very basic physical and chemical principles underly many central life processes. Life is not only compatible with the laws of physics and chemistry, rather, it exploits them in ingenious ways. After taking the course, students should be able to name examples of such situations for which they can provide a coherent line of reasoning that outlines these connections. They will be able to explain key experiments by which these connections either have been found or are nowadays routinely established, and outline simple back-of-the-envelope estimates by which one can convince oneself of either the validity or inapplicability of certain popular models and ideas. They should also have become sufficiently familiar with the key terminology frequently encountered in biology, such that they can start to further educate themselves by consulting biological and biophysical literature. The course uses Physical Biology of the Cell by Rob Phillips et al. (Garland Science, New York, NY, 2013, ISBN 978-0-8153-4450-6).

33-769 Quantum Mechanics III: Many Body and Relativistic Systems
Fall: 12 units
The first main theme of this course is quantum mechanics applied to selected many-body problems in atomic, nuclear and condensed matter physics. The second main theme is relativistic quantum mechanics. Creation and annihilation operators are introduced and used to discuss Hartree-Fock theory as well as electromagnetic radiation. The Dirac equation is introduced and applied to the hydrogen atom. Prerequisite: 33-756, 33-76l. 3 hrs. lecture

33-770 Field Theory I
Fall: 12 units
This course gives systematic studies of the relativistic field theories. Topics included are canonical quantization of fields, LSZ reduction formula, Feynman diagram techniques, application to quantum electrodynamics and the discussion of the methods of renormalization. Prerequisite: 33-769. 3 hrs. lecture.

33-771 Field Theory II
All Semesters: 12 units
Missing Course Description - please contact the teaching department.

33-777 Introductory Astrophysics
Fall: 12 units
Introductory Astrophysics will explore the applications of physics to the following areas: (i) celestial mechanics and dynamics, (ii) the physics of solar system objects, (iii) the structure, formation and evolution of stars and galaxies, (iv) the large scale structure of the universe of galaxies, (v) cosmology: the origin, evolution and fate of the universe.

33-779 Introduction to Nuclear and Particle Physics
Fall: 12 units
An introduction to the physics of atomic nuclei and elementary particles. This course is suitable as a one-semester course for students not specializing in this area and also provides an introduction to further work in 33-780, 33-78l. Topics included are symmetry principles of strong and weak interactions, quark model, classification of particles and nuclear forces. Prerequisite: 33-769 (or con-currently). 3 hrs. lecture. Typical Text: Perkins, Introduction to High Energy Physics, plus notes and reading.

33-780 Nuclear and Particle Physics II
Spring: 12 units
This course covers the phenomenology of weak interactions, parton model for the deep inelastic scattering, and introduction to gauge theories of weak and electromagnetic interactions. Various topics of current interest in particle physics will also be included. Prerequisite: 33-779, 33-770 (or concurrently). 3 hrs. lecture.

33-783 Solid State Physics
Fall: 12 units
This course is designed to give advanced graduate students a fundamental knowledge of the microscopic properties of solids in terms of molecular and atomic theory, crystal structures, x-ray diffraction of crystals and crystal defects, lattice vibration and thermal properties of crystals; free-electron model, energy bands, electrical conduction and magnetism. Prerequisite: 33-756. 3 hrs. lecture. Typical Text: Ashcroft and Mermin, Solid State Physics.
Prerequisite: 33-756 Min. grade B

MCS Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

38-101 EUREKA!: Discovery and Its Impact
Fall: 6 units
The MCS first-year seminar "EUREKA: Discovery and Its Impact" will equip new students with foundational knowledge, skills and perspectives that will support their development as emerging scientists. During the seminar, students will be presented with opportunities and experiences designed to help them frame how the MCS curriculum aspires to shape their evolving identities in the areas of scholar, person, professional and citizen, while also engendering a sense of excitement about science and scientific inquiry. The seminar will offer information and strategies that are employed both by successful students and by successful scientists in optimizing their approach to work and life, with a key focus on areas such as cognitive learning skills, research, teamwork, goal setting, time management, innovation, community engagement, ethics, resources and assessment. Additionally, the seminar will introduce first-year students to the learning outcomes and requirements associated with the MCS core curriculum, with a particular emphasis on the self-directed ENGAGE courses and the role of the e-portfolio system in documenting and framing student growth and development.

38-110 ENGAGE in Service
Fall and Spring: 1 unit
ENGAGE in Service is a 1-unit course (9 hours of work, minimum requirement for a passing grade) designed to promote MCS students' direct engagement with community development and service learning. To fulfill this requirement, students must engage in a minimum of 9 hours of work devoted to a non-profit organization or organizations of their choice, 3 of which must have a direct benefit to the local Pittsburgh community. Students may complete the requirements anytime during their undergraduate years, but must register for the class during the semester that they intend to complete it, no later than their penultimate semester. Coursework includes documentation of service via completion of a form for each eligible activity that includes a time log, a description of the activity, the name and contact information for their supervisor and the supervisor's signature. In addition, during the last semester of the project/course students will prepare a 1-2 page reflective paper on the lessons learned from their immersion in the organization(s) and its (their) work. No pay or other compensation can be received, and, in special cases, students may petition for a waiver if they have completed another service-learning course at Carnegie Mellon.

38-119 Grand Challenge Freshman Seminar: Feeding the World, Feeding Ourselves
Intermittent: 9 units
Food in the twenty-first century is ripe with paradox: fewer people than ever work as farmers or ranchers, but the quantity and global variety of foods available to consumers continues to expand; public health officials around the world are raising alarms about diseases linked to the over-consumption of fats and sugars, even as hundreds of millions of people do not know where their next meal is coming from; organic agriculture is booming, while agribusiness giants like Monsanto continue to expand. Producing food consumes more land and water resources than any other human activity. The individual and collective decisions people make about food shape individual and community health, social justice, and sustainability. If we are to make sound decisions about how to feed the world and feed ourselves, we need to understand the highly creative and contentious ways that people produce and consume food. In this class we will address the following central questions in order to unravel some paradoxes, and help us make informed choices, about foods we consume: (1) What are the origins of agriculture, and why does it matter for the future of food? (2) How do cultural, ecological, economic, and technological contexts shape food acquisition, preparation, and consumption? (3) What are the causes of hunger ¿ can we feed 8 billion people healthy food and not trash the planet? And (4) what roles have science and technology played in shaping ¿industrial food,¿ and in shaping the world around us?

38-220 ENGAGE in the Arts
Fall and Spring: 2 units
ENGAGE in the Arts is part of Mellon College of Science's Core Curriculum. In this 2-unit full-semester course, students will broaden their knowledge of the fine arts, extend their global and cultural awareness, and facilitate the further development of their self-identity. Coursework requires that students attend 8 distinct arts events, two of which must engage with a culture different from one's personal cultural background. In choosing events, students should be imbued with an attitude of openness to new ideas and a willingness to try something new. The course requires students to share, reflect, and document their participation in a variety of arts events by engaging with classmates and instructors through MyCORE, where they can upload coursework and find postings for events. Coursework can be completed at any time during students' undergraduate years, but they must register for the class during the semester that they intend to complete it.

38-230 ENGAGE in Wellness: Looking Inward
Spring: 1 unit
ENGAGE in Wellness: Looking Inward is a 1-unit mini-course that MCS students will enroll in the spring of the sophomore year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this first course, taken in the first mini of the sophomore year, students will select one of three areas on which to focus: intellectual, emotional or physical health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness in this area, develop short-term goals for the next year and a statement of a longer-term goal in this area, identify possible resources and then choose activities that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students' elect to pursue in fulfillment of their wellness plan. THIS COURSE IS FOR SOPHOMORES ONLY.

38-301 PROPEL
Spring: 6 units
PROPEL: Preparation, Readiness, and Optimization for Professional Excellence in Life - is a 6-unit seminar course that MCS students will enroll in the spring of their junior year. The course will leverage students' deepening disciplinary perspective in service of the development of competencies, skills and perspectives that are necessary to achieve professional excellence in today's society. The course will use traditional career development activities, such as interviewing, resume writing and networking, as a starting point for students to begin the process of reflecting on, and preparing for, their impending transitions into professional life. From there, the course will seek to expand students' conceptualization of the scientific workplace by exploring the interplay of science, innovation, public policy, entrepreneurism and business in professional settings today. The seminar will also equip students with significant insight into the ways in which global policy, societal and political forces, environmental issues and ethical considerations shape and influence the activity and research of working scientists. The course will offer additional experiences for students to refine their multidisciplinary teamwork and communication skills via small group projects focusing on the aforementioned course themes. Finally, "PROPEL" will include a formal academic advising component to ensure that all students are well positioned to complete the MCS core requirements and departmental requirements in the following year. THIS COURSE IS FOR MCS JUNIORS ONLY.

38-302 Science and Society
Spring: 4 units
The course is not designed to be a deep dive into any one topic, but rather seeks to equip students with insights into the scientific workplace by exploring the interplay between science and society, which might include areas such as public policy, political forces, business, technology, environmental issues, and economics. Additionally, the course will offer opportunities for students to develop and refine their multidisciplinary teamwork and communication skills via team projects focusing on the aforementioned course themes.

38-303 Professional Development and Life Skills
Spring: 2 units
This course will leverage students' deepening disciplinary perspective in service of the development of competencies, skills and perspectives that are necessary to achieve professional excellence in today's society. The course will use traditional career development activities, such as interviewing, resume writing and networking, as a starting point for students to begin the process of reflecting on, and preparing for their impending transitions into professional life.

38-330 ENGAGE in Wellness: Looking Outward
Fall: 1 unit
ENGAGE in Wellness: Looking Outward is a 1-unit mini-course that MCS students will enroll in the fall of the junior year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this second course, taken in the first mini of the junior year, students will select one of three areas on which to focus: spiritual, environmental and institutional or community health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness in this area, develop short-term goals for the next year and a statement of a longer-term goal in this area, identify possible resources and then choose activities that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students' elect to pursue in fulfillment of their wellness plan. This course is intended for juniors only. THIS COURSE IS FOR JUNIORS ONLY.

38-411 The Science and Mathematics of Art
Intermittent: 6 units
This interdisciplinary course will provide a view of the application of mathematical and scientific knowledge in the creation, analysis, conservation, restoration and preservation of art work. The course will combine science and art history lectures with field work to Museums and Art Galleries. Students from diverse science and mathematics backgrounds will be exposed to the methods, demands, and aims of other technical and non-technical disciplines. They will be challenged to consider and communicate how their own discipline relates to- and enables the development of art and to identify synergetic relationships between different areas of human endeavor. Students will collaboratively design and carry out final projects which combine research and creative work; these projects will be designed such that they can be used in local Museums for public outreach. A series of researchers and artists who work at the boundary between science and art will give guest lectures.
Prerequisites: 03-115 or 03-124 or 03-343 or 09-122 or 09-221 or 33-104 or 21-270 or 21-292 or 21-369 or 33-100 or 21-257

38-430 ENGAGE in Wellness: Looking Forward
Fall: 1 unit
ENGAGE in Wellness: Looking Forward is a 1-unit mini-course that MCS students will enroll in the fall of the senior year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this third course, taken in the first mini of the senior year, students will select one of three areas on which to focus: financial, social and occupational health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness in this area, develop short-term goals for the next year and a statement of a longer-term goal in this area, identify possible resources and then choose activities that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students' elect to pursue in fulfillment of their wellness plan. THIS COURSE IS FOR SENIORS ONLY.

38-709 Applied Cell and Molecular Biology
Fall: 12 units
This course will examine applications of modern cell and molecular biology, with emphasis on commercial products and processes. The course will include a basic background in the major topics that would be covered in courses on prokaryotic and eukaryotic molecular biology and molecular cell biology. The course is intended for non-specialists who seek an understanding and appreciation of fundamental concepts without the analysis of experimental detail that would support the development of concepts in a course for the specialist. The course will draw on the patent literature as a source of commercial applications of biological discoveries. Examples of the topics that might be included are: diagnostic and therapeutic monoclonal antibodies (e.g., Herceptin), therapeutic proteins (e.g., colony stimulating factors, erythropoietin, hormones), antibiotics, subunit molecular vaccines, amino acid fermentations, enzyme based processes for chemical synthesis, gene therapy, stem cells and regenerative medicine, herbicide tolerant plants, microbial diagnostics (e.g., multilocus sequence typing), transgenic animals, DNA fingerprinting.

38-710 Principles of Biotechnology
Spring: 12 units
This course is intended to provide an introduction to a set of core areas currently highlighted in the biotechnology industries. The objective is to provide the appropriate background for management level personnel to optimize their decision-making based on knowledgeable background in today's technologies. The focus will be on weekly modules of similar technologies with an introduction to technology/science behind the topic area and the applications of the technology in today's industries and markets.

38-801 Evidence Based Teaching in STEM
Fall and Spring: 7 units
Special Permission Only: This course is designed to prepare PhD students from science disciplines to: (1) teach effectively and efficiently as future faculty members; (2) critically read and apply peer-reviewed, STEM-based educational research; and (3) adapt approaches from the Scholarship of Teaching and Learning (SoTL) to formatively assess student learning and iteratively improve teaching and course design. Together, we will explore the research on teaching and student learning, identifying and challenging our assumptions regarding how college students learn best in science disciplines. Participants will leverage this research to cultivate a diverse toolkit of evidence-based, student-centered strategies for teaching and course design that may be applied to face-to-face, blended, or online courses, both within and across STEM disciplines. Prior teaching experience is not required, but students must have completed their first year of PhD study to enroll. This course will not prepare or license participants to teach K-12 students in Pennsylvania or elsewhere.

Minors Offered by the Mellon College of Science

The Mellon College of Science offers several minors to students interested in broadening their scientific training or acquiring a level of expertise in a particular scientific field. The intercollege minors described below are designed to supplement your degree in science; the departmental minors offer you a means of exploring another field and are open to students throughout the university.

Intercollege Minors

Please see the descriptions below.

- Environmental and Sustainability Studies
- Health Care Policy and Management
- Scientific Computing

Departmental Minors in the Mellon College of Science

For descriptions, please see the departmental sections which follow.

- Biological Sciences
- Chemistry
- Computational Finance
- Discrete Mathematics and Logic
- Mathematical Sciences
- Neuroscience
- Physics

Minor in Environmental and Sustainability Studies

Maggie Braun, *Program Director, MCS Dean's Office*
Abigail Owen, *Faculty Advisor, History Department*

This new minor replaces the earlier minors in Environmental Science (MCS), Environmental Studies (Dietrich), and Environmental Engineering & Sustainability (Engineering). Upon completion of the Minor in Environmental and Sustainability Studies, students should be able to:

1. Apply social and scientific perspectives to environmental problems
2. Distinguish among scientific methods for evaluating environmental problems
3. Identify and assess sources of environmental data
4. Identify environmental justice issues within the context of proposed policy solutions; distinguish among impacts on different communities, and different groups of stakeholders, when considering environmental problems and proposed solutions

In order for a student to receive a minor in Environmental and Sustainability Studies in conjunction with a B.S. or B.A. degree from another (primary) department, the successful completion of six (or seven) courses as distributed below is required. Students pursuing the minor must inform the Mellon College of Science of their intentions in writing using the MCS form for declaration of a minor so that the minor designation can be approved prior to graduation. The form may be obtained from the MCS undergraduate webpage at www.cmu.edu/mcs/undergrad/advising/forms. **It should be completed and submitted to the minor advisor's office, 3709 Wean Hall, no later than the end of the course add period of the final semester prior to graduation.** If you decide at a later date not to complete the minor, it would be helpful to notify the MCS Associate Dean for Undergraduate Affairs at mabraun@andrew.cmu.edu so that it can be removed from your record. Minors are listed on the transcript but not on the diploma.

Required Courses:

One Course in Chemistry

Choose one		Units
09-105	Introduction to Modern Chemistry I	10
09-107	Honors Chemistry: Fundamentals, Concepts and Applications (for students enrolled in MCS, Engineering, or SCS)	10
09-103	Atoms, Molecules and Chemical Change (for students enrolled in CFA, Tepper, or Dietrich)	9

Interdisciplinary Course

99-236	Introduction to Environmental Ideas	9

One Course in Statistics & Data Science (CFA Students only)

Choose one		
36-200	Reasoning with Data Students entering CMU prior to 2018 may substitute 36-201 for 36-200.	9

Electives (36 Units)

Appropriate electives chosen in consultation with the Faculty Advisor. The most recent list of approved electives can be found at www.cmu.edu/steinbrenner/education/environment-minor.html.

Total Number of Required Units 54

Minor in Health Care Policy and Management

Sponsored by:
Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:
Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 27 units from the following:		
79-330	Medicine and Society	9
90-836	Health Systems	6
90-721	Healthcare Management	6
90-861	Health Policy	6

Elective Courses

Complete a minimum of 18 units from these two sections:

Heinz College Courses		
90-831	Advanced Financial Management of Health Care	6
94-705	Health Economics	12

90-832	Health Law	6
90-833	Population Health	6
90-818	Health Care Quality & Performance Improvement	6
90-834	Health Care Geographical Information Systems	12
Other courses as approved		

Humanities and Social Sciences Courses (9 units each)		
80-245	Medical Ethics	9
76-494	Healthcare Communications	9
88-365	Behavioral Economics and Public Policy	9
67-476	Innovation in Information Systems: Health Care	9
42-444	Medical Devices	9
Other courses as approved		

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

Health Management/Administration Focus		Units
90-831	Advanced Financial Management of Health Care	6
90-832	Health Law	6
90-818	Health Care Quality & Performance Improvement	6
80-245	Medical Ethics	9
76-494	Healthcare Communications	9

Health Policy Focus		Units
94-705	Health Economics	12
90-832	Health Law	6
90-833	Population Health	6
88-365/90-882	Behavioral Economics and Public Policy	9
Other courses as approved		

Health Analytisc & IT Focus		Units
90-834	Health Care Geographical Information Systems	12
67-476	Innovation in Information Systems: Health Care	9
42-444	Medical Devices	9
Other courses as approved		

Minor in Scientific Computing

Dr. Maggie Braun, Advisor, *MCS Dean's Office*
mabraun@andrew.cmu.edu

Sometimes called “computational science,” scientific computing is the application of high-performance computers and modern computational technologies to problems in the sciences and engineering. Research in this area is inherently multidisciplinary, requiring strong ties with a scientific discipline.

MCS students can easily build on their scientific training with this applied computational program. The curriculum consists of five areas of concentration, which span the natural sciences, mathematics, programming, and research. The curriculum is structured to allow flexibility in choosing courses that meet students’ particular interests or best compliment their major. The minor is also a natural choice for students majoring in any technical area.

Required Courses

Students must meet the requirements of the following categories:

A. Non-Introductory Science Requirement (9-12 units)
Complete 1 course from Biological Sciences, Chemistry, or Physics at the 200 level or higher, excluding those courses listed below as part of the requirements of the minor. Courses with a significant science component from other colleges may be substituted with approval from the minor advisor.

B. Computational Science Requirement (18-24 units)
Complete 2 of the following courses:

03-250	Introduction to Computational Biology	12
03-511	Computational Molecular Biology and Genomics	9
09-560	Computational Chemistry	12
15-386	Neural Computation	9
33-241	Introduction to Computational Physics	9

C. Computational Methods Requirement (9 units)
Complete one of the following courses from outside of your home department.

21-320	Symbolic Programming Methods	9
21-369	Numerical Methods	12
33-232	Mathematical Methods of Physics	10
33-456	Advanced Computational Physics	9
36-410	Introduction to Probability Modeling	9

D. Applied Scientific Computing Research Project(s) (9 units)
Complete one approved research project in an area of applied scientific computing. In some cases, this research could be replaced with 9 units of an approved project-based course in advanced scientific computing. The administrator of the minor will maintain a list of appropriate courses. Under special circumstances summer research may count toward this requirement, although it cannot be counted toward the units required for graduation.

E. Complete any additional course from category C or D (9 units)

School of Computer Science

Tom Mitchell, Interim Dean

Guy Blelloch, Associate Dean for Undergraduate Education

Thomas Cortina, Assistant Dean for Undergraduate Education

Location: GHC 4115
www.cs.cmu.edu/undergraduate-programs

Carnegie Mellon founded one of the first Computer Science departments in the world in 1965. As research and teaching in computing grew at a tremendous pace at Carnegie Mellon, the university formed the School of Computer Science at the end of 1988. Carnegie Mellon was one of the first universities to elevate Computer Science into its own academic college at the same level as the Mellon College of Science and the College of Engineering. Today, the School of Computer Science consists of seven departments and institutes, including the Computer Science Department that started it all, along with the Human-Computer Interaction Institute, the Institute for Software Research, the Computational Biology Department, the Language Technologies Institute, the Machine Learning Department, and the Robotics Institute. Together, these units make the School of Computer Science a world leader in research and education. Recently, the School of Computer Science launched two new undergraduate majors: Computational Biology and Artificial Intelligence. These new majors, along with the highly-ranked Computer Science major, give students in the School of Computer Science distinct paths in the field of computing with ample opportunities in industry and advanced research.

The School of Computer Science offers the following majors and minors:

- B.S. in Artificial Intelligence
- B.S. in Computational Biology
- B.S. in Computer Science
- Bachelor's in Computer Science and Art (joint with the College of Fine Arts)
- Additional major in Computational Biology
- Additional major in Computer Science
- Additional major in Human-Computer Interaction
- Additional major in Robotics
- Minor in Computer Science
- Minor in Computational Biology
- Minor in Human-Computer Interaction
- Minor in Language Technologies
- Minor in Machine Learning
- Minor in Neural Computation
- Minor in Robotics
- Minor in Software Engineering

Information for these majors and minors can be found through the navigation menu or through the links below:

- Artificial Intelligence (p. 633) (B.S. degree)
- Computational Biology (p. 636) (B.S. degree, additional major, minor)
- Computer Science (p. 639) (B.S. degree, additional major, minor)
- SCS additional majors and minors (p. 643)

Students who apply to, and are directly admitted into, the School of Computer Science can choose between three primary majors: Artificial Intelligence, Computational Biology or Computer Science. Students admitted into the School of Computer Science and the College of Fine Arts are also given the option to pursue a joint major in Computer Science and Art. Suitably prepared students from other Carnegie Mellon colleges are eligible to apply for internal transfer to the School of Computer Science (for Computational Biology or Computer Science) and will be considered for transfer if grades in specific requirements are sufficiently high and space is available. Computation-oriented programs are also available within the Mellon College of Science, the Dietrich College of Humanities and Social Sciences, the College of Engineering and the College of Fine Arts.

Policies & Procedures

Academic Standards and Actions

Grading Practices

Grades given to record academic performance in SCS are detailed under Grading Practices at Undergraduate Academic Regulations (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateacademicregulations).

Dean's List WITH HIGH HONORS

SCS recognizes each semester those undergraduates who have earned outstanding academic records by naming them to the Dean's List with High Honors. The criterion for such recognition is a quality point average of at least 3.75 while completing a minimum of 36 factorable units and earning no incomplete grades.

Academic Actions

In the first year, quality point averages below 1.75 in either semester invoke an academic action. For all subsequent semesters an academic action will be taken if the semester quality point average or the cumulative quality point average (excluding the first year) is below 2.00.

Probation: The action of probation will be taken in the following cases based on QPA:

1. One semester of the first year is below 1.75 QPA;
2. The semester QPA of a student in good standing beyond the first year falls below 2.00.

The term of probation is one semester as a full-time student. First year students are no longer on probation at the end of the second semester if the second semester's QPA is 1.75 or above. Students in the third or subsequent semester of study are no longer on probation at the end of one semester if the semester QPA and cumulative QPA (excluding the first year) are 2.00 or above.

Probation Continued: A student who has had one semester on probation and is not yet meeting minimum requirements but whose record indicates that the standards are likely to be met at the end of the next semester of study is occasionally continued on probation. This action is normally taken only when a student's semester QPA is above 2.0 but their cumulative QPA is not yet above 2.0.

Suspension: A student who does not meet minimum standards based on QPA at the end of one semester of probation will be suspended:

- A first year student will be suspended if the QPA from each semester is below 1.75.
- A student on probation in the third or subsequent semester of study will be suspended if the semester QPA is below 2.00.

The minimum period of suspension is one academic year (two non-summer semesters). At the end of that period a student may return to campus (on probation) by:

1. completing a Return from Leave form from the HUB, and
2. submitting an additional written statement to the SCS Assistant Dean for Undergraduate Education, minimum one page, that outlines what the student did while on leave to address the issues that led to the suspension and that would indicate future success on return, and
3. (optional) submitting up to two letters of support from individuals supporting the student's return, and
4. written approval from the student's academic advisor and the Assistant Dean for Undergraduate Education, in consultation with the Office of Student Affairs and the Office of International Education as appropriate.

Students who have been suspended or have withdrawn are required to absent themselves from the campus (including residence halls and Greek houses) within a maximum of two days after the action and to remain off the campus for the duration of the time specified. This action includes debarment from part-time or summer courses at the university for the duration of the period of the action. Although suspended students may not hold student jobs, students on academic suspension may, under certain circumstances, have a non-student job with the university. Students on disciplinary or administrative suspension may not.

Drop: This is a permanent severance. Students who have been suspended and who fail to meet minimum standards in the semester that they return to school will be dropped.

Students who have been dropped are required to absent themselves from the campus (including residence halls and Greek houses) within a maximum of two days after the action.

Other Actions: In addition to academic actions based on QPA, the Associate Dean for Undergraduate Education may place students on probation, or subsequent suspension, if they do not demonstrate reasonable progress through the core curriculum of their major (e.g., not completing a core class after 3 attempts, not completing the required 100-level core courses by the end of the sophomore year, etc.). Students are encouraged to consult with their academic advisor about any concerns with regard to lack of progress in their chosen SCS major.

The relation indicated above between probation, suspension and drop is nominal. In unusual circumstances, SCS College Council may suspend or drop a student without prior probation.

Return from Leave of Absence

SCS undergraduate students may elect to take a leave of absence for a variety of reasons, after consultation with their academic advisor. Students returning from a leave of absence are required to submit a Return from Leave of Absence form to their academic advisor for approval by the student's academic advisor and the SCS Assistant Dean for Undergraduate Education. In addition, the student must also supply a letter that explains the reason for the leave, the actions that were performed during the leave to prepare the student for a successful return, and a description of the on-campus resources, if required, that would be used by the student in order to increase the likelihood of success. Students returning from a leave are also encouraged to provide up to two letters of support from people close to the student (e.g. family, friends, clergy, teachers, coaches, others as appropriate). Requests to return are reviewed by the student's academic advisor, the Assistant Dean and the Student Affairs liaison to determine eligibility and any resources that need to be put into place to assist the student upon return. Contact the CS Undergraduate Office for more information.

Internal Transfer

First year students admitted to SCS are considered undeclared during their first year. These students declare their SCS major in the second semester of their freshman year. SCS students who wish to transfer from one SCS major to another SCS major may do so by applying for transfer by mid-semester break during the semester the transfer is desired. These students should consult with their academic advisor and the program director of the intended major for more information about specific course requirements and academic plans. Internal SCS transfers do not have any grade requirements. Transfers are approved based on demonstrated interest, ability, and available space in the intended major.

Transfer into SCS / Dual-Degree

Undergraduate students admitted to colleges at CMU other than SCS and wishing to transfer to Computer Science or pursue a dual degree in Computer Science should consult with the SCS Assistant Dean for Undergraduate Education during their first year. Students wishing to transfer to Computational Biology or pursue a dual degree in Computational Biology should consult with the Assistant Department Head for Education in the Computational Biology Department during their first year. See the individual program pages for Computer Science (p. 639) and Computational Biology (p. 636) for locations.

- For the Computer Science major, students must complete 21-127 (or equivalent), 15-122, 15-150, 15-210, 15-213, 15-251 with an overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0 in order to apply for transfer or dual degree.
- For the Computational Biology major, students must complete 21-127 (or equivalent), 15-122, 15-251, 15-351 (or 15-210*), 03-121 and 02-250 with an overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0 in order to apply for transfer or dual degree. (*Students who take 15-210 will need to also take 15-150; this course is not required for the B.S. in Computational Biology but can count as an elective.)
- At this time, no transfers will be allowed into the Artificial Intelligence program for non-SCS students. Consult with the program director of the Artificial Intelligence major for any changes to this policy at the start of each academic year.

Students may apply for transfer by the mid-semester break in the semester when the last of the six required courses will be completed. In the case of courses in progress, the mid-semester grades will be used in the QPA calculation. The decision to allow transfer or dual degree will be made by committee based on the student's academic performance (in the specified courses and in their courses overall if necessary), additional involvement in SCS and other computing-related activities, and availability of space in the student's class level. Students should consult the office of the Assistant Dean for Undergraduate Education for complete information concerning minimum requirements, instructions and deadlines.

External Transfer

A student currently enrolled at another university or college who wishes to transfer to SCS should first apply through the Office of Admission. If the Office of Admission believes the applicant meets admission guidelines, the student's record is sent to SCS for evaluation. Admission is based on seat availability, overall academic performance and course rigor from the student's current institution, ability to complete the rigorous SCS program on time, and the application material including recommendations and reflection essay. It is important to note that extremely few external transfers are admitted to the SCS program at Carnegie Mellon University. At this time, no transfers will be allowed into the Artificial Intelligence program for non-CMU students. External transfers who are admitted for Computer Science or Computational Biology may not subsequently transfer into the Artificial Intelligence program due to high demand within CMU.

Graduation Requirements

1. A requirement for graduation is the completion of the program specified for a degree with a cumulative quality point average of 2.00 or higher for all courses taken after the first year.
2. Students must be recommended for a degree by the faculty of SCS.
3. A candidate for the bachelor's degree must complete at the University a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of course work.
4. Students will be required to have met all financial obligations to the university before being awarded a degree.

A student who does not meet the QPA requirement above must petition SCS College Council for a waiver of the first requirement.

General Education Requirements

All undergraduate degrees in the School of Computer Science include depth in their particular field of study but also breadth through the general education requirements. General education requirements are part of SCS degrees to give students an opportunity to learn more about the world from scientific and humanistic points of view. These additional skills are useful for graduates since computing is often embedded in domains that are not entirely within the bounds of computing. SCS students will need to use their computing skills to solve problems alongside scientists and engineers, artists, social and cognitive scientists, historians, linguists, economists and business experts, and SCS students will need to communicate effectively and understand the ethical implications of their work. The general education requirements help SCS students gain this broad perspective so they can work well in a wide variety of domains.

Science and Engineering

All candidates for a B.S. degree in the School of Computer Science must complete a minimum of 36 units offered by the Mellon College of Science and/or the College of Engineering (CIT).

Computational Biology majors

For Computational Biology majors, consult the Computational Biology (p. 636) program page for specific science and engineering requirements. The required science and engineering courses for the Computational Biology major also satisfy the General Education requirement for SCS.

Artificial Intelligence and Computer Science majors

For Artificial Intelligence and Computer Science majors, four courses in science and engineering are required, 9 units or more for each course, at least one course must have a laboratory component and at least two courses must be from the same department.

Non-lab courses that can be taken by AI and CS majors to satisfy this requirement are given in the list below. (Consult your academic advisor for additional choices available each semester.)

02-223	Personalized Medicine: Understanding Your Own Genome (can be paired with a course in Biology 03-xxx for two courses in one department)	9
03-121	Modern Biology	9
03-125	Evolution	9
03-132	Basic Science to Modern Medicine	9

03-133	Neurobiology of Disease	9
06-100	Introduction to Chemical Engineering	12
06-221	Thermodynamics	9
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
12-201	Geology	9
18-100	Introduction to Electrical and Computer Engineering	12
18-220	Electronic Devices and Analog Circuits	12
18-240	Structure and Design of Digital Systems	12
24-101	Fundamentals of Mechanical Engineering	12
24-231	Fluid Mechanics	10
24-261	Statics	10
24-351	Dynamics	10
33-114	Physics of Musical Sound	9
33-120	Science and Science Fiction	9
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-224	Stars, Galaxies and the Universe	9
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
42-341	Introduction to Biomechanics	9
85-219	Biological Foundations of Behavior (can be paired with a course in Biology 03-xxx for two courses in one department)	9

At present, courses meeting the lab requirement are:

02-261	Quantitative Cell and Molecular Biology Laboratory (can be paired with a course in Biology 03-xxx for two courses in one department)	9
03-124	Modern Biology Laboratory	9
09-101	Introduction to Experimental Chemistry (This 3 unit lab together with 09-105 satisfies the lab requirement.)	3
09-221	Laboratory I: Introduction to Chemical Analysis	12
27-100	Engineering the Materials of the Future	12
33-104	Experimental Physics	9
42-203	Biomedical Engineering Laboratory	9
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9

The following MCS and CIT courses cannot be used to satisfy the Science and Engineering requirement:

03-511	Computational Molecular Biology and Genomics	9
03-512	Computational Methods for Biological Modeling and Simulation	9
06-262	Mathematical Methods of Chemical Engineering	12
09-103	Atoms, Molecules and Chemical Change	9
09-231	Mathematical Methods for Chemists	9
12-271	Introduction to Computer Application in Civil & Environmental Engineering	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
18-200	ECE Sophomore Seminar	1
18-202	Mathematical Foundations of Electrical Engineering	12
18-213	Introduction to Computer Systems	12
18-345	Introduction to Telecommunication Networks	12
18-411	Computational Techniques in Engineering	12
18-482	Telecommunications Technology and Policy for the Internet Age	12
18-487	Introduction to Computer Security	12
18-540	Rapid Prototyping of Computer Systems	12
19-101	Introduction to Engineering and Public Policy	12
19-211	Ethics and Policy Issues in Computing	9
19-325	Technology and Policy Writing for Lay Audiences	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-432	Special Topics: Bitcoin and Cryptocurrencies	6
27-410	Computational Techniques in Engineering	12
33-100	Basic Experimental Physics	6
33-115	Physics for Future Presidents	9
33-124	Introduction to Astronomy	9
33-232	Mathematical Methods of Physics	10
42-201	Professional Issues in Biomedical Engineering	3

All Electrical and Computer Engineering graduate courses [18-6xx, 18-7xx, 18-8xx, 18-9xx] cannot be used for this requirement. In general, any MCS or CIT courses that are cross-listed with SCS courses or have significant mathematical or computational content **cannot** be used for this requirement. Consult with a CS undergraduate advisor about any course to be used for the Science and Engineering requirement before registration.

Humanities and Arts

All candidates for a B.S. degree in the School of Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts as prescribed below. Students pursuing a Bachelor's in Computer Science and Art (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/bxaintercollege/#bcsacurriculumtext) should consult the general education requirements for that program.

A. Freshman Writing Requirement (9 units)

Complete one of the following writing options for 9 units:		
76-101	Interpretation and Argument	9
76-102	Advanced First Year Writing: Special Topics (by invitation only)	9
or two of these three writing minis for 9 units total:		
76-106	Writing about Literature, Art and Culture	4.5
76-107	Writing about Data	4.5
76-108	Writing about Public Problems	4.5

B. Breadth Requirement (minimum 27 units: 9 units each)
Complete three courses, one each from Category 1, Category 2, and Category 3. Students may use two minis totaling 9 units or more to satisfy one of the categories, with permission of the Assistant Dean for Undergraduate Education, if the minis meet the goals of the desired category. **NOTE: Artificial Intelligence majors replace Category 1 with Category 1A: Cognitive Studies which is a subset of Category 1.**

Category 1 (for Computational Biology and Computer Science majors): Cognition, Choice and Behavior - this requirement explores the process of thinking, decision making, and behavior in the context of the individual.		
70-311	Organizational Behavior	9
80-130	Introduction to Ethics	9
80-150	Nature of Reason	9
80-180	Nature of Language	9
80-221	Philosophy of Social Science	9
80-241	Ethical Judgments in Professional Life	9
80-242	Conflict and Dispute Resolution	9
80-270	Philosophy of Mind	9
80-271	Philosophy and Psychology	9
80-275	Metaphysics	9
80-281	Language and Thought	9
85-102	Introduction to Psychology	9
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artifical Intelligence	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9
85-261	Abnormal Psychology	9

85-370	Perception	9
85-390	Human Memory	9
85-408	Visual Cognition	9
85-421	Language and Thought	9
88-120	Reason, Passion and Cognition	9

Category 1A (for Artificial Intelligence majors): Cognitive Studies - this requirement explores how the brain and the mind work.

85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artifical Intelligence	9
85-370	Perception	9
85-390	Human Memory	9
85-408	Visual Cognition	9
85-421	Language and Thought	9

Category 2 (all SCS majors): Economic, Political and Social Institutions - this requirement explores the processes by which institutions organize individual preferences and actions into collective outcomes.

19-101	Introduction to Engineering and Public Policy	12
36-303	Sampling, Survey and Society	9
70-332	Business, Society and Ethics	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
79-245	Capitalism and Individualism in American Culture	9
79-299	From Newton to the Nuclear Bomb: History of Science, 1750-1950	9
79-300	Guns in American History: Culture, Violence, and Politics	9
79-320	Women, Politics, and Protest	9
79-331	Body Politics: Women and Health in America	9
79-341	The Cold War in Documents and Film	9
79-383	The History of Capitalism	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-243	Ethics of Leadership	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-324	Philosophy of Economics	9
80-335	Social and Political Philosophy	9
80-341	Computers, Society and Ethics	9
84-104	Decision Processes in American Political Institutions	9
84-275	Comparative Politics	9
84-310	International Political Economy	9
84-320	Domestic Politics and International Affairs	9
84-322	Nonviolent Conflict and Revolution	9
84-324	The Future of Democracy	6
84-326	Theories of International Relations	9
84-362	Diplomacy and Statecraft	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-389	Terrorism and Insurgency	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6
84-414	International and Subnational Security	9
88-257	Experimental Economics	9

Category 3 (all SCS majors): Cultural Analysis - this requirement seeks to recognize cultures that have shaped and continue to shape the human experience; courses in this category are usually either broad in place, time, or cultural diversity.

57-173	Survey of Western Music History	9
60-205	Critical Theory in Art III	9
62-306	Music-Cinema-Culture	9
62-371	Photography, The First 100 Years, 1839-1939	9
70-342	Managing Across Cultures	9
76-221	Books You Should Have Read by Now: 16th & 17th C. Pop Culture	9
76-227	Comedy	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
79-104	Global Histories	9
79-201	Introduction to Anthropology	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-226	African History: Earliest Times to 1780	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-240	Development of American Culture	9
79-241	African American History: Africa to the Civil War	9
79-242	African American History: Reconstruction to the Present	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-265	Russian History: From the First to the Last Tsar	9
79-281	Introduction to Religion	9
79-282	Europe and the World Since 1800	9
79-311	PaleoKitchen: Food and Cooking in the Ancient World	6
79-316	Photography, the First 100 Years, 1839-1939	9
79-333	Sex, Gender & Anthropology	9
79-345	Roots of Rock & Roll	9
79-350	Early Christianity	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-395	The Arts in Pittsburgh	9
79-396	Music and Society in 19th and 20th Century Europe and the U.S.	9
80-100	Introduction to Philosophy	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism	9
80-261	Experience, Reason, and Truth	9
80-276	Philosophy of Religion	9
82-267	Topics in Italian Language & Culture	9
82-273	Introduction to Japanese Language and Culture	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-294	Topics in Russian Language and Culture	9
82-303	Introduction to French Culture	9
82-304	The Francophone World	9
82-314	Literature of the Arabic-speaking World	9
82-327	The Emergence of the German Speaking World	9
82-333	Introduction to Chinese Language and Culture	9
82-342	Spain: Language and Culture	9
82-343	Latin America Language and Culture	9
82-344	U.S. Latinos: Language and Culture	9
82-345	Introduction to Hispanic Literary & Cultural Studies	9

C. Humanities and Arts Electives (minimum 27 units)
Complete 3 non-technical courses of at least 9 units each from any of the departments in the College of Humanities & Social Sciences or the College of Fine Arts. Some of the courses taught in these units are considered technical courses and may not be used to satisfy this requirement (see Deletions below). Additionally, a select set of courses from Business Administration and from Environmental and Public Policy can also count for this requirement (see Additions below). Students may combine humanities/arts courses with lower units together to form a single course of 9 units or more. Students are encouraged, but not required, to take courses from different departments to gain additional breadth and to create new opportunities for engagement with the university community.

The most up-to-date list of additions and deletions can be found at http://www.csd.cs.cmu.edu/content/bscs-humanities-and-arts-requirements and supersedes the lists given below. Consult with a CS undergraduate advisor for additional information.

Deletions

The following courses may not count toward the unconstrained electives in Humanities and Arts in SCS due to the technical (computing and/or mathematical) nature of the courses:

36-200	Reasoning with Data	9
36-202	Statistics & Data Science Methods	9
36-207	Probability and Statistics for Business Applications	9
36-208	Regression Analysis	9
36-217	Probability Theory and Random Processes	9
36-220	Engineering Statistics and Quality Control	9
36-225	Introduction to Probability Theory	9
36-226	Introduction to Statistical Inference	9
36-247	Statistics for Lab Sciences	9
36-303	Sampling, Survey and Society	9
36-304	Biostatistics	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-314	Biostatistics	9
36-315	Statistical Graphics and Visualization	9
36-326	Mathematical Statistics (Honors)	9
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
36-428	Time Series	6
36-459	Statistical Models of the Brain	12
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-492	Topic Detection and Document Clustering	6
36-494	Astrostatistics	6
51-224	CD: Web Design	9
51-257	Introduction to Computing for Creative Practices	10
51-327	Design Center: Introduction to Web Design	9
51-328	Advanced Web Design	9
67-211	Business Oriented Sys:History, Des & Dev-Lens of CoBOL Programming Language	6
67-240	Mobile Web Design & Development	9
67-250	The Information Systems Milieux	9
67-261	Information Design Fundamentals	9
67-262	Database Design and Development	9
67-272	Application Design and Development	9
67-279	Introduction to Geographical Information Systems	6
67-306	Special Topics: Management of Computer and Information Systems	6
67-308	Innovation Studio: Health Care Information Systems	9
67-309	Special Topics: Information Assurance and Security	6
67-317	Mobile Web Development and Usability Testing	9
67-319	Global Technology Consulting Groundwork	3
67-324	Accelerating Innovation and Entrepreneurship	9
67-327	Web Application Security	6
67-328	Mobile to Cloud: Building Distributed Applications	9
67-329	Contemporary Themes in Global Systems	9
67-330	Technology Consulting in the Community	9
67-331	Technology Consulting in the Global Community	3
67-344	Organizational Intelligence in the Information Age	9
67-353	IT & Environmental Sustainability	6
67-364	Practical Data Science	9
67-373	Information Systems Consulting Project	12
67-390	Independent Study in Information Systems	Var.
67-391	Independent Study in Information Systems	Var.
67-440	IDeATe Mobile Application Design & Development	9
67-442	Mobile Application Development in iOS	9
67-475	Innovation in Information Systems	12
67-490	Practicum in Information Systems	Var.
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-274	Econometrics I	9
73-347	Game Theory for Economists	9
73-374	Econometrics II	9
76-481	Introduction to Multimedia Design	12
76-487	Web Design	12
80-110	Nature of Mathematical Reasoning	9
80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-222	Measurement and Methodology	9
80-223	Causality and Probability	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
80-314	Causal Discovery, Statistics, and Machine Learning	9
80-315	Modal Logic	9
80-405	Game Theory	9
80-411	Proof Theory	9
80-413	Category Theory	9
80-521	Seminar on Formal Epistemology	Var.
85-213	Human Information Processing and Artifical Intelligence	9
85-219	Biological Foundations of Behavior	9
85-370	Perception	9
85-414	Cognitive Neuropsychology	9
88-251	Empirical Research Methods	9

Additions

The following courses outside of Dietrich College and the College of Fine Arts may count toward the Humanities and Arts requirement in SCS:

17-333	Privacy Policy, Law, and Technology (formerly 08-533)	9
17-562	Law of Computer Technology (formerly 08-532)	9
19-101	Introduction to Engineering and Public Policy	12
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
32-102	Seapower and Maritime Affairs	6
32-201	Leadership & Management	9
32-402	Leadership and Ethics	9
70-160	Graphic Media Management	9
70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-332	Business, Society and Ethics	9
70-340	Business Communications	9
70-341	Team Dynamics and Leadership	9
70-342	Managing Across Cultures	9
70-345	Business Presentations	9
70-350	Acting for Business	9
70-364	Business Law	9
70-365	International Trade and International Law	9
70-381	Marketing I	9
70-430	International Management	9

Honors Research Thesis

Students considering going on to graduate school in Computer Science or related disciplines should take a wide variety of Computer Science and Mathematics courses, as well as consider getting involved in independent research as early as possible. This would be no later than the junior year and can begin even earlier. Students interested in graduate school in computer science or its related areas are strongly encouraged to participate in the SCS Honors Undergraduate Research Thesis program. Additionally, graduate CS courses can be taken with permission of the instructor and in consultation with an academic advisor.

The goal of the SCS Honors Undergraduate Research Thesis Program is to introduce students to the breadth of tasks involved in independent research, including library work, problem formulation, experimentation, analysis, technical writing and public speaking. In particular, students write a survey paper summarizing prior results in their desired area of research, present a public poster session in December of their senior year describing their current progress, present their final results in an oral summary in the year-end university-wide Undergraduate Research Symposium (Meeting of the Minds) and submit a written thesis at the end of their senior year. Students work closely with faculty research advisors to plan and carry out their research. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Students should prepare their research prospectus (i.e. proposal of work) during the spring semester of their junior year, and students in this program are advised to plan their schedules carefully to ensure there is ample time to perform the required research for the thesis during the senior year.

Students interested in research are urged to consult with their undergraduate advisor and the SCS Assistant Dean no later than the end of their sophomore year in order to plan their workload effectively. Although there is no specific QPA requirement to participate, students are expected to have at least a 3.5 QPA in the core SCS topics relevant to their proposed research to be successful in their work. For those students with no background in research, they may consider using Research and Innovation in Computer Science (15-300, 9 units) as an introduction to the research process in their junior year since this course will introduce students to various research projects going on in the School of Computer Science and important skills that are needed to be an effective researcher. This course leads to a subsequent Research Practicum in Computer Science (15-400, 12 units) that allows students to complete a small-scale research study or experiment and present a research poster. Students who use 15-400 to start their senior thesis can use these units toward the required 36 units. Students should consult with their academic advisor concerning how the units earned toward the senior thesis can be used toward elective requirements for their major.

Interested juniors should submit a project prospectus of no more than three pages by the end of their junior year, although submissions over the summer prior to the senior year will also be considered for review. A prospectus must include:

- The name of the research advisor (an SCS faculty member)
- A short abstract (two paragraphs, max)
- A description of the problem to be worked on and its significance
- A tactical description of the proposed research plan, including:
    - a description of the background reading to be carried out,
    - a description of the research contribution,
    - a description of the expected results of the research, and
    - a reasonably detailed timeline for the thesis work
- A bibliography of related work (all references belong here)
- The signature of the research advisor, signifying endorsement of the project and willingness to supervise and evaluate it

Students who need help finding potential advisors should get in touch with the Associate Dean or Assistant Dean for Undergraduate Education. Applications to the program are due by the end of the semester prior to the start of the thesis, typically the end of the Junior Spring semester.

Students successfully completing this thesis will earn SCS College Honors and can compete for various SCS research awards given out during commencement.

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HEATHER MILLER, Assistant Professor, Institute for Software Research – Ph.D., École Polytechnique Fédérale de Lausanne; Carnegie Mellon, 2018–

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ALAN MONTGOMERY, Associate Professor of Marketing – Ph.D., University Of Chicago; Carnegie Mellon, 1999–

ANDREW MOORE, Dean and Professor, School of Computer Science – Ph.D., University of Cambridge; Carnegie Mellon, 1993–

IGOR MORDATCH, Assistant Professor, Robotics Institute – Ph.D., University of Washington; Carnegie Mellon, 2017–

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Artificial Intelligence Program

Reid Simmons, Director of the BSAI program (NSH 3213)

Jean Harpley, Program Coordinator (NSH 1517)
www.cs.cmu.edu/bs-in-artificial-intelligence

Overview

Carnegie Mellon University has led the world in artificial intelligence education and innovation since the field was created. It's only natural, then, that the School of Computer Science would offer the nation's first bachelor's degree in Artificial Intelligence, which started in Fall 2018.

The new BSAI program gives students the in-depth knowledge needed to transform large amounts of data into actionable decisions. The program and its curriculum focus on how complex inputs — such as vision, language and huge databases — can be used to make decisions or enhance human capabilities. The curriculum includes coursework in computer science, math, statistics, computational modeling, machine learning and symbolic computation. Because Carnegie Mellon is devoted to AI for social good, students will also take courses in ethics and social responsibility, with the option to participate in independent study projects that change the world for the better — in areas like healthcare, transportation and education.

Just as AI unites disciplines from machine learning to natural language processing, instruction in the BSAI program includes faculty members from the school's Computer Science Department, Human-Computer Interaction Institute, Institute for Software Research, Language Technologies Institute, Machine Learning Department and Robotics Institute.

Students who graduate with a B.S. in AI from SCS will have the computer science savvy and skills our students are known for, with the added expertise in machine learning and automated reasoning that you'll need to build the AI of tomorrow.

How to Apply

The BSAI program is reserved for current and future SCS students only. Therefore, students must first be accepted into the School of Computer Science as first year students. Once at Carnegie Mellon and enrolled in SCS, students can declare a BSAI major in the spring of their first year. Initially, the program will accommodate roughly 100 students total, or about 30–35 from each class.

A limited number of current SCS sophomores and juniors may apply to transfer into the program. Consult with the director of the BSAI program for information.

Curriculum

BSAI majors will take core courses in math and statistics, computer science, artificial intelligence and ethics, along with general education courses in science and engineering, and humanities and arts.

Math and Statistics

All of the following:		Units
15-151	Mathematical Foundations for Computer Science (if not offered, substitute 21-127)	10
21-122	Integration and Approximation (students without credit or a waiver for 21-120, Differential and Integral Calculus, must take 21-120 before 21-122)	10
21-241	Matrices and Linear Transformations	10
21-259	Calculus in Three Dimensions	9
36-218	Probability Theory for Computer Scientists or: (15-259 or 21-325 or 36-225) and 36-226	9
36-401	Modern Regression	9

Computer Science

All of the following:		Units
07-128	Freshman Immigration Course	1
15-122	Principles of Imperative Computation (students without credit or a waiver for 15-112, Fundamentals of Programming and Computer Science, must take 15-112 before 15-122)	10
15-150	Principles of Functional Programming	10
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Artificial Intelligence

All of the following three AI core courses:		Units
07-180	Concepts in Artificial Intelligence	5
15-281	Artificial Intelligence: Representation and Problem Solving	12
10-315	Introduction to Machine Learning (Undergrad)	12
plus one of the following AI core courses:		
16-385	Computer Vision	12
11-411	Natural Language Processing	12

One Decision Making and Robotics course (min. 9 units):		Units
15-386	Neural Computation	9
15-482	Autonomous Agents	12
15-483	Truth, Justice, and Algorithms	9
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-350	Planning Techniques for Robotics	12
16-362	Mobile Robot Algorithms Laboratory	12
16-384	Robot Kinematics and Dynamics	12
others as designated by the AI Undergraduate Program		

One Machine Learning course from the following (min.9 units):		
10-403	Deep Reinforcement Learning & Control	12
10-417	Intermediate Deep Learning	12
10-418	Machine Learning for Structured Data	12
11-441	Machine Learning for Text Mining	9
11-485	Introduction to Deep Learning	9
36-402	Advanced Methods for Data Analysis	9
others as designated by the AI Undergraduate Program		

One Perception and Language course from the following (min. 9 units):		
11-442	Search Engines	9
11-492	Speech Processing	12
15-387	Computational Perception	9
15-463	Computational Photography	12
16-421	Vision Sensors	12
others as designated by the AI Undergraduate Program		

One Human-AI Interaction course from the following (min. 12 units):		
05-317	Design of Artificial Intelligence Products	12
05-391	Designing Human Centered Software	12
16-467	Human Robot Interaction	12
others as designated by the AI Undergraduate Program		

School of Computer Science electives

Two general computer science electives:	Units
These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and SCS graduate courses might not be allowed. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)	18

Ethics Course

One of the following courses:		Units
16-161	ROB Freshman Seminar: Artificial Intelligence and Humanity	9
17-200	Ethics and Policy Issues in Computing	9
80-249	AI, Society, and Humanity	9

Humanities and Arts

All candidates for the bachelor's degree in Artificial Intelligence must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 624). **SPECIAL NOTE FOR AI STUDENTS: AI majors must satisfy Category 1 of the General Education requirements by taking one of the following Cognitive Studies (Category 1A) courses:**

- 85-211 Cognitive Psychology
- 85-213 Human Information Processing and Artifical Intelligence
- 85-370 Perception
- 85-390 Human Memory
- 85-408 Visual Cognition
- 85-421 Language and Thought

Science and Engineering

All candidates for the bachelor's degree in Computer Science must complete a minimum of 36 units offered by the Mellon College of Science and/or the College of Engineering (CIT). These courses offer students an opportunity to explore scientific and engineering domains that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 624).

Computing @ Carnegie Mellon

The following course is required of all students to familiarize them with the campus computing environment:

99-101	Computing @ Carnegie Mellon	3

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements

Area	Courses	**Units**
Mathematics	6	**57**
Computer Science	5	**56**
Artificial Intelligence	8	**80**
SCS Electives	2	**18**
Ethics	1	**9**
Science/Engineering	4	**36**
Humanities/Arts (includes Cognitive Studies)	7	**63**
SCS First Year Seminar	1	**1**
Computing @ Carnegie Mellon	1	**3**
Free Electives	varies	**37**
		360

Undergraduate Research Thesis

AI majors may use the SCS Honors Research Thesis as part of their degree. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Up to 18 units can be counted toward SCS elective requirements (9 per semester for 2 semesters maximum). Students interested in research may also consider using Research and Innovation in Computer Science (15-300, 9 units) in their junior year since this course will introduce students to various research projects going on in the School of Computer Science that may lead to a senior thesis. This course leads to a subsequent Research Practicum in Computer Science (15-400, 12 units) that allows students to complete a small-scale research study or experiment and present a research poster. Students who use 15-400 to start their senior thesis can use these units toward the required 36 units.

For more information about the SCS Honors Research Thesis, refer to the SCS Honors Research Thesis (p. 627) section for learning objectives, application requirements and expected outcomes.

BSAI Roadmap: Sample Course Sequence

The sample given below is for a student who already has credit for introductory programming and introductory calculus. Students with no credit for introductory programming will take 15-112 in their first semester and shift some CS courses to later semesters after consulting with their academic advisor; students with no credit for calculus will take 21-120 in their first semester and shift 21-122 and 21-259 to subsequent semesters. These students should still be able to complete their degree in four years given the light load of their senior year. Students with credit for 21-120 and 21-122 may start with a more advanced math class (e.g. 21-241) in their first year. It is recommended that students keep their academic load lighter for their Senior Fall semester to account for offsite job interviews or for their Senior Spring semester to account for visits to graduate schools.

FRESHMAN YEAR:

Fall		Units
07-128	Freshman Immigration Course	1
15-122	Principles of Imperative Computation	10
15-151	Mathematical Foundations for Computer Science	10
21-122	Integration and Approximation	10
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
		43

Spring		Units
07-180	Concepts in Artificial Intelligence	5
15-150	Principles of Functional Programming	10
15-213	Introduction to Computer Systems	12
21-241	Matrices and Linear Transformations	10
21-259	Calculus in Three Dimensions	9
		46

SOPHOMORE YEAR:

Fall		Units
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
36-218	Probability Theory for Computer Scientists	9
xx-xxx	Science and Engineering Elective	9

xx-xxx	Ethics Elective	9
		51

Spring		Units
10-315	Introduction to Machine Learning (Undergrad)	12
15-251	Great Ideas in Theoretical Computer Science	12
85-xxx	Cognitive Studies Elective	9
xx-xxx	Science and Engineering Elective	9
xx-xxx	Humanities and Arts Elective	9
		51

JUNIOR YEAR:

Fall		Units
11-411	Natural Language Processing	12
or 16-385	Computer Vision	
36-401	Modern Regression	9
xx-xxx	AI Elective: Machine Learning	9
xx-xxx	Humanities and Arts elective	9
xx-xxx	Free Elective	9
		48

Spring		Units
xx-xxx	AI Elective: Human-AI Interaction	12
xx-xxx	AI Elective: Decision Making and Robotics	9
xx-xxx	Science and Engineering elective	9
xx-xxx	Humanities and Arts elective	9
xx-xxx	Free Elective	9
		48

SENIOR YEAR:

Fall		Units
xx-xxx	AI Elective: Perception and Language	9
xx-xxx	SCS Elective	9
xx-xxx	Science and Engineering Elective	9
xx-xxx	Humanities and Arts Elective	9
		36

Spring		Units
xx-xxx	SCS Elective	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Free Elective	10
xx-xxx	Free Elective	9
		37

Minimum number of units required for the degree:360

The flexibility in the curriculum allows many different schedules, of which the above is only one possibility. Some elective courses are offered only once per year (Fall or Spring). AI cluster electives (decision making and robotics, machine learning, perception and language, and human-AI interaction) may be taken in any order and in any semester if prerequisites are met and seats are available. Constrained electives are shown in the specific semesters in the schedule above as an example only. Students should consult with their academic advisor to determine the best elective options depending on course availability, their academic interests and their career goals.

Computational Biology Program

Robert F. Murphy, PhD, Department Head
Location: GHC 7725

Phillip Compeau, PhD, Program Director & Assistant Dept. Head for Education
Location: GHC 7403

Samantha Mudrinich, Academic Program Manager
Location: GHC 7414
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Bachelor of Science in Computational Biology

Success in computational biology requires significant technical knowledge of fundamental computer science as well as a broad biological intuition and general understanding of experimental biology. However, most importantly, it requires students who can integrate their knowledge by making connections between the two fields.

There is significant industry demand for excellent computational biology students, in biotech, pharmaceuticals, and biomedical research. Both established companies and startups struggle to find employees with the correct skillset, and our students will be able to take advantage of the fact that an undergraduate computational biology major has the rigorous training required to handle the challenges of modern research that is not provided by any of our peer institutions.

Students completing the undergraduate program in computational biology will also be ideally prepared for Ph.D. programs in any of a range of biomedical areas, including Computational Biology, Systems Biology, or Quantitative Biology. Students who complete pre-medical requirements will be very well-prepared to attend medical school; after all, the next generation of physicians will need to better understand the computational approaches needed for automated medical testing, automated medical imaging, and the coming personalized medicine revolution.

Degree Requirements

(students entering Fall 2019)

Students completing the Bachelor of Science in Computational Biology follow certain policies that apply to all SCS students; please consult the SCS policies page (http://coursecatalog.web.cmu.edu/schoolofcomputerscience/#policiestext) for a complete listing of these expectations.

Students must complete a **minimum of 360 units** for the degree in computational biology.

For Mellon College of Sciences students interested in computational biology who matriculated at Carnegie Mellon before Fall 2017, please go to Previous Catalogs (http://coursecatalog.web.cmu.edu/previous) for degree requirements.

Mathematics/Statistics Core

21-122	Integration and Approximation	10
15-151	Mathematical Foundations for Computer Science (or 21-127/21-128 if not offered)	10
36-218	Probability Theory for Computer Scientists (Students taking 15-259 should take 36-326 instead.)	9
or 36-226	Introduction to Statistical Inference	
or 36-326	Mathematical Statistics (Honors)	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
Total Units		39

General Science Core

09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
Total Units		22

Biological Core

03-121	Modern Biology (or 03-151 if seats available)	9
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis (or 03-220 if not offered)	9
03-232	Biochemistry I (Students taking 03-231, including pre-med students, will take organic chemistry as a prerequisite, which will satisfy a biology elective requirement.)	9
or 03-231	Honors Biochemistry	
03-320	Cell Biology	9
Total Units		36

Computer Science Core

07-128	Freshman Immigration Course (This course may be replaced by 03-201 or 03-202 if and only if 07-128 is not offered)	1
15-122	Principles of Imperative Computation	10
15-251	Great Ideas in Theoretical Computer Science	12
15-351	Algorithms and Advanced Data Structures (Students taking 15-150 and 15-210 as prerequisites for 15-451 may apply these courses as CS electives.)	12
or 15-451	Algorithm Design and Analysis	
10-315	Introduction to Machine Learning (Undergrad)	12
Total Units		47

Computational Biology Core

02-251	Great Ideas in Computational Biology (This course may be replaced by 02-250 if 02-251 is not offered)	12
02-261	Quantitative Cell and Molecular Biology Laboratory	12
or 03-343	Experimental Techniques in Molecular Biology	
02-402	Computational Biology Seminar	3
02-510	Computational Genomics	12
02-512	Computational Methods for Biological Modeling and Simulation	9
Total Units		48

Major Electives

02-3xx	Computational Biology Electives at 300 level or above (Includes 03-445 or 03-545 if research is computational)	18-24
03-3xx	Biology Electives at 300 level or above (09-217 also counts as a biology elective)	9-12
15-xxx	Computer Science or 10-xxx Machine Learning Electives	18-24
Total Units		45-60

Humanities & Arts

All candidates for the bachelor's degree in Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 624).

Computing @ Carnegie Mellon (1 course)

The following course is required of all students to familiarize them with the campus computing environment:

99-101	Computing @ Carnegie Mellon	3

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements

Area	
Math/Stats Core	39
General Science Core	22
Biological Core	36
Computer Science Core	47
Computational Biology Core	48
Major Electives	45-60
General Education (Humanities & Arts)	63
Computing at Carnegie Mellon	3
Remaining Units	42-57
Total Units	360

Sample Course Sequence

The sample given below assumes a student has credit for an introductory programming course, but no credit for calculus. The course sequence below is simply a suggested guide to which courses may be appropriate for students completing the undergraduate program in computational biology in each term. Individual students will have individual paths based on their backgrounds and needs.

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
07-128 Freshman Immigration Course	02-251 Great Ideas in Computational Biology	02-261 Quantitative Cell and Molecular Biology Laboratory	03-232 Biochemistry I
15-122 Principles of Imperative Computation	03-121 Modern Biology	03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	21-241 Matrices and Linear Transformations
15-131 Great Practical Ideas for Computer Scientists	09-105 Introduction to Modern Chemistry I	33-121 Physics I for Science Students	15-251 Great Ideas in Theoretical Computer Science
15-151 Mathematical Foundations for Computer Science	xx-xxx Humanities and Arts Elective	36-218 Probability Theory for Computer Scientists	02-xxx Computational Biology Elective
76-101 Interpretation and Argument	15-351 Algorithms and Advanced Data Structures	xx-xxx Humanities and Arts Elective	
21-122 Integration and Approximation			
99-101 Computing @ Carnegie Mellon			

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
02-512 Computational Methods for Biological Modeling and Simulation	02-402 Computational Biology Seminar	02-xxx Computational Biology Elective	xx-xxx Humanities and Arts Elective
03-320 Cell Biology	02-510 Computational Genomics	xx-xxx Humanities and Arts Elective	xx-xxx Free Elective
10-315 Introduction to Machine Learning (Undergrad)	03-xxx Biology Elective	xx-xxx Free Elective	xx-xxx Free Elective
15-xxx/10-xxx CS/ML Elective	15-xxx/10-xxx Computer Science/Machine Learning Elective	xx-xxx Free Elective	xx-xxx Free Elective
xx-xxx Humanities and Arts Elective	xx-xxx Humanities and Arts Elective		

Additional Major in Computational Biology

The Additional Major in Computational Biology is designed for undergraduate students wishing to study computational biology as a second field of study at Carnegie Mellon University in addition to their primary major.

The additional major is open to all students who complete the prerequisite coursework listed below, with the requirement that a student from outside SCS must have a 3.0 overall QPA when applying.

To prevent double-counting, students must complete at least seven courses of at least 9 units each as part of the additional major in computational biology (not including pre-requisites) that are unique to the additional major.

Students interested in the Additional Major in Computational Biology should contact the Computational Biology Undergrad Program Director.

Prerequisite Courses

02-250	Introduction to Computational Biology	12
or 02-251	Great Ideas in Computational Biology	
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
15-122	Principles of Imperative Computation	10
15-151	Mathematical Foundations for Computer Science	10
or 21-127	Concepts of Mathematics	
or 21-128	Mathematical Concepts and Proofs	
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
Total Units		61

Mathematics/Statistics Core

36-218	Probability Theory for Computer Scientists	9
or 36-226	Introduction to Statistical Inference	
or 36-326	Mathematical Statistics (Honors)	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
Total Units		19

General Science Core

09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
Total Units		22

Biological Core

03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
or 03-220	Genetics	

03-232	Biochemistry I (Students taking 03-231, including pre-med students, will take organic chemistry as a prerequisite, which will satisfy a biology elective requirement.)	9
or 03-231	Honors Biochemistry	
03-320	Cell Biology	9
Total Units		27

Computer Science Core

15-251	Great Ideas in Theoretical Computer Science	12
15-351	Algorithms and Advanced Data Structures (Students taking 15-150 and 15-210 as prerequisites for 15-451 may apply these courses as CS electives.)	12
or 15-451	Algorithm Design and Analysis	
10-315	Introduction to Machine Learning (Undergrad)	12
Total Units		36

Computational Biology Core

02-261	Quantitative Cell and Molecular Biology Laboratory	12
02-402	Computational Biology Seminar	3
02-510	Computational Genomics	12
02-512	Computational Methods for Biological Modeling and Simulation	9
Total Units		36

Major Electives

02-3xx	Computational Biology Electives at 300 level or above (Includes 03-445 or 03-545 if research is computational)	18-24
03-3xx	Biology Electives at 300 level or above (09-217 also counts as a biology elective)	9-12
15-xxx	Computer Science or 10-xxx Machine Learning Electives	18-24
Total Units		45-60

General Education (Humanities & Arts)

For specific courses that may be used to satisfy each elective, please consult the General Education Requirements for your primary major.

Computational Biology Minor

SCS Majors: Please see the Computational Biology Concentration (p. 687)

Ziv Bar-Joseph, PhD, *Director*
Phillip Compeau, PhD, *Advisor*
Samantha Mudrinich, *Program Manager*

The computational biology minor is open to students in any major of any college at Carnegie Mellon outside the School of Computer Science. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in biological sciences that are central to computational biology.

Students are encouraged to declare the minor as early as possible in their undergraduate careers and in all cases before their final semester so that the minor advisor can provide advice on their curriculum.

Why Minor in Computational Biology?

Computational Biology is concerned with solving biological and biomedical problems using mathematical and computational methods. It is recognized as an essential element in modern biological and biomedical research. There have been fundamental changes in biology and medicine over the past two decades due to spectacular advances in high throughput data collection for genomics, proteomics and biomedical imaging. The resulting availability of unprecedented amounts of biological data demands the application of advanced computational tools to build integrated models of biological systems, and to use them to devise methods of prevent or treat disease. Computational Biologists inhabit and expand the interface of computation and biology, making them integral to the future of biology and medicine.

Policy on Double Counting

No more than two courses may be double counted with your major's core requirements. Courses in the minor may not be counted towards another SCS minor. Consult the minor advisor for more information.

Curriculum Overview

The minor in computational biology requires a total of five courses: 3 core courses, 1 biology elective, and 1 computational biology elective, for a **total of at least 45 units**.

Prerequisites

Students must take both of the following courses as prerequisites:		Units
03-121	Modern Biology	9-10
or 03-151	Honors Modern Biology	
15-122	Principles of Imperative Computation	10

Core Classes

Students must take both of the following courses:		
02-250	Introduction to Computational Biology	12
or 02-251	Great Ideas in Computational Biology	
02-261	Quantitative Cell and Molecular Biology Laboratory (03-343 Experimental Techniques in Molecular Biology may be substituted for 02-261 with permission of the minor advisor; 03-116 may be used to replace 02-261 if and only if the latter is not offered)	9-12
Students must take one of the following courses:		
02-510	Computational Genomics	12
02-512	Computational Methods for Biological Modeling and Simulation	9

Biology Elective

Please select one of the following courses:		
03-220	Genetics	9
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-231	Honors Biochemistry	9
03-232	Biochemistry I	9
03-320	Cell Biology	9
03-327	Phylogenetics	9
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-364	Developmental Neuroscience	9
03-439	Introduction to Biophysics	9
03-442	Molecular Biology	9
03-534	Biological Imaging and Fluorescence Spectroscopy	9
42-202	Physiology	9

Computational Biology Elective

Please select one of the following courses:		
02-xxx	Any 02-xxx listed course 02-300 or above	9-12

Computer Science Program

Srinivasan Seshan, Department Head, Computer Science Department
Location: GHC 7019

Thomas Cortina, Program Director, Assistant Dean for Undergraduate Education
Location: GHC 4117

Mary Widom, Program Coordinator, CS Undergraduate Office
Location: GHC 4115
www.csd.cs.cmu.edu

The B.S. program in Computer Science combines a solid core of Computer Science courses with the ability to gain additional depth through a required minor in a second subject or a concentration in a computing area. In addition, the curriculum provides breadth through numerous choices for science, engineering, humanities and fine arts courses. As computing is a discipline with strong links to many fields, this provides students with unparalleled flexibility to pursue allied (or non-allied) interests.

Students apply to, and are directly admitted into, the School of Computer Science. Admitted students may choose to pursue an undergraduate degree in Computer Science and, upon successful completion, are awarded a Bachelor of Science in Computer Science. Suitably prepared students from other Carnegie Mellon colleges are eligible to apply for internal transfer to the School of Computer Science and will be considered for transfer if grades in core CS requirements are sufficiently high and space is available.

Students in the B.S. program in Computer Science are expected to acquire the following skills upon graduation:

- Identify, use, design, develop and analyze appropriate abstractions and algorithms to solve problems while being able to prove the algorithm's performance and correctness across a variety of metrics (e.g., time, space, parallel vs. sequential implementation, computability).
- Implement solutions to problems in domains such as artificial intelligence, graphics and sound, software engineering, and human-computer interaction, by applying the fundamentals of those areas to create solutions to current problems while being exposed to research developments that will enable them to adapt as the technology changes.
- Reason about and implement programs in various programming languages and paradigms
- Describe, specify, and develop large-scale, open-ended software systems subject to constraints such as performance and/or resource issues
- Communicate technical material effectively to technical and non-technical audiences
- Work both individually and in teams
- Recognize the social impact of computing and the attendant responsibility to consider the legal, moral and ethical implications of computing technologies.

Due to the tremendous number of ongoing research projects within the School, many students obtain part-time or summer jobs, or receive independent study credit, working on research while pursuing their undergraduate degree. Students seeking a research/graduate school career may pursue an intensive course of research, equivalent to four classroom courses, culminating in the preparation of a senior research thesis.

SCS also offers a B.S. degree in Artificial Intelligence, a B.S. degree in Computational Biology and a Bachelor's Degree in Computer Science and the Arts (jointly with the College of Fine Arts). More detail about the Artificial Intelligence major, the Computational Biology major and the Computer Science and the Arts program is available in separate sections of the Undergraduate Catalog. SCS offers additional majors in Computer Science (for non-CS majors), Human-Computer Interaction, and Robotics, and minors in Computational Biology, Computer Science (for non-CS majors), Human-Computer Interaction, Language Technologies, Machine Learning, Neural Computation, Robotics, and Software Engineering. Information about additional majors and minors in SCS besides those in Computer Science are listed in a separate section in the Undergraduate Catalog.

Curriculum - B.S. in Computer Science

The following requirements are for students entering Fall 2019.

Computer Science

Computer Science Core (all of the following):		Units
07-128	Freshman Immigration Course	1
15-122	Principles of Imperative Computation (students without credit or a waiver for 15-112, Fundamentals of Programming and Computer Science, must take 15-112 before 15-122)	10
15-150	Principles of Functional Programming	10
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12
15-451	Algorithm Design and Analysis	12

One Logics/Languages elective (min. 9 units):		
15-312	Foundations of Programming Languages	12
15-314	Programming Language Semantics	12
15-316	Software Foundations of Security and Privacy	9
15-317	Constructive Logic	9
15-414	Bug Catching: Automated Program Verification	9
15-424	Logical Foundations of Cyber-Physical Systems	12
17-355	Program Analysis	12
80-413	Category Theory	9
others as designated by the CS Undergraduate Program		

One Software Systems elective (min. 12 units):		
15-410	Operating System Design and Implementation	15
15-411	Compiler Design	15
15-418	Parallel Computer Architecture and Programming	12
15-440	Distributed Systems	12
15-441	Computer Networks	12
15-445	Database Systems	12
others as designated by the CS Undergraduate Program		

One Artificial Intelligence elective (min. 9 units):		
10-315	Introduction to Machine Learning (Undergrad)	12
11-411	Natural Language Processing	12
11-485	Introduction to Deep Learning	9
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
16-384	Robot Kinematics and Dynamics	12
16-385	Computer Vision	12
others as designated by the CS Undergraduate Program		

One Domains elective (min. 9 units):		
02-251	Great Ideas in Computational Biology	12
05-391	Designing Human Centered Software	12
15-322	Introduction to Computer Music	9
15-330	Introduction to Computer Security	12
15-455	Undergraduate Complexity Theory	9
15-462	Computer Graphics	12
17-313	Foundations of Software Engineering	12
others as designated by the CS Undergraduate Program		

Two Computer Science electives:	Units
These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)	18

Mathematics

All of the following courses:		
15-151	Mathematical Foundations for Computer Science (if not offered, substitute 21-127 or 21-128)	10
21-122	Integration and Approximation (Students without credit or a waiver for 21-120, Differential and Integral Calculus, must take 21-120 before 21-122.)	10
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	9
Plus one of the following four choices:		
15-259	Probability and Computing	12
21-325	Probability	9
36-218	Probability Theory for Computer Scientists	9
36-225-36-226	Introduction to Probability Theory - Introduction to Statistical Inference (must take both courses in this sequence to satisfy requirement)	18

Technical Communication

One Technical Communications course:		Units
15-300	Research and Innovation in Computer Science	9
17-200	Ethics and Policy Issues in Computing	9
76-270	Writing for the Professions	9

Science and Engineering

All candidates for the bachelor's degree in Computer Science must complete a minimum of 36 units offered by the Mellon College of Science and/or the College of Engineering (CIT). These courses offer students an opportunity to explore scientific and engineering domains that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 624).

Humanities and Arts

All candidates for the bachelor's degree in Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. Some courses from the Tepper School of Business also qualify for this requirement. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 624).

Required Minor or Concentration

Students completing the bachelor's degree in Computer Science must complete either a minor outside of SCS or a concentration within SCS. A minor is a sequence of (typically 5-6) courses within a particular department to give students a core of a specific discipline but not an entire major of study. Refer to the sections for other CMU colleges for details about available non-SCS minors. An SCS concentration is a sequence of (typically 4-5) courses within an SCS department to give students further depth in specific areas of research important to SCS. SCS concentrations are available only to SCS students and assume that these students have a significant core knowledge in Computer Science including 15-210, 15-213 and 15-251. See the SCS Concentrations section for a list of available concentrations and their requirements. Completion of an additional major (or dual degree) also satisfies this requirement. Students should consult with their academic advisor to plan for their desired minor or concentration starting in the sophomore year.

Double Counting

In general, courses taken in satisfaction of the minor or additional major may also count toward any general education category in the CS major (i.e. courses outside of the Computer Science and Mathematics requirements). Double counting toward Computer Science and Mathematics courses in the CS major is strictly limited and depends on the chosen minor (or additional major). In general, students may double count at most 5 of the 12 core Computer Science requirements toward all other declared additional majors and minors. Additional majors and minors have their own double counting rules as well. Consult with a CS undergraduate advisor and an advisor from the department of the minor (or additional major) for specific restrictions on double counting.

Computing @ Carnegie Mellon (1 course)

The following course is required of all students to familiarize them with the campus computing environment:

99-101	Computing @ Carnegie Mellon	3

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements:

Area	Courses	**Units**
Computer Science (core courses, constrained electives, and SCS electives)	12	**125**
Mathematics	5	**48**
Technical Communication	1	**9**
Science/Engineering	4	**36**
Humanities/Arts	7	**63**
Minor or Concentration Requirement/Free electives	Varies	**75**
Computing @ Carnegie Mellon	1	**3**
First Year Seminar	1	**1**
		360

Sample Course Sequence

The sample given below is for a student who already has credit for introductory programming and one semester of calculus. Students with credit for two semesters of calculus may start with a more advanced math class (e.g. 21-241) in their first year. Students with no credit for introductory programming and/or one semester of calculus will take 15-112 and/or 21-120 in their first semester and shift a few courses to later semesters after consulting with their academic advisor; these students should still be able to complete their degree in four years. It is recommended that students keep their academic load lighter for their Senior Fall semester to account for offsite job interviews or for their Senior Spring semester to account for visits to graduate schools.

Freshman Year:

Fall		Units
07-128	Freshman Immigration Course	1
07-131	Great Practical Ideas for Computer Scientists (optional, not required for CS major)	2
15-122	Principles of Imperative Computation	10
15-151	Mathematical Foundations for Computer Science (if not offered, substitute 21-127)	10
21-122	Integration and Approximation	10
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
		45

Spring		Units
15-150	Principles of Functional Programming	10
15-213	Introduction to Computer Systems	12
21-259	Calculus in Three Dimensions	9
xx-xxx	Science/Engineering Course	9
xx-xxx	Humanities and Arts Elective	9
		49

Sophomore Year:

Fall		Units
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-241	Matrices and Linear Transformations	10
xx-xxx	Science/Engineering Course	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Minor Requirement / Free Elective	9
		49

Spring		Units
15-251	Great Ideas in Theoretical Computer Science	12
xx-xxx	Computer Science: Domains Elective*	9
xx-xxx	Probability Course*	9
xx-xxx	Science/Engineering Course	9
xx-xxx	Humanities and Arts Elective	9
		48

Junior Year:

Fall		Units
15-451	Algorithm Design and Analysis	12
xx-xxx	Computer Science: Logic/Languages Elective*	9
xx-xxx	Technical Communications Course*	9
xx-xxx	Minor Requirement / Free Elective	10
xx-xxx	Minor Requirement / Free Elective	9
		49

Spring		Units
15-xxx	Computer Science: Systems Elective*	12
xx-xxx	Computer Science: Artificial Intelligence Elective*	9
xx-xxx	Science/Engineering Course	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Minor Requirement / Free Elective	9
		48

Senior Year:

Fall		Units
xx-xxx	School of Computer Science Elective	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Minor Requirement / Free Elective	9
xx-xxx	Minor Requirement / Free Elective	9
		36

Spring		Units
xx-xxx	School of Computer Science Elective	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Minor Requirement / Free Elective	9
xx-xxx	Minor Requirement / Free Elective	9
		36

Minimum number of units required for the degree: 360

*The flexibility in the curriculum allows many different schedules, of which the above is only one possibility. Some elective courses are offered only once per year (Fall or Spring). Constrained electives (probability, logic/languages, software systems, artificial intelligence and domains) may be taken in any order and in any semester if prerequisites are met and seats are available. Constrained electives are shown in the specific semesters in the schedule above as an example only. Students should consult with their academic advisor to determine the best elective options depending on course availability, their academic interests and their career goals.

Undergraduate Research Thesis

CS majors may use the SCS Honors Research Thesis as part of their degree. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Up to 18 units can be counted toward CS elective requirements (9 per semester for 2 semesters maximum). Students interested in research may also consider using Research and Innovation in Computer Science (15-300, 9 units) as their technical communications requirement in their junior year since this course will introduce students to various research projects going on in the School of Computer Science that may lead to a senior thesis. This course leads to a subsequent Research Practicum in Computer Science (15-400, 12 units) that allows students to complete a small-scale research study or experiment and present a research poster. Students who use 15-400 to start their senior thesis can use these units toward the required 36 units.

For more information about the SCS Honors Research Thesis, refer to the SCS Honors Research Thesis (p. 627) section for learning objectives, application requirements and expected outcomes.

Dual Degree in Computer Science

Students wishing to pursue a Dual Degree in Computer Science are required to apply in the same way as students wishing to transfer into the Computer Science major. Details are given in the SCS Policies section. Besides the student's primary degree requirements, a student accepted for Dual Degree in CS is required to complete at least 450 units in total and meet all requirements for the CS major including all general education requirements (humanities/arts and science/engineering). Dual degree students do not need to complete 15-128, and these students will replace 15-151 with either 21-127 or 21-128. Since the CS major requires at least a minor or concentration in another area, the student's primary major will substitute for this requirement. Note that the primary major must be completed prior to or at the same time as the dual degree in CS to satisfy the minor requirement; a dual degree in CS cannot be certified if the primary degree is not completed. Students should consult with the Assistant Dean in the CS Undergraduate Office and/or their CS academic advisor to review all requirements, once approved.

Double-Counting Restriction

Students pursuing a Dual Degree in Computer Science must complete all requirements for the CS primary major (except 15-128 which is not required and 15-151 which will be replaced with 21-127 or 21-128). In addition, at most 5 of the 12 computer science requirements can double count with all other declared majors and minors. Students, especially from interdisciplinary majors or with multiple majors or minors, are urged to consult with the Assistant Dean or Undergraduate Program Coordinator in the CS Undergraduate Office to determine double-counting restrictions specific to their own situations.

Computer Science Additional Major

Students interested in pursuing an additional major in Computer Science should first consult with an advisor in the CS Undergraduate Office. Students are expected to complete the requirements for the CS minor first before continuing on to the additional major. Completion of the CS additional major requires 12 computer science courses (not including 15-110 and 15-112 if needed), 5 mathematics courses, and 1 technical communication course. Students are expected to complete all courses for the additional major with an average QPA of 3.0 or higher.

Declaration for the additional major is allowed only after all math requirements are completed or in progress, and at least 9 of the 12 CS requirements (core and electives) are completed or in progress. Due to high demand, seats in upper-level CS courses are not guaranteed for additional majors so students should plan to be flexible in selecting constrained and general electives. Acceptance to complete a Computer Science additional major is not guaranteed and depends on student performance and seat availability.

The following courses are required for the Additional Major in Computer Science:

Computer Science requirements (12 courses):

Core courses (all are required):		Units
15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10

15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12
15-451	Algorithm Design and Analysis	12

One Logic & Languages elective (minimum 9 units):		Units
15-312	Foundations of Programming Languages	12
15-314	Programming Language Semantics	12
15-316	Software Foundations of Security and Privacy	9
15-317	Constructive Logic	9
15-414	Bug Catching: Automated Program Verification	9
15-424	Logical Foundations of Cyber-Physical Systems	12
17-355	Program Analysis	12
80-413	Category Theory	9
others as designated by the CS Undergraduate Program		

One Systems elective (minimum 12 units):		Units
15-410	Operating System Design and Implementation	15
15-411	Compiler Design	15
15-418	Parallel Computer Architecture and Programming	12
15-440	Distributed Systems	12
15-441	Computer Networks	12
15-445	Database Systems	12
others as designated by the CS Undergraduate Program		

One Artificial Intelligence elective (minimum 9 units):		Units
10-315	Introduction to Machine Learning (Undergrad) (or 10-301 by permission)	12
11-411	Natural Language Processing	12
11-485	Introduction to Deep Learning	9
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
16-384	Robot Kinematics and Dynamics	12
16-385	Computer Vision	12
others as designated by the CS Undergraduate Program		

One Domains elective (minimum 9 units):		Units
02-251	Great Ideas in Computational Biology	12
05-391	Designing Human Centered Software	12
15-322	Introduction to Computer Music	9
15-330	Introduction to Computer Security	12
15-455	Undergraduate Complexity Theory	9
15-462	Computer Graphics	12
17-313	Foundations of Software Engineering	12
others as designated by the CS Undergraduate Program		

Two Computer Science electives (minimum 18 units):	Units
These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and SCS graduate courses might not be allowed. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)	18

Math requirements (minimum 5 courses):

		Units
All of the following courses:		
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	9
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
Plus one of the following:		
15-259	Probability and Computing	12
21-325	Probability	9
36-218	Probability Theory for Computer Scientists	9
36-226	Introduction to Statistical Inference (for students already taking 36-217 or 36-225)	9

Technical Communication requirement (1 course):

One Technical Communications course:		Units
15-300	Research and Innovation in Computer Science (seating limited, by permission of instructor only)	9
17-200	Ethics and Policy Issues in Computing	9
76-270	Writing for the Professions	9

Double-Counting Restriction

Students pursuing an Additional Major in Computer Science must complete all requirements listed above. In addition, at most 5 of the 12 computer science requirements can be double counted toward all other declared majors and minors. The mathematics and technical communication requirements can be double counted without restriction. Students, especially from interdisciplinary majors or with multiple majors or minors, are urged to consult with the Assistant Dean or Undergraduate Program Coordinator in the CS Undergraduate Office to determine double-counting restrictions specific to their own situations.

Computer Science Minor

FOR STUDENTS ENTERING CMU IN FALL 2018

Students interested in pursuing a minor in Computer Science should first consult with an advisor in the CS Undergraduate Office after completion of the prerequisites, 15-122, 15-150 and with at least one of the 200-level required courses in progress. Students are expected to complete all courses for the minor with a C or higher (for a minor average QPA of 2.0 or higher).

The following courses are required for the Minor in Computer Science:

Prerequisites:		Units
15-112	Fundamentals of Programming and Computer Science (some students may need to take 15-110 prior to 15-112 for additional preparation)	12
21-127	Concepts of Mathematics	10-12
or 21-128	Mathematical Concepts and Proofs	

Computer Science core courses:		
15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
15-210	Parallel and Sequential Data Structures and Algorithms	12

One of the following Computer Science core courses:		
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Two additional Computer Science electives, of at least 9 units each:	
CS elective courses must be 15-213 or higher, at least 9-units each. 15-221 and 15-351 cannot be used. One course can be from any other SCS department besides the Computer Science Department, with prior approval. Note: Students who take 15-213/18-213 or 15-251 as part of another degree are required to replace that CS minor requirement with another CS elective (15-xxx) as defined above, for a total of 3 additional CS electives.	18

Double-Counting Restriction

Students may double-count a maximum of 2 courses for the CS minor (not including the prerequisites) toward all other majors and minors. Students, especially from computing-related majors, interdisciplinary majors or with multiple majors or minors, are urged to consult with the Assistant Dean or Undergraduate Program Coordinator in the CS Undergraduate Office to review double-counting restrictions specific to their own situations.

SCS Additional Majors and Minors

This page lists Additional Majors and Minors apart from those in Artificial Intelligence (p. 633), Computational Biology (p. 636) and Computer Science (p. 639). Select from the tabs below to view more information about each program.

Students should consult with their own academic advisor as well as the advisor for the given minor for specific double-counting rules, especially for students who are pursuing an SCS minor with a major or other minors closely related to computing. Additional help can be provided by the Assistant Dean in the Computer Science Undergraduate Program office (Gates-Hillman Center 4th Floor).

A note on SCS Concentrations: For CS Majors entering CMU in 2018 or later, these students will be required to pursue a minor outside of SCS or a concentration within SCS; minors in SCS will not be allowed for these students. Additional majors in SCS are still allowed. Computer Science majors entering prior to 2018 can substitute an SCS concentration for the minor requirement if available and approved by their academic advisor and program director. Artificial Intelligence and Computational Biology majors can complete an SCS concentration if they wish, but it is not required for these degrees. Consult the SCS Concentrations section for details on available SCS concentrations.

Human-Computer Interaction Additional Major

Vincent Aleven, *Undergraduate Director*
Location: Newell Simon Hall (NSH) 3531
www.hcii.cmu.edu

Overview

Human-Computer Interaction (HCI) is a fast growing field devoted to the design, implementation, and evaluation of interactive computer-based technology. Examples of HCI products include intelligent computer tutors, wearable computers, social networking sites, and internet connected personal digital assistants (PDAs). Constructing an HCI product is a cyclic, iterative process that has at least three stages: Design, Implementation, and Evaluation.

The Design stage involves principles of design and human behavior, the Implementation stage principles of computer science, and the Evaluation stage empirical research methods common to several disciplines. There are thus four topical areas to cover in this major: Human Behavior, Design, Implementation, and Evaluation. In slightly more detail, the major involves the following sorts of knowledge and skill:

Design

- Eliciting from the client, formulating, and articulating functional specifications
- Knowing how human factors and cognitive models should inform design
- Knowing the principles of, and having experience with, communication design
- Understanding how implementation constraints should inform design
- Incorporating evaluation results into iterated designs

Implementation Programming Skills

- Standard programming languages - e.g., C++, Java
- Rapid prototyping skill (e.g., Visual Basic, Flash)
- Computational literacy, i.e., knowledge sufficient for effective communication and decision making about:
- interface construction tools and languages
- multimedia authoring tools
- data structures and algorithms
- Operating systems, platforms, etc.

Evaluation

- Experimental design
- Focus Groups
- Surveys
- Usability Testing (Cognitive walkthroughs, user models, heuristic evaluation, GOMS)
- Statistical Analysis

There are over 45 courses relevant to these areas that are now offered by eight different departments in four different colleges at Carnegie Mellon (the School of Computer Science, the Dietrich College of Humanities and Social Sciences, and the College of Fine Arts, and the Tepper School of Business).

Curriculum

Required Courses

Psychology		Units
85-211	Cognitive Psychology	9
or 85-241	Social Psychology	
or 85-213	Human Information Processing and Artifical Intelligence	

Interaction Design Studio 1		
05-651	Interaction Design Studio 1 [c]	12

Statistics (one of the following):		
36-200	Reasoning with Data	9
36-207	Probability and Statistics for Business Applications	9
36-220	Engineering Statistics and Quality Control	9
36-225-36-226	Introduction to Probability Theory - Introduction to Statistical Inference [b]	18
36-247	Statistics for Lab Sciences	9
70-207	Probability and Statistics for Business Applications	9

Introduction to Programming		
15-104	Introduction to Computing for Creative Practice	10
or 15-110	Principles of Computing	
or 15-112	Fundamentals of Programming and Computer Science	
or 15-121	Introduction to Data Structures	

Interaction Design Studio 2		
05-650	Interaction Design Studio II	12

Human-Computer Interaction Methods		
05-410	User-Centered Research and Evaluation	12

Interface Programming		
05-430	Programming Usable Interfaces [a]	15

Project Course		
05-571	Undergraduate Project in HCI	12

Notes

- [a]The required HCI programming course 05-430 Programming Usable Interfaces is only guaranteed to be offered in the Fall. Spring offerings are only when instructor resources are available. When you register for this course, you must also sign up for a recitation time, which is equivalent to the User Interface Lab. The labs differ on their computer science prerequisites. Section D should be taken by students majoring in computer science or with advanced technical skills. Section A through C require only an introductory course in computer science as a prerequisite, and can be taken either by computer science majors or non-computer science majors.
- [b]The statistics course is required so that majors will be able to understand and conduct empirical research in HCI. Therefore a mathematically-oriented probability course, such as 36-217 Probability Theory and Random Processes does not fulfill either requirement. However, the sequence of 36-225 Introduction to Probability Theory and 36-226 Introduction to Statistical Inference (i.e., a mathematical statistics course followed by a statistical inference course) fulfills the statistics prerequisite requirement.
- [c]Design majors do not need to take 05-651 Interaction Design Studio 1 as a prerequisite, since they learn similar material in other courses for their major.

[a] The required HCI programming course 05-430 Programming Usable Interfaces is only guaranteed to be offered in the Fall. Spring offerings are only when instructor resources are available. When you register for this course, you must also sign up for a recitation time, which is equivalent to the User Interface Lab. The labs differ on their computer science prerequisites. Section D should be taken by students majoring in computer science or with advanced technical skills. Section A through C require only an introductory course in computer science as a prerequisite, and can be taken either by computer science majors or non-computer science majors.

[b] The statistics course is required so that majors will be able to understand and conduct empirical research in HCI. Therefore a mathematically-oriented probability course, such as 36-217 Probability Theory and Random Processes does not fulfill either requirement. However, the sequence of 36-225 Introduction to Probability Theory and 36-226 Introduction to Statistical Inference (i.e., a mathematical statistics course followed by a statistical inference course) fulfills the statistics prerequisite requirement.

[c] Design majors do not need to take 05-651 Interaction Design Studio 1 as a prerequisite, since they learn similar material in other courses for their major.

Electives (4)

Electives are intended to provide HCI double majors advanced concepts and skills relevant to HCI or breadth of experience not available from their primary major. Given these goals, most electives will be 300-level courses or higher. Courses at the 100-level and 200-level in one's primary major will not count as electives, although the same course taken by a non-major may count (approval is still required).

Students can take electives in the HCII or courses relevant to HCI from many other departments on campus. All external electives are approved on a case-by-case basis.

The following courses have been approved as electives in the past, organized by the offering department:

Human-Computer Interaction		Units
05-291	Learning Media Design	12
05-320	Social Web	12
05-395	Applications of Cognitive Science	9
05-413	Human Factors	9
05-418	Design Educational Games	12
05-432	Personalized Online Learning	12
05-434	Machine Learning in Practice	12
05-452	Service Design	12
05-499	Special Topics in HCI	12
05-540	Rapid Prototyping of Computer Systems	12
05-589	Independent Study in HCI-UG	Var.
05-823	E-Learning Design Principles and Methods	12
Machine Learning		
10-601	Introduction to Machine Learning (Master's)	12
Computer Science		
15-390	Entrepreneurship for Computer Science	9
15-421	Information Security and Privacy	12
15-437	Web Application Development	12
15-462	Computer Graphics	12
15-466	Computer Game Programming	12
Statistics		
36-309	Experimental Design for Behavioral & Social Sciences	9
Architecture		
48-339	IDeATe: Making Things Interactive	12
Design		
51-241	How People Work	9
51-324	Basic 3D Prototyping	4.5
51-327	Design Center: Introduction to Web Design	9
51-328	Advanced Web Design	9
51-383	Topics: Conceptual Models	9
51-385	Design for Service	9
51-424	Web Portfolio	4.5
51-359	Tools for UX Design	9
Business Administration		
70-415	Introduction to Entrepreneurship	9

Double Counting

All prerequisites can be double counted with any requirements in your primary major. At most, two non-prerequisite courses can be double counted with core requirements in primary majors.

Accelerated Master's Programs

The HCII currently offers a three semester (12-month), 15 course Masters in HCI. Undergraduates currently enrolled in the HCI major may apply for the Accelerated Masters program in the fall semester of their senior year. If admitted, student finish the masters degree the following Fall semester.

Admission to the Major

The HCI undergraduate major is currently available only as a additional major. Because space is limited in the major's required courses, enrollment in the HCI undergraduate major is currently limited to about 35 students in each graduating class. The admissions period occurs in spring semesters. For more details, see the website at hcii.cmu.edu/academics/hci-undergraduate.

Human-Computer Interaction Minor

The Minor in Human-Computer Interaction will give students core knowledge about techniques for building successful user interfaces, approaches for conceiving, refining, and evaluating interfaces that are useful and useable, and techniques for identifying opportunities for computational technology to improve the quality of people's lives. The students will be able to effectively collaborate in the design, implementation, and evaluation of easy-to-use, desirable, and thoughtful interactive systems. They will be prepared to contribute to multidisciplinary teams that create new interactive products, services, environments, and systems.

The key concepts, skills and methods that students will learn in the HCI Minor include:

- Fieldwork for understanding people's needs and the influence of context
- Generative approaches to imagining many possible solutions such as sketching and "bodystorming"
- Iterative refinement of designs
- Basic visual design including typography, grids, color, and the use of images
- Implementation of interactive prototypes
- Evaluation techniques including discount and empirical evaluation methods

The HCI minor is targeted at undergraduates who expect to get jobs where they design and/or implement information technology-based systems for end users, and well as students with an interest in learning more about the design of socio-technical systems. It is appropriate for students with majors in Computer Science and Information Systems, as well as students in less software-focused majors, including Design, Architecture, Art, Business Administration, Psychology, Statistics, Decision Science, Mechanical Engineering, Electrical Engineering, English and many others in the university.

Curriculum

The only prerequisite for this Minor is an introductory-level college programming course (such as 15-110, 15-112, 15-121, or 51-257) and to be in good standing with the University.

In addition to the programming prerequisite, the Minor has required two courses—05-391 Designing Human Centered Software (DHCS) and 05-392 Interaction Design Overview (IxDO)—and four electives. The student will be required to get a grade of "C" or better in each course in order for it to count as part of the Minor. There is no final project or research required for the Minor.

Required Courses

- 05-391 Designing Human Centered Software (DHCS)[1]: This course provides an overview of the most important methods taught in the Additional Major in HCI, such as Contextual Inquiry, Prototyping and Iterative Design, Heuristic Evaluation, and Think Aloud User Studies. It covers in a more abbreviated form the content of 05-410 User-Centered Research and Evaluation, 05-430 Programming Usable Interfaces.
- 05-392 (IxDO)[2]: This is a design course that will combine material from 05-651 *and* 05-650 for students who do not have any previous

experience with design, in a form that will fit appropriately in to a one-semester format.

Electives

The HCI minor requires four electives approved by the undergraduate director.

Double Counting

Students may double count up to two (2) of the required courses or electives with any other major or minor.

Relationship between the BHCI Major and Minor

Admission

- **BHCI Major:** Application and admissions required, information on the HCII website (http://www.hcii.cmu.edu).
- **BHCI Minor:** Admissions form available at the HCII website (http://www.hcii.cmu.edu).

Prerequisites

- **BHCI Major:**
  - Freshman-level programming
  - Statistics
  - Cognitive Psychology
  - Interaction Design Studios
- **BHCI Minor:**
  - Freshman-level programming

Core Courses

- **BHCI Major:**
  - Interaction Design Studio I & II (IxDS)
  - User Centered Research & Evaluation (UCRE)
  - Interface Programming (PUI)
  - BHCI Project
- **BHCI Minor:**
  - Interaction Design Overview (IxDO)
  - Designing Human Centered Systems (DHCS)

Electives

- **BHCI Major:** Four (4) electives
- **BHCI Minor:** Four (4) electives

Double Counting

- **BHCI Major:** Two (2) core courses or electives with primary major.
- **BHCI Minor:** Two (2) core courses or electives with primary major.

Footnotes

[1] Alternatively, a student can take *both* the BS/MHCI empirical methods course (05-410) *and* the BS/MHCI core-programming course (either 05-430 Programming Usable Interfaces . If students take this course sequence, they would get credit for fulfilling this requirement plus one elective.

[2] Alternatively, students can fulfill the design requirement by taking both 05-650 *and* 05-651. If students take this course sequence, they would get credit for fulfilling this requirement plus one elective.

These alternative ways of fulfilling the requirements for the HCI minor are designed for students who are in the HCI 2nd major who want to "downgrade" to the minor. These students can use some the courses completed for the HCI 2nd major as a way of fulfilling the requirements for the minor.

Students who are in the HCI minor right from the start are strongly encouraged to follow the regular requirements outlined above and are strongly discouraged from trying these alternative ways of fulfilling the requirements. It can be extremely difficult to get into any of the alternative courses. This is true especially for 05-650, but for other courses as well. The fact that a student in the minor has already taken 05-651 will not give priority for getting into 05-650.

IDeATe Minors

Kelly Delaney, *Advisor*
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https://ideate.cmu.edu

The Integrative Design, Arts and Technology (IDeATe) network offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students engage in active "learning by doing" in state-of-the-art maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of eight areas, all of which can be taken as minors. The themes of these areas integrate knowledge in technology and the arts. Four of these minors are based in the School of Computer Science:

Animation & Special Effects Minor

Explore the technical and artistic aspects of 3D and 2D animation in an integrated manner and within different application contexts, from film animation and special effects to interactive displays.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
60-218	IDeATe Portal: Real-Time Animation Recommended portal course for this area	10
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
60-223	IDeATe: Introduction to Physical Computing	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
99-361	IDeATe Portal	9

IDeATe Animation & Special Effects Courses - Minimum of 27 Units

		Units
15-365/60-422	Experimental Animation	12
15-463	Computational Photography	12
15-465/60-414	Animation Art and Technology	12
60-125	IDeATe: Introduction to 3D Animation	12
60-220	IDeATe Technical Character Animation	10
60-333	IDeATe: Character Rigging for Production	10
60-398	Critical Studies: Social History of Animation	9
60-410	Advanced ETB: Moving Image Magic: Visual Effects and Motion Graphics	10
60-415	Advanced ETB: Animation Studio	10
60-417	Advanced ETB: Video	10

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their Animation & Special Effects minor courses toward other requirements.

Intelligent Environments Minor

Develop spaces and devices that support efficiency and high quality of experience in contexts like daily activity, built environment, making process (from laying plaster to robot development), and arts performance.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
16-223	IDeATe Portal: Creative Kinetic Systems Recommended Portal Course for this area	10
60-223	IDeATe: Introduction to Physical Computing Recommended Portal Course for this area	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
60-218	IDeATe Portal: Real-Time Animation	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
99-361	IDeATe Portal	9

IDeATe Intelligent Environments Courses - Minimum of 27 Units

		Units
05-333	Gadgets, Sensors and Activity Recognition in HCI	12
16/54-375	IDeATe: Robotics for Creative Practice	10
16-376	IDeATe: Kinetic Fabrics	10
16-455/48-530	IDeATe: Human-Machine Virtuosity	12
16-467	Human Robot Interaction	12
18/05-540	Rapid Prototyping of Computer Systems	12
48-339	IDeATe: Making Things Interactive	12
48/53-558	Reality Computing	12
49-313	Designing for the Internet of Things	12
51-400	Transition Design	9
62-315	IDeATe: Shaping the Built Environment: Experiments in Geometry and Matter	9

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their Intelligent Environments minor courses toward other majors and minors.

Design for Learning Minor

Design effective new media systems for learning using new technologies, learning science principles and media arts knowledge. Produce engaging and effective experiences from games to tangible learning tool kits and remote systems.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
60-218	IDeATe Portal: Real-Time Animation	10
60-223	IDeATe: Introduction to Physical Computing	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
99-361	IDeATe Portal	9

IDeATe Design for Learning Courses - Minimum of 27 Units

05-291	Learning Media Design	12
05-292	IDeATe: Learning in Museums	12
05-418	Design Educational Games	12
05-432	Personalized Online Learning	12
05-823	E-Learning Design Principles and Methods	12
51-400	Transition Design	9
51-486	Learner Experience Design	9
79-343	Education, Democracy, and Civil Rights	9
85-392	Human Expertise	9

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their Design for Learning minor courses toward requirements for other majors and minors.

Physical Computing Minor

Build interfaces and circuitry to embed in physical contexts, such as mobile environments and new creative practice instruments.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
16-223	IDeATe Portal: Creative Kinetic Systems Recommended Portal Course for this area	10
60-223	IDeATe: Introduction to Physical Computing Recommended Portal Course for this area	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
60-218	IDeATe Portal: Real-Time Animation	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
99-361	IDeATe Portal	9

IDeATe Physical Computing Courses - Minimum of 27 Units

		Units
05-333	Gadgets, Sensors and Activity Recognition in HCI	12
05/18-540	Rapid Prototyping of Computer Systems	12
15-294	Rapid Prototyping Technologies	5
15-394	Intermediate Rapid Prototyping	5
16/54-375	IDeATe: Robotics for Creative Practice	10
16-376	IDeATe: Kinetic Fabrics	10
16-455/48-530	IDeATe: Human-Machine Virtuosity	12

18/05-540	Rapid Prototyping of Computer Systems	12
18-578	Mechatronic Design	12
24-672	Special Topics in DIY Design and Fabrication	12
39-245	Rapid Prototype Design	9
48-339	IDeATe: Making Things Interactive	12
48/53-558	Reality Computing	12
49-313	Designing for the Internet of Things	12
62-315	IDeATe: Shaping the Built Environment: Experiments in Geometry and Matter	9, 12
62-362	Activating the Body: Physical Computing and Technology in Performance	10
62-478	IDeATe: digiTOOL	6

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their Physical Computing minor courses toward requirements for other majors and minors.

Language Technologies Minor

Alan W. Black, *Chair*
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www.lti.cs.cmu.edu/learn

Human language technologies have become an increasingly central component of computer science. Information retrieval, machine translation and speech technology are used daily by the general public, while text mining, natural language processing and language-based tutoring are common within more specialized professional or educational environments. The Language Technologies Institute prepares students for this world by offering a minor that gives you the opportunity to not only learn about language technologies, but to also apply that knowledge through a directed project.

Prerequisites

Prerequisites		Units
15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10

Recommended		
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
15-259	Probability and Computing	12
or 21-325	Probability	
or 36-218	Probability Theory for Computer Scientists	

Curriculum

Core requirement:		
11-324	Human Language for Artificial Intelligence	12

Electives (choose 3):		
11-411	Natural Language Processing	12
11-441	Machine Learning for Text Mining	9
11-442	Search Engines	9
11-492	Speech Processing	12
11-711	Algorithms for NLP	12
11-731	Machine Translation and Sequence-to-Sequence Models	12
11-751	Speech Recognition and Understanding	12
11-752	Speech II: Phonetics, Prosody, Perception and Synthesis	12
11-761	Language and Statistics	12
80-180	Nature of Language	9
80-280	Linguistic Analysis	9

Project:	
A semester-long directed research project OR paper to provide hands-on experience and an in-depth study of a topic (in same area as a chosen elective)	12

Double Counting of Courses

Students may double count 11-324 Human Language for Artificial Intelligence and 80-180 Nature of Language toward any other major or minor.

Machine Learning Minor

Dr. Matt Gormley, *Program Director*
Dorothy Holland-Minkley, *Program Coordinator*
ml-minor@cs.cmu.edu
www.ml.cmu.edu/academics/minor-in-machine-learning.html

Machine learning and statistical methods are increasingly used in many application areas including natural language processing, speech, vision, robotics, and computational biology. The Minor in Machine Learning allows undergraduates to learn about the core principles of this field.

Prerequisites

The 4-5 prerequisite courses must be taken before a student applies to the Machine Learning Minor.

Prerequisites		Units
15-122	Principles of Imperative Computation	10
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
36-217	Probability Theory and Random Processes	9
or 36-218	Probability Theory for Computer Scientists	
or 36-225	Introduction to Probability Theory	
or 15-259	Probability and Computing	
or 21-325	Probability	
If 36-218 is completed with at least a B, 36-226/36-326 may be skipped. If a lower grade is earned or a different probability course is taken, 36-226 or 36-326 must be taken.		
36-226	Introduction to Statistical Inference	9
or 36-326	Mathematical Statistics (Honors)	

Core Courses

The Machine Learning Minor has 2 core courses that provide a foundation in the field.

Core Courses		
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (Undergrad)	
10-403	Deep Reinforcement Learning & Control	12
or 10-405	Machine Learning with Large Datasets (Undergraduate)	
or 10-417	Intermediate Deep Learning	
or 10-418	Machine Learning for Structured Data	

Electives

The Machine Learning Minor requires at least 3 electives of at least 9 units each in Machine Learning. Students may select one of the following options to satisfy the electives requirement:

- 3 Principal courses
- 2 Principal courses + 1 Interdisciplinary course
- 2 Principal courses + 1 semester of CS Senior Honors Thesis or Senior Research
- 1 Principal course + 2 semesters of CS Senior Honors Thesis or Senior Research

Students should note that some of these elective courses (those at the 600-level and higher) are primarily aimed at graduate students, and so should make sure that they are adequately prepared for them before enrolling.

Graduate-level cross-listings of these courses can also be used for the ML Minor, if the student is adequately prepared for the more advanced version and the home department approves the student's registration.

Principal Electives

10-403	Deep Reinforcement Learning & Control	12
10-405	Machine Learning with Large Datasets (Undergraduate)	12
or 10-745	Scalability in Machine Learning	
10-417	Intermediate Deep Learning	12
or 11-485	Introduction to Deep Learning	
or 10-707	Topics in Deep Learning	

10-418	Machine Learning for Structured Data	12
or 10-708	Probabilistic Graphical Models	
10-702	Statistical Machine Learning	12
or 10-716	Advanced Machine Learning: Theory and Methods	
10-725	Convex Optimization	12
36-401	Modern Regression	9
Other courses as approved		

Interdisciplinary Electives

02-510	Computational Genomics	12
03-511	Computational Molecular Biology and Genomics	9
10-335	Art and Machine Learning	12
10-737	Creative AI	12
11-411	Natural Language Processing	12
11-441	Machine Learning for Text Mining	9
11-661	Language and Statistics	12
11-731	Machine Translation and Sequence-to-Sequence Models	12
11-751	Speech Recognition and Understanding	12
11-755	Machine Learning for Signal Processing	12
11-777	Multimodal Machine Learning	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
15-388	Practical Data Science	9
15-482	Autonomous Agents	12
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
16-720	Computer Vision	12
16-745	Optimal Control and Reinforcement Learning	12
16-824	Visual Learning and Recognition	12
16-831	Statistical Techniques in Robotics	12
17-537	Artificial Intelligence Methods for Social Good	9
17-640	IoT, Big Data, and ML: A Hands-on Approach	12
36-315	Statistical Graphics and Visualization	9
36-402	Advanced Methods for Data Analysis	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-700	Probability and Mathematical Statistics	12
or 36-705	Intermediate Statistics	
Other courses as approved		

CS Senior Honors Thesis

The CS Senior Honors Thesis consists of 36 units of academic credit for this work. Up to 24 units (12 units each semester) may be counted towards the ML Minor. Students must consult with the Computer Science Department for information about the CS Senior Honors Thesis. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

07-599	SCS Honors Undergraduate Research Thesis	Var.

Senior Research

Senior research consists of 2 semesters of 10-500 Senior Research Project, totaling 24 units and counting as 2 electives.

The research must be a year-long senior project, supervised or co-supervised by a Machine Learning Core Faculty member. It is almost always conducted as two semester-long projects, and must be done in senior year. Some samples of available Machine Learning Senior Projects are available on the Machine Learning Department webpage.

Interested students should contact the faculty they wish to advise them to discuss the research project, before the semester in which research will take place. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Minor Director to confirm that the project will count for the Machine Learning Minor.

The student should expect to meet with the Minor Director during both Senior Fall and Spring to discuss the project, and will present the work and submit a year-end write-up to the Minor Director at the end of Senior year.

10-500	Senior Research Project	24

Double Counting

No course in the Machine Learning Minor may be counted towards another SCS minor. Additionally, at least 3 courses (each being at least 9 units) must be used for only the Machine Learning Minor, not for any other major, minor, or concentration. (These double counting restrictions apply specifically to the Core Courses and the Electives. Prerequisites may be counted towards other majors, minors, and concentrations and do not count towards the 3 courses that must be used for only the Machine Learning Minor.)

GRADES

All courses for the Machine Learning Minor, including prerequisites, must be passed with a C or better.

ADMISSION

The Machine Learning Minor is open to undergraduate students in any major at Carnegie Mellon outside the School of Computer Science. (SCS students should instead consider the Machine Learning Concentration.) Students should apply for admission at least one semester before their expected graduation date, but are encouraged to apply as soon as they have taken the prerequisite classes for the minor. The application can be found on the Machine Learning Minor website.

Neural Computation Minor

Dr. Tai Sing Lee, *Director*
Melissa Stupka, *Administrative Coordinator*
www.cnbc.cmu.edu/upnc/nc_minor

Neural computation is a scientific enterprise to understand the neural basis of intelligent behaviors from a computational perspective. Study of neural computation includes, among others, decoding neural activities using statistical and machine learning techniques, and developing computational theories and neural models of perception, cognition, motor control, decision-making and learning. The neural computation minor allows students to learn about the brain from multiple perspectives, and to acquire the necessary background for graduate study in neural computation. Students enrolled in the minor will be exposed to, and hopefully participate in, the research effort in neural computation and computational neuroscience at Carnegie Mellon University.

The minor in Neural Computation is an intercollege minor jointly sponsored by the School of Computer Science, the Mellon College of Science, and the Dietrich College of Humanities and Social Sciences, and is coordinated by the Center for the Neural Basis of Cognition (CNBC) (http://www.cnbc.cmu.edu).

The Neural computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, H&SS and MCS.

The Neural Computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, Dietrich College and MCS. The primary objective of the minor is to encourage students in biology and psychology to take computer science, engineering and mathematics courses, to encourage students in computer science, engineering, statistics and physics to take courses in neuroscience and psychology, and to bring students from different disciplines together to form a community. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in cognitive science and neuroscience that are central to computational neuroscience.

APPLICATION

tudents must apply for admission no later than November 30 of their senior years; an admission decision will usually be made within one month. Students are encouraged to apply as early as possible in their undergraduate careers so that the director of the Neural Computation minor can provide advice on their curriculum, but should contact the program director any time even after the deadline.

To apply, send email to the director of the Neural Computation minor Dr. Tai Sing Lee (tai@cnbc.cmu.edu) and copy Melissa Stupka (mstupka@cnbc.cmu.edu). Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Your class and College/School at Carnegie Mellon
- Semester you intend to graduate
- All (currently) declared majors and minors
- Statement of purpose (maximum 1 page) – Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses for the Minor (this is your plan, NOT a commitment)
- Research projects you might be interested in

Curriculum

The Minor in Neural Computation will require a total of five courses: four courses drawn from the four core areas (A: neural computation, B: neuroscience, C: cognitive psychology, D: intelligent system analysis), one from each area, and one additional depth elective chosen from one of the core areas that is outside the student's major. The depth elective can be replaced by a one-year research project in computational neuroscience. No more than two courses can be double counted toward the student's major or other minors. However, courses taken for general education requirements of the student's degree are not considered to be double counted. A course taken to satisfy one core area cannot be used to satisfy the course requirement for another core area. The following listing presents a set of current possible courses in each area. Other computational neuroscience courses are being developed at Carnegie Mellon and University of Pittsburgh that will also satisfy core area A requirement and the requirements will be updated as they come on-line. Substitution is possible but requires approval.

A. Neural Computation

		Units
15-386	Neural Computation	9
15-387	Computational Perception	9
15-883	Computational Models of Neural Systems	12
85-419	Introduction to Parallel Distributed Processing	9
86-375	Computational Perception	9
Pitt-Mathematics-1800 Introduction to Mathematical Neuroscience		9

B. Neuroscience

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
42-630	Introduction to Neuroscience for Engineers (crosslisted with 18-690)	12
85-765	Cognitive Neuroscience	Var.
Pitt-Neuroscience 1000 Introduction to Neuroscience		9

C. Cognitive Psychology

85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artifical Intelligence	9
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-426	Learning in Humans and Machines	9
85-765	Cognitive Neuroscience	Var.

D. Intelligent System Analysis

10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (Undergrad)	
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
15-387	Computational Perception	9
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-299	Introduction to Feedback Control Systems	12
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
18-290	Signals and Systems	12
24-352	Dynamic Systems and Controls	12
36-225	Introduction to Probability Theory	9
36-247	Statistics for Lab Sciences	9
36-401	Modern Regression	9
36-410	Introduction to Probability Modeling	9
36-746	Statistical Methods for Neuroscience and Psychology	12
42-631	Neural Data Analysis	9
42-632	Neural Signal Processing	12
86-375	Computational Perception	9
86-631	Neural Data Analysis	9

Prerequisites

The required courses in the above four core areas require a number of basic prerequisites: basic programming skills at the level of 15-110 Principles of Computing and basic mathematical skills at the level of 21-122 Integration and Approximation or their equivalents. Some courses in Area D require additional prerequisites. Area B Biology courses require, at minimum, 03-121 Modern Biology. Students might skip the prerequisites if they have the permission of the instructor to take the required courses. Prerequisite courses are typically taken to satisfy the students' major or other requirements. In the event that these basic skill courses are not part of the prerequisite or required courses of a student's major, one of them can potentially count toward the five required courses (e.g. the depth elective), conditional on approval by the director of the minor program.

Research Requirements (Optional)

The minor itself does not require a research project. The student however may replace the depth elective with a year-long research project. In special circumstances, a research project can also be used to replace one of the five courses, as long as (1) the project is not required by the student's major or other minor, (2) the student has taken a course in each of the four core areas (not necessarily for the purpose of satisfying this minor's requirements), and (3) has taken at least three courses in this curriculum not counted toward the student's major or other minors. Students interested in participating in the research project should contact any faculty engaged in computational neuroscience or neural computation research at Carnegie Mellon or in the University of Pittsburgh. A useful webpage that provides listing of faculty in neural computation is www.cnbc.cmu.edu/computational-neuroscience. The director of the minor program will be happy to discuss with students about their research interest and direct them to the appropriate faculty.

Fellowship Opportunities

The Program in Neural Computation (PNC) administered by the Center for the Neural Basis of Cognition currently provides 3-4 competitive full-year fellowships ($11,000) to Carnegie Mellon undergraduate students to carry out mentored research in neural computation. The fellowship has course requirements similar to the requirements of the minor. Students do not apply to the fellowship program directly. They have to be nominated by the faculty members who are willing to mentor them. Therefore, students interested in the full-year fellowship program should contact and discuss research opportunities with any CNBC faculty at Carnegie Mellon or University of Pittsburgh working in the area of neural computation or computational neuroscience and ask for their nomination by sending email to Dr. Tai Sing Lee, who also administers the undergraduate fellowship program at Carnegie Mellon. See www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/ for details.

The Program in Neural Computation also offers a summer training program for undergraduate students from any U.S. undergraduate college. The students will engage in a 10-week intense mentored research and attend a series of lectures in neural computation. See www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/ for application information.

Robotics Additional Major

Dr. Howie Choset, *Director*
Barbara (B.J.) Fecich, *Administrative Coordinator*
http://addlmajor.ri.cmu.edu

The Additional Major in Robotics focuses on the theme that robotics is both multidisciplinary and interdisciplinary. This means that it draws from many fields, such as mechanical engineering, computer science and electrical engineering, and it also integrates these fields in a novel manner. The foundation of this program lies in motion and control. Upon this base, sensing, cognition, and action are layered. Since robotics involves building artifacts that embody these fundamentals, foci, and systems thinking, there is a "hands-on" course requirement. These foci are brought together by a unique systems perspective special to robotics. Students will complete a capstone course that will tie together previously learned skills and knowledge.

Admission

The Additional Major in Robotics is available to all Carnegie Mellon undergraduate students. Students should apply for the Robotics Additional Major their freshman year. Students in their sophomore year may apply, provided they meet the requirements and their schedule can accommodate the courses. The application is available via the program website and is due early February. Decisions on admittance to the Additional Major will be emailed to students in time for Fall registration. Application materials include:

- Full name and email address
- Home college, expected graduation date, and list of all declared Majors and Minors
- Statement of purpose (maximum 1 page, single spaced, to articulate why the student wants to pursue the Robotics Additional Major)
- Proposed schedule of required courses
- Unofficial Academic Record (can be downloaded from SIO)

Curriculum

Prerequisites

Calculus		Units
21-259	Calculus in Three Dimensions	9

Linear Algebra (choose one)		
18-202	Mathematical Foundations of Electrical Engineering	12
21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	10
21-260	Differential Equations	9
24-311	Numerical Methods	12

Programming in C		
15-122	Principles of Imperative Computation	10
or knowledge and experience programming in C		

Required Courses

Choose 10 courses total (one from each category plus two electives):

Overview		Units
16-311	Introduction to Robotics	12

Controls		
06-464	Chemical Engineering Process Control	9
16-299	Introduction to Feedback Control Systems	12
18-370	Fundamentals of Control	12
24-451	Feedback Control Systems	12
16-xxx	Upper-level RI course with instructor and Program Director's permission	9-12

Kinematics		
16-384	Robot Kinematics and Dynamics	12
16-xxx	Upper-level RI course with instructor and Program Director's permission	9-12

Machine Perception		
15-387	Computational Perception	9
15-463	Computational Photography	12
16-385	Computer Vision	12
16-421	Vision Sensors	12
16-423	Designing Computer Vision Apps	12
85-370	Perception	9
85-395	Applications of Cognitive Science	9
16-xxx	Upper-level RI course with instructor and Program Director's permission	9-12

Cognition and Reasoning		
10-301	Introduction to Machine Learning	12
10-315	Introduction to Machine Learning (Undergrad)	12
11-344	Machine Learning in Practice	12
15-381	Artificial Intelligence: Representation and Problem Solving	9
15-482	Autonomous Agents	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-350	Planning Techniques for Robotics	12
85-395	Applications of Cognitive Science	9
16-xxx	Upper-level RI course with instructor and Program Director's permission	9-12

"Hands-on Course"		
15-491	Special Topic: CMRoboBits: AI and Robots for Daily-Life Problems	12
16-362	Mobile Robot Algorithms Laboratory	12
16-423	Designing Computer Vision Apps	12
18-349	Introduction to Embedded Systems	12
18-578	Mechatronic Design	12
18-500	ECE Design Experience	12
24-671	Special Topics: Electromechanical Systems Design	12
16-xxx	Upper-level RI project course e.g., 16-861 or 16-865 or independent study with instructor and Program Director's permission	9-12

Systems Engineering		
16-450	Robotics Systems Engineering	12

Capstone Course		
16-474	Robotics Capstone	12

Required Electives (choose two)		
11-344	Machine Learning in Practice	12
10-301	Introduction to Machine Learning	12
10-315	Introduction to Machine Learning (Undergrad)	12
15-381	Artificial Intelligence: Representation and Problem Solving	9
15-424	Logical Foundations of Cyber-Physical Systems	12
15-462	Computer Graphics	12
15-463	Computational Photography	12
16-467	Human Robot Interaction	12
16-745	Optimal Control and Reinforcement Learning	12
16-761	Mobile Robots	12
16-899	Special Topics	12
15-482	Autonomous Agents	12
15-491	Special Topic: CMRoboBits: AI and Robots for Daily-Life Problems	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-264	Humanoids	12
16-362	Mobile Robot Algorithms Laboratory	12
16-385	Computer Vision	12
16-421	Vision Sensors	12
16-423	Designing Computer Vision Apps	12
16-597	Undergraduate Reading and Research	Var.
18-342	Fundamentals of Embedded Systems	12
18-349	Introduction to Embedded Systems	12
18-578	Mechatronic Design	12
24-677	Special Topics: Linear Control Systems	12
24-771	Linear Systems	12
85-370	Perception	9
85-395	Applications of Cognitive Science	9
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-426	Learning in Humans and Machines	9

Students may count up to 12 units of 16-597 Undergraduate Reading and Research towards the major requirements. A student can also take additional courses from the core; e.g., a student who takes 16-385 as a core can take 16-421 as an elective.

Graduate level Robotics courses may be used to meet elective requirement with permission from the Program Director. Graduate level Mechanical Engineering and Electrical and Computer Engineering courses that are relevant to robotics may be used to meet the elective requirement with permission from the Program Director.

A 3.0 QPA in the Additional Major curriculum is required for graduation. Courses that are taken Pass/Fail or audited cannot be counted for the Additional Major.

Double-Counting Restriction

Students are permitted to double count a maximum of six courses from their Primary Major towards the Additional Major in Robotics. CS Majors are permitted to double count a maximum of five courses from their Primary Major towards the Additional Major in Robotics.

Robotics Minor

Dr. Howie Choset, *Director*
Barbara (B.J.) Fecich, *Administrative Coordinator*
http://undergrad.ri.cmu.edu/academics/minor

The Minor in Robotics provides an opportunity for undergraduate students at Carnegie Mellon to learn the principles and practices of robotics through theoretical studies and hands-on experience with robots. The Minor is open to students in any major of any college at Carnegie Mellon. Students initially learn the basics of robotics in an introductory robotics overview course. Additional required courses teach control systems and robotic manipulation. Students also choose from a wide selection of electives in robotics, perception, computer vision, cognition and cognitive science, or computer graphics. Students have a unique opportunity to undertake independent research projects, working under the guidance of Robotics Institute faculty members; this provides an excellent introduction to robotics research for those considering graduate studies.

All Robotics Minors are required to take Introduction to Robotics (16-311). This course is designed to help students understand the big picture of what is going on in robotics through topics such as kinematics, mechanisms, motion planning, sensor based planning, mobile robotics, sensors, and vision. The minor also requires students to take a controls class and a kinematics class. These courses provide students with the necessary intuition and technical background to move on to more advanced robotics courses. In addition to the required courses, students must take 2 electives. The student must have course selection approved by the Director during the application submission process.

A 2.5 QPA in the Minor curriculum is required for graduation. Courses that are taken Pass/Fail or audited cannot be counted for the Minor.

Admission

Admission to the Undergraduate Minor in Robotics is limited to current Carnegie Mellon students. Students interested in signing up for the minor should fill out the application form available on the program website.

Prerequisite

Successful candidates for the Robotics Minor will have prerequisite knowledge of C language, basic programming skills, and familiarity with basic algorithms. Students can gain this knowledge by taking 15-122 Principles of Imperative Computation.

Required Courses

Overview:		Units
16-311	Introduction to Robotics	12

Controls (choose one of the following):		
06-464	Chemical Engineering Process Control	9
16-299	Introduction to Feedback Control Systems (Computer Science)	12
18-370	Fundamentals of Control	12
24-451	Feedback Control Systems	12
16-xxx	Upper-level RI course with instructor and Program Director's permission	

Kinematics (choose one of the following):		
16-384	Robot Kinematics and Dynamics	12
16-xxx	Upper-level RI course with instructor and Program Director's permission	

Electives

Two Electives (chosen from the following):		Units
10-301	Introduction to Machine Learning	12
10-315	Introduction to Machine Learning (Undergrad)	12
11-344	Machine Learning in Practice	12
15-381	Artificial Intelligence: Representation and Problem Solving	9
15-424	Logical Foundations of Cyber-Physical Systems	12
15-462	Computer Graphics	12
15-463	Computational Photography	12
15-482	Autonomous Agents	12
15-491	Special Topic: CMRoboBits: AI and Robots for Daily-Life Problems	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-264	Humanoids	12
16-350	Planning Techniques for Robotics	12
16-362	Mobile Robot Algorithms Laboratory	12
16-385	Computer Vision	12
16-421	Vision Sensors	12
16-423	Designing Computer Vision Apps	12
16-467	Human Robot Interaction	12
16-597	Undergraduate Reading and Research	Var.
16-745	Optimal Control and Reinforcement Learning	12
16-761	Mobile Robots	12
16-899	Special Topics	12
18-342	Fundamentals of Embedded Systems	12
18-349	Introduction to Embedded Systems	12
18-500	ECE Design Experience	12
18-578	Mechatronic Design	12
24-671	Special Topics: Electromechanical Systems Design	12
24-677	Special Topics: Linear Control Systems	12
24-771	Linear Systems	12
85-370	Perception	9
85-395	Applications of Cognitive Science	9
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-426	Learning in Humans and Machines	9

Graduate level Robotics courses may be used to meet the elective requirement with permission from the Program Director. Graduate level Mechanical Engineering and Electrical and Computer Engineering courses that are relevant to robotics may be used to meet the elective requirement with permission from the Program Director.

Students may count up to 12 units of 16-597 Undergraduate Reading and Research towards the minor requirements.

Double-Counting Restriction

Courses being used to satisfy the requirements for the Robotics Minor may not be counted towards another minor. Students are permitted to double count a maximum of two courses from their Major (excluding General Education requirements) towards the Minor in Robotics. Free electives are not subject to the double counting policy.

Software Engineering Minor

Michael Hilton, *Director*
mhilton@andrew.cmu.edu
http://isri.cmu.edu/education/undergrad

Effectively building modern software systems at scale requires not just programming skills, but also engineering skills. These skills include the ability to interact effectively with customers to gather the requirements for a system in a precise way; to develop a design that resolves competing quality attributes; to make tradeoffs among schedule, cost, features, and quality to maximize value to stakeholders; to work effectively with other engineers; and to assure the quality of the delivered software system. We hear regularly from industry that these skills are crucial to them, and that they are interested in students with a strong software engineering background.

The software engineering minor is designed to teach the fundamental tools, techniques, and processes of software engineering. Through internships and a mentored project experience, students gain an understanding of the issues of scale and complexity that motivate software engineering tools and techniques. The core curriculum includes material both on engineering the software product and on the process, teamwork, and management skills that are essential to successful engineering. Graduates of the program should have the technical, process, and teamwork skills to be immediately productive in a mature engineering organization.

Admission

The Software Engineering Minor is open to undergraduate students in any major in the university. We encourage students to submit applications no later than 3 days before the beginning of Spring and Fall course registration, so that subsequent decisions can help students plan their subsequent course schedule effectively. However, students may petition the Director for admission outside this general schedule.

To apply, send the directors an email. Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Semester you intend to graduate
- QPA
- All (currently) declared majors and minors, or home college if no major declared
- Statement of purpose (maximum 1 page) - Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses and internship (this is your plan, NOT a commitment)

Prerequisite

		Units
17-214	Principles of Software Construction: Objects, Design, and Concurrency	12

Core Course Requirements

17-313	Foundations of Software Engineering	12
17-413	Software Engineering Practicum	12

Electives

The minor requires three elective courses, one selected from each of the following categories:

1. One domain-independent course focused on technical software engineering material:

15-414	Bug Catching: Automated Program Verification	9
17-355	Program Analysis	12
17-356	Software Engineering for Startups	12
17-615	Software Process Definition	9
17-651	Models of Software Systems	12
17-652	Methods: Deciding What to Design	12
17-653	Managing Software Development (prereq: 17-413 or an internship)	12
17-654	Analysis of Software Artifacts	12
17-655	Architectures for Software Systems (prereq: 17-413 or an internship)	12
17-731	Foundations of Privacy	12
17-781	Mobile and IoT Computing Services	12
17-821	Computational Modeling of Complex Socio-Technical Systems	12

Other Software Engineering graduate classes may be taken; you must get preapproval from the program director prior to taking the class.

2. One engineering-focused course with a significant software component:

15-410	Operating System Design and Implementation	15
15-412	Operating System Practicum	Var.
15-440	Distributed Systems	12
15-441	Computer Networks	12
17-437	Web Application Development	12
17-643	Hardware for Software Engineers	Var.

Other courses may be acceptable; you must get preapproval from the program director prior to taking the course.

3. One course that explores computer science problems related to existing and emerging technologies and their associated social, political, legal, business, and organizational contexts:

15-390	Entrepreneurship for Computer Science	9
17-200	Ethics and Policy Issues in Computing	9
17-331	Information Security, Privacy, and Policy	12
17-333	Privacy Policy, Law, and Technology	9
17-334	Usable Privacy and Security	9
17-562	Law of Computer Technology	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
70-311	Organizational Behavior	9
70-415	Introduction to Entrepreneurship	9
70-421	Entrepreneurship for Computer Scientists	9
70-471	Supply Chain Management	9

Required Internship and Reflection Course

A software engineering internship of a minimum of 8 full-time weeks in an industrial setting is required. The student must be integrated into a team and exposed to industry pressures. The intern may work in development, management, quality assurance, or other relevant positions. The director of the SE minor program has sole discretion in approving an internship experience based on these criteria. Students should confirm that an internship position is appropriate before accepting it, but internships that fulfill the criteria will also be accepted after the fact.

- *17-415 Software Engineering Reflection (required 6 unit course, number to be determined, to be offered Fall semester):* Each student will conduct an analysis of some personal software engineering experience, typically (but not always) based on the engineering internship above. The student will then write and edit a short paper presenting this analysis. Initial course meetings will cover the reflective, writing, and speaking process. In later meetings, each student will present his or her experience through a 30-45 minute talk, which will be evaluated for communication skills and critical reflective content. This course is limited to enrollment of 16, and students who are admitted to the minor program are given first priority.

17-415	Software Engineering Reflection	6

Double Counting Rule

At most 2 of the courses used to fulfill the minor requirements may be counted towards any other major or minor program. This rule does not apply to 17-214 (a prerequisite for the minor) or courses counted for general education requirements.

Other Departments and Institutes Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

SCS: Computational Biology Courses

02-201 Programming for Scientists
Fall and Spring: 10 units
Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required. Course not open to CS majors.

02-223 Personalized Medicine: Understanding Your Own Genome
Fall: 9 units
Do you want to know how to discover the tendencies hidden in your genome? Since the first draft of a human genome sequence became available at the start of this century, the cost of genome sequencing has decreased dramatically. Personal genome sequencing will likely become a routine part of medical exams for patients for prognostic and diagnostic purposes. Personal genome information will also play an increasing role in lifestyle choices, as people take into account their own genetic tendencies. Commercial services such as 23andMe have already taken first steps in this direction. Computational methods for mining large-scale genome data are being developed to unravel the genetic basis of diseases and assist doctors in clinics. This course introduces students to biological, computational, and ethical issues concerning use of personal genome information in health maintenance, medical practice, biomedical research, and policymaking. We focus on practical issues, using individual genome sequences (such as that of Nobel prize winner James Watson) and other population-level genome data. Without requiring any background in biology or CS, we begin with an overview of topics from genetics, molecular biology, stats, and machine learning relevant to the modern personal genome era. We then cover scientific issues such as how to discover your genetic ancestry and how to learn from genomes about migration and evolution of human populations. We discuss medical aspects such as how to predict whether you will develop diseases such as diabetes based on your own genome, how to discover disease-causing genetic mutations, and how genetic information can be used to recommend clinical treatments.

02-250 Introduction to Computational Biology
Spring: 12 units
This 12-unit class provides a general introduction to computational tools for biology. The course is divided into two modules. Module 1 covers computational molecular biology/genomics. It examines important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research. In the process, it covers basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. Module 2 covers computational cell biology, including biological modeling and image analysis. It includes homework assignments requiring modification of scripts to perform computational analyses. The modeling component includes computer models of population dynamics, biochemical kinetics, cell pathways, neuron behavior, and stochastic simulations. The imaging component includes basics of machine vision, morphological image analysis, image classification and image-derived models. Lectures and examinations are joint with 03-250, but recitations are separate. Recitations for this course are intended primarily for computational biology majors as well as computer science, statistics or engineering majors at the undergraduate or graduate level who have had significant prior experience with computer science or programming. Students may not take both 02-250 and 03-250 for credit.
Prerequisites: (02-201 or 15-110 or 15-112) and (03-151 or 03-121) and 21-122

02-251 Great Ideas in Computational Biology
Spring: 12 units
This 12-unit course provides an introduction to many of the great ideas that have formed the foundation for the transformation of life sciences into a fully-fledged computational discipline. This gateway course is intended as a first exposure to computational biology for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded students who are interested in exploring the field. By completing this course, students will encounter a handful of fundamental algorithmic approaches deriving straight from very widely cited primary literature, much of which has been published in recent years. The course also introduces basic concepts in statistics, mathematics, and machine learning necessary to understand these approaches. Many of the ideas central to modern computational biology have resulted in widely used software that is applied to analyze (often very large) biological datasets; an important feature of the course is that students will be exposed to this software in the context of compelling biological problems.
Prerequisites: (15-112 or 02-201) and (15-151 or 21-127 or 21-128)

02-261 Quantitative Cell and Molecular Biology Laboratory
Fall and Spring
This is an introductory laboratory-based course designed to teach basic biological laboratory skills used in exploring the quantitative nature of biological systems and the reasoning required for performing research in computational biology. Over the course of the semester, students will design and perform multiple modern experiments and quantitatively analyze the results of these experiments. During this course students will also have an opportunity to use techniques learned during the course to experimentally answer an open question. Designing the experiments will require students to think critically about the biological context of the experiments as well as the necessary controls to ensure interpretable experimental results. During this course students will gain experience in many aspects of scientific research, including: sequencing DNA, designing and performing PCR for a variety of analyses, maintaining cell cultures, taking brightfield and fluorescent microscopy images, developing methods for automated analysis of cell images, communicating results to peers and colleagues. As space is limited, laboratory sections will be small. Additional sections will be added to accommodate all students on the waitlist. Course Outline: (1) 3-hour lab per week, (1) 1-hour lecture per week.

02-317 Algorithms in Nature
Intermittent: 9 units
Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. No prior biological knowledge required.
Prerequisites: 15-251 and 15-210

Course Website: http://www.algorithmsinnature.org

02-319 Genomics and Epigenetics of the Brain
Fall: 9 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in genomic technology are in the process of revolutionizing how we conduct molecular biology research. These new techniques have given us an appreciation for the role that epigenetics modifications of the genome play in gene regulation, development, and inheritance. In this course, we will cover the biological basis of genomics and epigenetics, the basic computational tools to analyze genomic data, and the application of those tools to neuroscience. Through programming assignments and reading primary literature, the material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: (03-151 or 03-121) and (03-220 or 03-221) and (15-112 or 15-110 or 02-201 or 15-121)

02-402 Computational Biology Seminar
Fall and Spring: 3 units
This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Students will be expected to digest what they have learned in the seminar by writing short summaries on each speaker's topic.

02-403 Special Topics in Bioinformatics and Computational Biology
Intermittent: 6 units
A decade ago, mass spectrometry (MS) was merely a qualitative research technique allowing the analysis of samples regarding the presence of specific biomolecules. However, as MS has turned quantitative, more sophisticated experiments can be performed, such as the recording of signal transduction kinetics and the analysis of the composition of protein complexes and organelles. This makes MS-based proteomics a powerful method to study spatiotemporal protein dynamics. The development of relative quantification approaches, which generally use 2H, 13C or 15N isotope labels, has especially led to an increase in quantification accuracy and set off numerous new experimental approaches to study protein regulation. In this mini-course, we will cover mass spectrometry principles, discuss classical as well as current primary literature addressing method development and quantitative analysis, and highlight state-of-the-art biological studies that employ MS. A combination of lectures, student presentations, and written exercises will establish a thorough knowledge of current bio-analytical MS approaches.
Prerequisites: (03-250 Min. grade C or 02-250 Min. grade C) and 03-121 Min. grade C

02-421 Algorithms for Computational Structural Biology
Intermittent: 12 units
Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-425 Computational Methods for Proteogenomics and Metabolomics
Spring: 9 units
Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.
Prerequisites: 02-250 or 02-604

02-450 Automation of Scientific Research
Spring: 9 units
Biology is increasingly becoming a "big data" science, as biomedical research has been revolutionized by automated methods for generating large amounts of data on diverse biological processes. Integration of data from many types of experiments is required to construct detailed, predictive models of cell, tissue or organism behaviors, and the complexity of the systems suggests that these models need to be constructed automatically. This requires iterative cycles of acquisition, analysis, modeling, and experimental design, since it is not feasible to do all possible biological experiments. This course will cover a range of automated biological research methods and a range of computational methods for automating the acquisition and interpretation of the data (especially active learning, proactive learning, compressed sensing and model structure learning). Grading will be based on class participation, homeworks, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of biology, statistics, and programming. Experience with Machine Learning is useful but not mandatory.
Prerequisites: (10-701 or 10-315) and 15-122

Course Website: https://sites.google.com/site/automationofbiologicalresearch/

02-499 Independent Study in Computational Biology
Fall and Spring
The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-500 Undergraduate Research in Computational Biology
Fall and Spring
This course is for undergraduate students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator who will enroll you in the course. 02-250 is a suggested pre-requisite.

02-510 Computational Genomics
Fall and Spring: 12 units
Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. In this course we will discuss classical approaches and latest methodological advances in the context of the following biological problems: 1) sequence analysis, focusing on gene finding and motifs detection, 2) analysis of high throughput molecular data, such as gene expression data, including normalization, clustering, pattern recognition and classification, 3) molecular and regulatory evolution, focusing on phylogenetic inference and regulatory network evolution, 4) population genetics, focusing on how genomes within a population evolve through recombination, mutation, and selection to create various structures in modern genomes and 5) systems biology, concerning how to combine diverse data types to make mechanistic inferences about biological processes. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course may be taken for 12 units, which requires completion of a course project, or for 9 units, which does not.
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C)

02-512 Computational Methods for Biological Modeling and Simulation
Fall: 9 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.
Prerequisites: 15-110 or 15-112 or 02-201

02-514 String Algorithms
Fall: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Burrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.
Prerequisite: 15-251

02-515 Advanced Topics in Computational Genomics
Spring: 12 units
Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for ciritiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-518 Computational Medicine
Fall: 12 units
Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.

Course Website: https://sites.google.com/site/computationalmedicinecmu/

02-530 Cell and Systems Modeling
Fall: 12 units
This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed.
Prerequisites: (03-151 or 33-121 or 03-121) and (03-232 or 03-231) and 21-112 and 09-105

02-601 Programming for Scientists
Fall and Spring: 12 units
Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed, and students will have the opportunity to design their own programming project on a scientific topic of their choice. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required. Course not open to CS majors.

Course Website: http://compeau.cbd.cmu.edu/programming-for-scientists/

02-602 Professional Issues for Computational and Automated Scientists
Fall and Spring: 3 units
This course gives Master's in Computational Biology and Master's in Automated Science students the opportunity to develop the professional skills necessary for a successful career in either academia or industry. This course, required in the first semester of both programs, will include assistance with elevator pitches, interview preparation, resume and cover letter writing, networking, and presentation skills. The course will also include opportunities to connect with computational biology professionals as part of industry outreach. The course will meet once a week and is pass/fail only.

02-604 Fundamentals of Bioinformatics
Spring: 12 units
How do we find potentially harmful mutations in your genome? How can we reconstruct the Tree of Life? How do we compare similar genes from different species? These are just three of the many central questions of modern biology that can only be answered using computational approaches. This 12-unit course will delve into some of the fundamental computational ideas used in biology and let students apply existing resources that are used in practice every day by thousands of biologists. The course offers an opportunity for students who possess an introductory programming background to become more experienced coders within a biological setting. As such, it presents a natural next course for students who have completed 02-601. 02-250 is a suggested pre-requisite for undergraduates.

02-605 Professional Issues in Automated Science
Fall
This course gives MS in Automated Science students an opportunity to develop professional skills necessary for a successful career in computational biology. This course will include assistance with resume writing, interview preparation, presentation skills, and job search techniques. This course will also include opportunities to network with computational biology professionals and academic researchers.

02-613 Algorithms and Advanced Data Structures
Fall and Spring: 12 units
The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. 02-250 is a suggested pre-requisite.

02-651 New Technologies and Future Markets
Fall: 12 units
This course focuses on technological trends and how these trends can help shape or disrupt new and existing markets. Students will learn to identify, analyze, and synthesize emerging trends and perform detailed research on how these trends can influence and create markets. By understand the drivers behind these trends students will be able to identify key market opportunity inflection points in biotechnology as well as the relationship between business processes and information technology (IT). Students will also learn to assess some information technologies and the potential of applying them to solve problems and create commercially viable solutions. The course is designed for the student interested in finding new venture opportunities on the cutting edge of technology and finding and evaluating the opportunities for further development. For MS Biotechnology Innovation and Computation students only.
Prerequisite: 11-695

02-654 Biotechnology Enterprise Development
Fall: 12 units
In this course students learn how to develop a biotech start-up, create a Minimum Viable Product (MVP), business model and strategy for the product. Students will learn about business modeling, customer development, customer validation, proposal, product branding, and marketing for their product. The course will require students to spend most time to validate their start up concept and prototypes with potential customers and adapt to critical feedback and revise their respective value propositions accordingly. Students learn to balance technical product development with customer requirements, business strategy and budget constraints. This course provides real world, hands-on learning on what it is like to start a company. Different business modeling will be covered. By understand customer discovery and validation concepts will aid students to effectively modify their original concepts to meet market demands. Student teams will learn how to revise, improve their prototype by the end of the term. This is a fast paced course in which students are expected to spend most of the time outside of the classroom to interact with potential customers to validate, test, verify, and integrate essentials elements for their start-up business proposal. Up to now, students have been learning some technologies and methods for solving problems in the life science industry and build a prototype for their start-up. However, a new venture proposal is not a collection of isolated bits. It should be thorough validated via customer's inputs and market needs to tell a single story of how the venture will reach its end goals. Final deliverable is creation and presentation of a well explicated, business proposal in addition to a product prototype corresponding to the business proposal.
Prerequisites: 02-651 and 11-695

02-680 Essential Mathematics and Statistics for Scientists
Fall: 9 units
This course is for first year master's students looking for a rigorous introduction to mathematics and statistics as preparation for more advanced coursework in computational courses. Closed to enrollment for undergraduates.

02-699 Independent Study in Computational Biology
Fall and Spring
The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-703 Special Topics in Bioinformatics and Computational Biology
Intermittent: 6 units
A decade ago, mass spectrometry (MS) was merely a qualitative research technique allowing the analysis of samples regarding the presence of specific biomolecules. However, as MS has turned quantitative, more sophisticated experiments can be performed, such as the recording of signal transduction kinetics and the analysis of the composition of protein complexes and organelles. This makes MS-based proteomics a powerful method to study spatiotemporal protein dynamics. The development of relative quantification approaches, which generally use 2H, 13C or 15N isotope labels, has especially led to an increase in quantification accuracy and set off numerous new experimental approaches to study protein regulation. In this mini-course, we will cover mass spectrometry principles, discuss classical as well as current primary literature addressing method development and quantitative analysis, and highlight state-of-the-art biological studies that employ MS. A combination of lectures, student presentations, and written exercises will establish a thorough knowledge of current bio-analytical MS approaches.

02-710 Computational Genomics
Spring: 12 units
Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. In this course we will discuss classical approaches and latest methodological advances in the context of the following biological problems: 1) sequence analysis, focusing on gene finding and motifs detection, 2) analysis of high throughput molecular data, such as gene expression data, including normalization, clustering, pattern recognition and classification, 3) molecular and regulatory evolution, focusing on phylogenetic inference and regulatory network evolution, 4) population genetics, focusing on how genomes within a population evolve through recombination, mutation, and selection to create various structures in modern genomes and 5) systems biology, concerning how to combine diverse data types to make mechanistic inferences about biological processes. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc.

02-711 Computational Molecular Biology and Genomics
Spring: 12 units
An advanced introduction to computational molecular biology, using an applied algorithms approach. The first part of the course will cover established algorithmic methods, including pairwise sequence alignment and dynamic programming, multiple sequence alignment, fast database search heuristics, hidden Markov models for molecular motifs and phylogeny reconstruction. The second part of the course will explore emerging computational problems driven by the newest genomic research. Course work includes four to six problem sets, one midterm and final exam.
Prerequisites: (03-151 or 03-121) and 15-122

02-712 Computational Methods for Biological Modeling and Simulation
Fall: 12 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.
Prerequisites: (15-112 or 15-110) and (02-613 or 02-201)

02-714 String Algorithms
Fall: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.
Prerequisite: 15-251

02-715 Advanced Topics in Computational Genomics
Spring: 12 units
Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for ciritiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-717 Algorithms in Nature
Fall: 12 units
Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. See also: www.algorithmsinnature.org no prior biological knowledge required.

02-718 Computational Medicine
Fall: 12 units
Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.
Prerequisites: 10-401 or (10-601 and 10-701)

Course Website: https://sites.google.com/site/computationalmedicinecmu/

02-719 Genomics and Epigenetics of the Brain
Fall: 12 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in genomic technology are in the process of revolutionizing how we conduct molecular biology research. These new techniques have given us an appreciation for the role that epigenetics modifications of the genome play in gene regulation, development, and inheritance. In this course, we will cover the biological basis of genomics and epigenetics, the basic computational tools to analyze genomic data, and the application of those tools to neuroscience. Through programming assignments and reading primary literature, the material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: (03-121 or 03-151) and 03-220 and (15-110 or 02-201 or 15-121)

02-721 Algorithms for Computational Structural Biology
Intermittent: 12 units
Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-725 Computational Methods for Proteogenomics and Metabolomics
Spring: 12 units
Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.
Prerequisites: 02-604 or 02-250 or 02-251

02-730 Cell and Systems Modeling
Fall: 12 units
This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed. *THIS COURSE WILL BE AT PITT
Prerequisites: (33-121 or 03-121 or 03-151) and (03-232 or 03-231) and 21-112 and 09-105

Course Website: https://sites.google.com/site/cellandsystemsmodeling/

02-740 Bioimage Informatics
Intermittent: 12 units
With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.

02-750 Automation of Scientific Research
Spring: 12 units
Biology is increasingly becoming a "big data" science, as biomedical research has been revolutionized by automated methods for generating large amounts of data on diverse biological processes. Integration of data from many types of experiments is required to construct detailed, predictive models of cell, tissue or organism behaviors, and the complexity of the systems suggests that these models need to be constructed automatically. This requires iterative cycles of acquisition, analysis, modeling, and experimental design, since it is not feasible to do all possible biological experiments. This course will cover a range of automated biological research methods and a range of computational methods for automating the acquisition and interpretation of the data (especially active learning, proactive learning, compressed sensing and model structure learning). Grading will be based on class participation, homeworks, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of biology, statistics, and programming.
Prerequisites: 10-601 or 10-701

Course Website: https://sites.google.com/site/automationofbiologicalresearch/?pli=1

02-760 Laboratory Methods for Computational Biologists
Fall and Spring: 6 units
Computational biologists frequently focus on analyzing and modeling large amounts of biological data, often from high-throughput assays or diverse sources. It is therefore critical that students training in computational biology be familiar with the paradigms and methods of experimentation and measurement that lead to the production of these data. This one-semester laboratory course gives students a deeper appreciation of the principles and challenges of biological experimentation. Students learn a range of topics, including experimental design, structural biology, next generation sequencing, genomics, proteomics, bioimaging, and high-content screening. Class sessions are primarily devoted to designing and performing experiments in the lab using the above techniques. Students are required to keep a detailed laboratory notebook of their experiments and summarize their resulting data in written abstracts and oral presentations given in class-hosted lab meetings. With an emphasis on the basics of experimentation and broad views of multiple cutting-edge and high-throughput techniques, this course is appropriate for students who have never taken a traditional undergraduate biology lab course, as well as those who have and are looking for introductory training in more advanced approaches. Grading: Letter grade based on class participation, laboratory notebooks, experimental design assignments, and written and oral presentations. 02-250 is a suggested pre-requisite.

02-761 Laboratory Methods for Automated Biology I
Fall: 12 units
In order to rapidly generate reproducible experimental data, many modern biology labs leverage some form of laboratory automation to execute experiments. In the not so distant future, the use of laboratory automation will continue to increase in the biological lab to the point where many labs will be fully automated. Therefore, it is critical for automation scientists to be familiar with the principles, experimental paradigms, and techniques for automating biological experimentation with an eye toward the fully automated laboratory. In this laboratory course, students will learn about various automatable experimental methods, design of experiments, hardware for preparing samples and executing automated experiments, and software for controlling that hardware. These topics will be taught in lectures as well as through laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on liquid handling, plate control, plate reading, and remote control of the automated system based on experimental data. The second project will be focused on the design, implementation, and analysis of a high content screening campaign using fluorescence microscopy, image analysis, and tissue culture methods.

02-801 Computational Biology Internship
Fall and Summer: 3 units
This course is for students participating in an internship or co-op.

02-900 Ph.D. Thesis Research
All Semesters
This course is for Ph.D students doing supervised research for academic credit.

SCS: Human-Computer Interaction Courses

05-291 Learning Media Design
Fall: 12 units
[IDeATe collaborative course] Learning is a complex human phenomenon with cognitive, social and personal dimensions that need to be accounted for in the design of technology enhanced learning experiences. In this studio course students will apply learning science concepts to critique existing forms of learning media, establish a set of design precedents to guide project work and produce a series of design concepts that support learning interactions in a real-world context. Collaborating in small interdisciplinary teams, students will partner with a local informal learning organization (e.g. museum, after school program provider, maker space) to conduct learning design research studies, synthesize findings, establish learning goals and iteratively prototype and assess design concepts. As final deliverables, students will present their design research findings, design concepts, and prototypes to stakeholders, and draft a media-rich proposal for their learning media concept to pitch to a local funder. Please note that there may be usage/materials fees associated with this course. Please note that there may be usage/materials fees associated with this course.

05-292 IDeATe: Learning in Museums
Spring: 12 units
Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences though a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts that improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions. This course will culminate in a media-rich presentation of design concepts and a prototype to a stakeholder audience, and include an evaluation plan describing how learning outcomes for the project would be assessed.

05-300 HCI Undergraduate Pro Seminar
All Semesters: 2 units
HCI is a broad field that brings together approaches from design, computer science, and psychology. This course provides an introduction to the field of HCI and to the HCI community at CMU. Guest speakers from around campus will provide a general introduction to these approaches and how they are pursued at CMU, and will describe research opportunities that are available to undergraduates. The course will also discuss career options in both industry and academia for students of HCI, and will include presentations from HCI alumni and sessions on preparing resumes, creating portfolios, and interviewing for jobs. The course is designed for current or potential HCI majors and minors but is open to anyone with an interest in applying for the HCI major/minor. Note that class will begin 5 minutes after the scheduled start to accommodate students arriving to Craig street from the main campus.

Course Website: https://hcii.cmu.edu/academics/courses

05-317 Design of Artificial Intelligence Products
Intermittent: 12 units
This course teaches students how to design new products and services that leverage the capabilities of AI and machine learning to improve the quality of people¿s lives. Students will learn to follow a matchmaking design, user-centered design, and service design process. Students will learn to ideate; reframing problematic situations by envisioning many possible products and services. Students will learn to iteratively refine and assess their ideas with real users/customers. Class projects will focus on the challenges of deploying systems that generate errors and the challenges of situating intelligent systems such that they harmonize the best qualities of human and machine intelligence.

Course Website: https://hcii.cmu.edu/academics/courses

05-318 Human AI Interaction
Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: http://www.hcii.cmu.edu/academics/courses

05-320 Social Web
Intermittent: 12 units
With the growth of online environments like MySpace, Second Life, World of Warcraft, Wikipedia, blogs, online support groups, and open source development communities, the web is no longer just about information. This course, jointly taught by a computer scientist and a behavioral scientist, will examine a sampling of the social, technical and business challenges social web sites must solve to be successful, teach students how to use high-level tools to analyze, design or build online communities, and help them understand the social impact of spending at least part of their lives online. This class is open to advanced undergraduates and graduate students with either technical or non-technical backgrounds. Course work will include lectures and class discussion, homework, class presentations, and a group research or design project.

05-333 Gadgets, Sensors and Activity Recognition in HCI
Fall: 12 units
Recent advances in HCI have been driven by new capabilities to deliver inexpensive devices to users, to display information in mobile and other contexts, to sense the user and their environment, and use these sensors to create models of a user's context and actions. This course will consider both concepts surrounding these new technological opportunities through discussion of current literature - and practical considerations the skills needed to actually build devices. About 1/3 of this class will review current advances in this area. The remainder will be devoted to development of individual skills so that students leaving the class will have an ability to actually build small devices for human interaction (in short: "HCI gadgets"). In particular, the course will concentrate on the basics of building simple microcontroller-based devices and will also provide very basic coverage of the machine learning techniques needed for simple sensor-driven statistical models. The course is designed to be accessible to students with a wide range of backgrounds including both technically-oriented and non-technical students (especially Designers) interested in HCI. The class will be project oriented with 4-5 electronic prototype building projects during the semester. At least two of these projects will be self-defined in nature and can be adapted to the existing skills and interests of each student. There are no formal prerequisites for this class. However, the class will involve programming and debugging of micro-controllers. Some coverage of the language used to do this will be provided, and if required by your background, the programming component of the projects can be made comparatively small (but, in that case some other aspect of the projects will need to be expanded). However, you should not take this course if you have no programming background. This course assumes no background in electronics.

Course Website: http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci

05-341 Organizational Communication
All Semesters: 9 units
Most of management is communication. You communicate to get information that will be the basis of decisions, coordinate activity, to provide a vision for the people who work for and with you, to and to sell yourself and your work. The goal of this course is to identify communication challenges within work groups and organizations and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. The intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly participate in when you move to a work environment, and strategies for improving communication within your groups. Because technology is changing communication patterns and outcomes both in organizations and more broadly in society, the course examines these technological changes. Readings come primarily from the empirical research literature.

Course Website: http://www.hcii.cmu.edu/courses/organizational-communication

05-391 Designing Human Centered Software
All Semesters: 12 units
Why are things so hard to use these days? Why doesn't this thing I just bought work? Why is this web site so hard to use? These are frustrations that we have all faced from systems not designed with people in mind. The question this course will focus on is: how can we design human-centered systems that people find useful and usable? This course is an introduction to designing, prototyping, and evaluating user interfaces. If you take only one course in Human-Computer Interaction, this is the course for you. This class is a core course for undergrads in the HCI Minor but open to all undergrads and grad students, with either technical or non-technical backgrounds. We will cover theory as well as practical application of ideas from Human-Computer Interaction. Course work includes lectures, class discussion, homework, class presentations, and group project. Students will need a prerequisite of a fundamental computer programming course.
Prerequisites: 15-112 or 15-110 or 15-104 or 15-122

Course Website: http://www.hcii.cmu.edu/courses/designing-human-centered-software

05-392 Interaction Design Overview
Fall: 9 units
This studio course offers a broad overview of communication and interaction design. Students will learn design methodologies such as brainstorming, sketching, storyboarding, wire framing, and prototyping. Students learn to take a human-centered design approach to their work. Assignments include short in-class exercises as well as individual and team-based projects. Students take part in studio critiques, engaging in critical discussions about the strengths and weaknesses of their own work and the work of others. No coding is required.

05-395 Applications of Cognitive Science
Spring: 9 units
The goal of this course is to examine cases where basic research on cognitive science, including cognitive neuroscience, has made its way into application, in order to understand how science gets applied more generally. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se; for example, as a product, a change in practice, or a legal statute. Examples are virtual reality (in vision, hearing, and touch), cognitive tutors, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students. They should bring to the course an interest in application; extensive prior experience in cognitive science is not necessary. The course will include tutorials on basic topics in cognitive science such as perception, memory, and spatial cognition. These should provide sufficient grounding to discuss the applications.

Course Website: http://www.hcii.cmu.edu/courses/applications-cognitive-science

05-410 User-Centered Research and Evaluation
Fall: 12 units
This course provides and overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of task analysis, and analytic and empirical evaluation methods. This is a companion course to courses in visual design (51-422) and software implementation (05-430, 05-431). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school e.g. seniors, juniors, etc This course is NOT open to students outside the HCI major. When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school.

05-413 Human Factors
Fall: 9 units
This course uses theory and research from human factors, cognitive science, and social science to understand and design the interactions of humans with the built world, tools, and technology. The course emphasizes current work in applied domains such as automotive design, house construction, medical human factors, and design of information devices. The course also will emphasize not only individual human factors (e.g., visual response, anthropometry) but also the organizational arrangements that can amplify or correct human factors problems. Through reading, discussion, and projects, you will learn about human perceptual, cognitive, and physical processes that affect how people interact with, and use, technology and tools. You will learn why we have so many automobile accidents, voting irregularities, and injuries from prescription medication. You will learn some tried and true solutions for human factors problems, and some of the many problems in human factors that remain. You will also have gained experience in research in this field.

Course Website: http://www.hcii.cs.cmu.edu

05-417 Computer-mediated Communication
Spring: 6 units
This course examines fundamental aspects of interpersonal communication and considers how different types of computer-mediated communications (CMC) technologies affect communication processes. Among the topics we will consider are: conversational structure and CMC, tools to support nonverbal and paralinguistic aspects of communication such as gesture and eye gaze, and social and cultural dimensions of CMC. Students will be expected to post to weekly discussion lists, to write a paper on a specific aspect of CMC, and to present a talk on their final project to the class. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

05-418 Design Educational Games
Spring: 12 units
The potential of digital games to improve education is enormous. However, it is a significant challenge to create a game that is both fun and educational. In this course, students will learn to meet this challenge by combining processes and principles from game design and instructional design. Students will also learn to evaluate their games for fun, learning, and the integration of the two. They will be guided by the EDGE framework for the analysis and design educational games. The course will involve a significant hands-on portion, in which students learn a design process to create educational games digital or non-digital. They will also read about existing educational games and discuss game design, instructional design, learning and transfer, and the educational effectiveness of digital games. They will analyze an educational game and present their analysis to the class.

Course Website: http://www.hcii.cmu.edu/courses/design-educational-games

05-430 Programming Usable Interfaces
Spring: 15 units
This course is combines lecture, and an intensive programming lab and design studio. It is for those who want to express their interactive ideas in working prototypes. It will cover the importance of human-computer interaction/interface design, iterative design, input/output techniques, how to design and evaluate interfaces, and research topics that will impact user interfaces in the future. In lab, you will learn how to design and program effective graphical user interfaces, and how to perform user tests. We will cover a number of prototyping tools and require prototypes to be constructed in each, ranging from animated mock-ups to fully functional programs. Assignments will require implementing UIs, testing that interface with users, and then modifying the interface based on findings. Some class sessions will feature design reviews of student work. This course is for HCII Masters students and HCI dual majors with a minimal programming background. Students will often not be professional programmers, but will need to interact with programmers. RECITATION SELECTION: Students taking this course can sign up for either Prototyping Lab recitation. PREREQUISITES: Proficiency in a programming language, program structure, algorithm analysis, and data abstraction. Normally met through an introductory programming course using C, C++, Pascal or Java, such as 15100, 15112, 15127 or equivalent. Students entering this course should be able to independently write a 300-line program in 48 hours. This course is NOT open to students outside of the BHCI program.
Prerequisites: 15-110 or 15-104 or 15-112 or 15-127 or 15-100

05-431 Software Structures for User Interfaces
Fall: 15 units
SSUI (15-credit, combined lecture and lab) This course considers the basic and detailed concepts that go into building software to implement user interfaces. It considers factors of input, output, application interface, and related infrastructure as well as the typical patterns used to implement them. It will also consider how these components are organized and managed within a well-structured object oriented system. After considering these fundamental concepts in the first portion of the class, the later part will consider advanced topics related to emerging future concepts in user interface design. The course includes an intensive programming lab, either on the topic of mobile or web interfaces. This course is intended for HCII Master, BHCI dual majors and others who wish to understand the structures needed for professional development of interactive systems, and has a strong programming background. PREREQUISITES: Comfort in programming and related concepts equivalent to an undergraduate CS degree. Should be proficient in programming, and comfortable with abstract concepts relating to program structure, algorithm analysis, and data abstraction. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-432 Personalized Online Learning
Fall: 12 units
Online learning has become widespread (e.g., MOOCs, online and blended courses, and Khan Academy) and many claim it will revolutionize higher education and K-12. How can we make sure online learning is maximally effective? Learners differ along many dimensions and they change over time. Therefore, advanced learning technologies must adapt to learners to provide individualized learning experiences. This course covers a number of proven personalization techniques used in advanced learning technologies. One of the techniques is the use of cognitive modeling to personalize practice of complex cognitive skills in intelligent tutoring systems. This approach, developed at CMU, may well be the most significant application of cognitive science in education and is commercially successful. We will also survey newer techniques, such as personalizing based on student meta-cognition, affect, and motivation. Finally, we will look at personalization approaches that are widely believed to be effective but have not proven to be so. The course involves readings and discussion of different ways of personalizing instruction, with an emphasis on cognitive modeling approaches. Students will learn to use the Cognitive Tutor Authoring Tools (CTAT) to implement tutor prototypes that rely on computer-executable models of human problem solving to personalize instruction. The course is meant for graduate or advanced undergraduate students in Human-Computer Interaction, Psychology, Computer Science, Design, or related fields, who are interested in educational applications. Students should either have some programming skills or experience in the cognitive psychology of human problem solving, or experience with instructional design.

Course Website: http://www.hcii.cmu.edu/courses/personalized-online-learning

05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces
Fall: 6 units
Section A: Programming Usable Interfaces Section B: Software Structures for Usable Interfaces This is a lecture-only course (see 05-430/05-630 or 05-431/631 for the lecture + lab version of these courses) that is intended for those who want to learn how to design and evaluate user interfaces. We will cover the importance of human-computer interaction and interface design, the iterative design cycle used in HCI, an overview of input and output techniques, how to design and evaluate interaction techniques, and end with a discussion of hot topics in research that will impact user interfaces in the coming years. This course is only intended for HCII Masters students or HCI undergraduate majors who have already taken an associated User Interface lab, or non-MHCI/BHCI students interested in the design of user interfaces. PREREQUISITES: There are no prerequisites for this lecture-only course. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-434 Machine Learning in Practice
Fall and Spring: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization. 05-834 is the HCII graduate section. If you are an LTI student, please sign up for the LTI graduate course number (11-663) ONLY to count properly towards your degree requirements. 05-434 is the HCII undergraduate section. If you are an LTI student, please sign up for the LTI undergraduate course number (11-344) ONLY to count properly towards your degree requirements.

Course Website: http://www.hcii.cmu.edu/courses/applied-machine-learning

05-435 Advanced Fabrication Techniques for HCI
Fall: 12 units
This course will consider how new fabrication techniques such as 3D printing, laser cutting, CNC machining and related computer controlled technologies can be applied to problems in Human-Computer Interaction. Each offering will concentrate on a particular application domain for its projects. This year the course will consider assistive technology. This course will be very hands-on and skills-oriented, with the goal of teaching students the skills necessary to apply these technologies to HCI problems such as rapid prototyping of new device concepts. To this end? Every student in this course will build and take home a 3D printer. (There will be $400-$500 cost associated with this course to make that possible. Details on this are still to be determined.)

05-439 The Big Data Pipeline: Collecting and Using Big Data for Interactive Systems
Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: http://data.cmubi.org

05-440 Interaction Techniques
Intermittent: 12 units
This course will provide a comprehensive study of the many ways to interact with computers and computerized devices. An "interaction technique" starts when the user does something that causes an electronic device to respond, and includes the direct feedback from the device to the user. Examples include physical buttons and switches, on-screen menus and scroll bars operated by a mouse, touch screen widgets and gestures such as flick-to-scroll, text entry on computers or touch screens, consumer electronic controls such as remote controls, game controllers, and adaptations of all of these for people with disabilities. We will start with a history of the invention and development of these techniques, discuss the various options used today, and continue on to the future with the latest research on interaction techniques presented at conferences such as ACM CHI and UIST. Guest lectures from inventors of interaction techniques are planned. Students will have a choice for final projects that can focus on historical or novel interaction techniques. For example, one option will be to create a novel technique, perform a user study of it, and write a paper about the result, which may be suitable for conference submission. Another option will be to investigate and write a paper or make a video about the history and various previous designs for widely used interaction techniques, possibly including an interview with the inventor(s).

Course Website: http://www.cs.cmu.edu/~bam/uicourse/05440inter/

05-452 Service Design
Fall: 12 units
In this course, we will collectively define and study services and product service systems, and learn the basics of designing them. We will do this through lectures, studio projects, and verbal and written exposition. Classwork will be done individually and in teams.

05-499 Special Topics in HCI
Fall and Spring: 12 units
The Special Topics in HCI is an opportunity for students interested in HCI to gain a deeper understanding of a specific area in this field. Each class is designed to cover an emerging research area within HCI, from designing large-scale peer learning systems to creating video games around audience agency. All sections will help students: (1) build a more comprehensive understanding of an area of study within HCI, (2) work closely with faculty and peers to create mini-projects or team assignments that help students master the course material, (3) explore evidence-based research methods and techniques in HCI. Sections will vary in topic and often change from semester to semester. Because of this, students can take multiple sections, as they are individual classes. The Undergraduate section is 499 and the graduate section is 899. For descriptions of specific sections for this academic year, visit the "Courses" section on the Human-Computer Interaction Institute website: http://hcii.cmu.edu/academics/courses
Course Website: http://www.hcii.cmu.edu/academics/courses

05-540 Rapid Prototyping of Computer Systems
Spring: 12 units
This is a project-oriented course, which will deal with all four aspects of project development: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time. Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided development tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time.

Course Website: http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems

05-571 Undergraduate Project in HCI
Spring: 12 units
Experiential learning is a key component of the MHCI program. Through a substantial team project, students apply classroom knowledge in analysis and evaluation, implementation and design, and develop skills working in multidisciplinary teams. Student teams work with Carnegie Mellon University-based clients or external clients to iteratively design, build and test a software application which people directly use.
Prerequisites: 05-610 Min. grade B or 05-630 Min. grade B or 05-631 Min. grade B or 05-431 Min. grade B or 05-430 Min. grade B or 05-410 Min. grade B

Course Website: http://www.hcii.cmu.edu/courses/undergraduate-project-hci

05-589 Independent Study in HCI-UG
All Semesters
In collaboration with and with the permission of the professor, undergraduate students may engage in independent project work on any number of research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, complete a contract, and present a tangible deliverable. The Undergraduate Program Advisor's signature is required for HCI undergraduate-level Independent Study courses.

05-600 HCI Pro Seminar
Fall: 6 units
Students will attend weekly HCII Seminar Series of talks given by national leaders in the field of Human-Computer Interaction, attend communication workshops and conflict management workshops. This course is for MHCI students only.

Course Website: http://www.hcii.cs.cmu.edu

05-610 User-Centered Research and Evaluation
Fall: 12 units
This course provides and overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of task analysis, and analytic and empirical evaluation methods. This is a companion course to courses in visual design (05-650) and software implementation (05-630, 05-631). This course is NOT open to students outside of the MHCI program.

Course Website: http://www.hcii.cs.cmu.edu

05-618 Human AI Interaction
Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: https://www.hcii.cmu.edu/academics/courses

05-650 Interaction Design Studio II
Spring: 12 units
This course follows Interaction Design Fundamentals (05-651). Students are expected to apply what they have learned about design thinking and methodologies as a starting point for all assignments. Students will work in teams to perform guerrilla research, synthesize data, and consider the needs of multiple stakeholders in their design of mobile services and other intelligent systems. Design concepts go beyond user interfaces to include sensors, controls, and ubiquitous computing. Emphasis is placed on the quality of the students ideas and their ability to give form to their design concepts. By completing and presenting their work, students will gain skills related to professional UX design practice.
Prerequisites: 05-651 or 51-248 or 51-228 or 51-262 or 51-261 or 51-228 or 51-761 or 51-268

Course Website: http://www.hcii.cmu.edu/courses/interaction-design-studio

05-651 Interaction Design Studio 1
Fall: 12 units
This studio course introduces students to design thinking and the basic practices of interaction design. We follow a human-centered design process that includes research, concept generation, prototyping, and refinement. Students must work effectively as individuals and in small teams to design mobile information systems and other interactive experiences. Assignments approach design on three levels: specific user interactions, contexts of use, and larger systems. Students will become familiar with design methodologies such as sketching, storyboarding, wire framing, prototyping, etc. No coding is required. This course serves as a prerequisite for Interaction Design Studio (05-650). Students who are required to take this course have priority and will be enrolled first.

05-823 E-Learning Design Principles and Methods
Fall: 12 units
This course is about e-learning design principles, the evidence and theory behind them, and how to apply these principles to develop effective educational technologies. It is organized around the book "e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning" by Clark & Mayer with further readings drawn from cognitive science, educational psychology, and human-computer interaction. You will learn design principles 1) for combining words, audio, and graphics in multimedia instruction, 2) for combining examples, explanations, practice and feedback in online support for learning by doing, and 3) for balancing learner versus system control and supporting student metacognition. You will read about the experiments that support these design principles, see examples of how to design such experiments, and practice applying the principles in educational technology development.

Course Website: http://www.learnlab.org/research/wiki/index.php/E-learning_Design_Principles_2013#Course_Details

05-839 Interactive Data Science
Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: https://hcii.cmu.edu/academics/courses

05-840 Tools for Online Learning
Fall: 12 units
In this course, we will explore issues that pertain to interaction and interface design. The class will focus on elements of the larger interaction design process including basic design principles, information architecture and navigation, planning and brainstorming methods, and techniques for developing rapid sketches and prototypes. Course Requirements: This class will not focus on learning specific software tools. Students are expected to have prior experience using a variety of design and programming tools. Please speak with the instructor if you have questions regarding these prerequisites. This course was design for students in the METALS program.

Institute for Software Research Courses

08-200 Ethics and Policy Issues in Computing
Spring: 9 units
In this course, students will study the social impacts of computing technology and systems. The course will provide a brief introduction to ethics and to the new and difficult ethical questions modern computing technology presents us with. It will focus on a number of areas in which computers and information technology are having an impact on society including data privacy, social media, and autonomous technologies.

08-722 Data Structures for Application Programmers
Fall and Spring: 6 units
This course is an introduction to Data Structures and a few fundamental algorithms for students with some prior programming experience (functions, loops and arrays mainly in Java). It covers the conceptual and implementation views of some common data structures and algorithms. It also goes over the Java Collections (such as List, ArrayList, LinkedList, Set, HashSet, TreeSet, Map, HashMap, TreeMap, PriorityQueue) to solidify the understanding of the data structures. There is an introduction to the analysis of algorithms that operate on them. Following learning-by-doing methodology, there will be many repetitions of writing code and reviews of the items covered in lectures. Students are required to be familiar with Java Programming before taking this course. Those who are not are encouraged to take 08-671 in mini 1 before taking this course. Students are required to have a reasonably modern laptop computer on which install the Java software used for this course.

SCS: Language Technologies Institute Courses

11-291 Applied Computational Intelligence Lab
Intermittent: 9 units
What would an "intelligent" picture on the wall do? What if it could see and hear you? What should it say if it could talk? What if your pantry, wardrobe or medicine cabinet could sense, think and act? What should they do and say? What should your cell phone be saying to you? These are not whimsical or theoretical questions...they inevitably arise as ordinary everyday objects around us acquire the ability to sense changes in their environment, think about their implications, and act in pursuit of their goals. These objects are connected to the web and become conduits for services, erasing the distinction between products and services. The ability to invent and build smart products/services is becoming a key skill in the new technology-driven services economy. The focus of the course will be on building "ordinary" objects that can sense, think and act in the real world and on exploring the implications of these capabilities. Students will select their own project and by the end of the semester will create a working prototype that will be exhibited in a public place. Prizes will be offered for the most creative projects. In the course of their projects, students will learn how to use state-of-the-art tools for: Object detection using video cameras, microphones and other sensors Movement and gesture detection Speech recognition and generation Reasoning and planning: While the course organizers have many ideas for specific projects, students will be encouraged to design their own projects. Students are expected to work in small groups on their own time and receive faculty advice as needed. There will be weekly meetings of the whole class.
Prerequisites: 21-127 Min. grade C and 15-122 Min. grade C

11-324 Human Language for Artificial Intelligence
Fall: 12 units
An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-344 Machine Learning in Practice
Fall: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization.

11-364 An Introduction to Knowledge-Based Deep Learning and Socratic Coaches
Spring: 12 units
The subject of this course will be deep learning, one of the most dynamic and exciting emerging areas of computer science. Deep learning deals with and is conquering the problems resulting from the enormous quantity of data that now surrounds us. Furthermore, the course will explore knowledge-based deep learning, a new methodology invented by the instructor that offers many potential advantages over conventional deep learning. This is a learn-by-doing, team-project based course, which will be divided into four phases. In phase one, each student will read and present a number of papers describing state-of-the-art deep learning systems and successful applications. In phase two, each team will implement the system described in one of the papers. In phase three, each team will scale that implementation to one of the large benchmark datasets. In phase four, each team will do a special research project implementing a knowledge-based deep learning system based on pending patent applications of Professor Baker. As a potential follow-on for successful projects, students may participate in a summer course on entrepreneurial applications of deep learning or work as interns in a bootstrap startup based on the knowledge-based deep learning projects. Prerequisite: Strong quantitative aptitude, programming skill, ability to quickly absorb new ideas, teamwork skills.

11-411 Natural Language Processing
Intermittent: 12 units
This course will introduce students to the highly interdisciplinary area of Artificial Intelligence known alternately as Natural Language Processing (NLP) and Computational Linguistics. The course aims to cover the techniques used today in software that does useful things with text in human languages like English and Chinese. Applications of NLP include automatic translation between languages, extraction and summarization of information in documents, question answering and dialog systems, and conversational agents. This course will focus on core representations and algorithms, with some time spent on real-world applications. Because modern NLP relies so heavily on Machine Learning, we'll cover the basics of discrete classification and probabilistic modeling as we go. Good computational linguists also know about Linguistics, so topics in linguistics (phonology, morphology, and syntax) will be covered when fitting. From a software engineering perspective, there will be an emphasis on rapid prototyping, a useful skill in many other areas of Computer Science. In particular, we will introduce some high-level languages (e.g., regular expressions and Dyna) and some scripting languages (e.g., Python and Perl) that can greatly simplify prototype implementation.
Prerequisite: 15-122

11-423 ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.
Spring: 12 units
Students will work individually or in small groups to create artificial human(oid) languages for fictional human cultures or SciFi worlds. Students will implement language technologies for their languages. In the course of creating the languages, students will learn about the building blocks of human language such as phones, phonemes, morphemes, and morpho-syntactic constructions including their semantics and pragmatics. Class instruction will focus specifically on variation among human languages so that the students can make conlangs that are not just naively English-like. We will also touch on philosophical issues in philosophy of language and on real-world socio-political issues related to language policy. Students will be required to use at least one of the following technologies: language documentation tools that are used for field linguistics and corpus annotation, automatic speech recognition, speech synthesis, morphological analysis, parsing, or machine translation. Learning Objectives: 1. The building blocks (phonemes, morphemes, etc.) of language, how languages are built from them, and how they interact 2. Metalinguistic awareness and knowledge about variation in human language 3. Language, thought, and culture: how does language reflect thought and culture, and vice versa. Why wouldn't Elvish be a good language for Klingons? 4. Language policy in the real world: For students who want to manipulate real languages. 5. Historical linguistics and language change: for students who want to manipulate real languages or make families of related conlangs for fictional worlds. 6. Practical experience with a language technology. http://tts.speech.cs.cmu.edu/11-823/
Course Website: http://tts.speech.cs.cmu.edu/11-823

11-441 Machine Learning for Text Mining
Fall and Spring: 9 units
This course provides a comprehensive introduction to the theory and implementation of algorithms for organizing and searching large text collections. The first half of the course studies text search engines for enterprise and Web environments; the open-source Indri search engine is used as a working example. The second half studies text mining techniques such as clustering, categorization, and information extraction. Programming assignments give hands-on experience with document ranking algorithms, categorizing documents into browsing hierarchies, and related topics.

11-442 Search Engines
Fall: 9 units
This course studies the theory, design, and implementation of text-based search engines. The core components include statistical characteristics of text, representation of information needs and documents, several important retrieval models, and experimental evaluation. The course also covers common elements of commercial search engines, for example, integration of diverse search engines into a single search service ("federated search", "vertical search"), personalized search results, diverse search results, and sponsored search. The software architecture components include design and implementation of large-scale, distributed search engines.

Course Website: http://boston.lti.cs.cmu.edu/classes/11-642/

11-485 Introduction to Deep Learning
Intermittent: 9 units
Neural networks have increasingly taken over various AI tasks, and currently produce the state of the art in many AI tasks ranging from computer vision and planning for self-driving cars to playing computer games. Basic knowledge of NNs, known currently in the popular literature as "deep learning", familiarity with various formalisms, and knowledge of tools, is now an essential requirement for any researcher or developer in most AI and NLP fields. This course is a broad introduction to the field of neural networks and their "deep" learning formalisms. The course traces some of the development of neural network theory and design through time, leading quickly to a discussion of various network formalisms, including simple feedforward, convolutional, recurrent, and probabilistic formalisms, the rationale behind their development, and challenges behind learning such networks and various proposed solutions. We subsequently cover various extensions and models that enable their application to various tasks such as computer vision, speech recognition, machine translation and playing games. Instruction Unlike prior editions of 11-785, the instruction will primarily be through instructor lectures, and the occasional guest lecture. Evaluation Students will be evaluated based on weekly continuous-evaluation tests, and their performance in assignments and a final course project. There will be six hands-on assignments, requiring both low-level coding and toolkit-based implementation of neural networks, covering basic MLP, convolutional and recurrent formalisms, as well as one or more advanced tasks, in addition to the final project.
Prerequisites: 15-112 and 21-120 and 21-241

11-492 Speech Processing
Fall: 12 units
Speech Processing offers a practical and theoretical understanding of how human speech can be processed by computers. It covers speech recognition, speech synthesis and spoken dialog systems. The course involves practicals where the student will build working speech recognition systems, build their own synthetic voice and build a complete telephone spoken dialog system. This work will be based on existing toolkits. Details of algorithms, techniques and limitations of state of the art speech systems will also be presented. This course is designed for students wishing understand how to process real data for real applications, applying statistical and machine learning techniques as well as working with limitations in the technology.
Prerequisite: 15-211 Min. grade B

11-546 Applied Legal Analytics & Artificial Intelligence
Spring: 12 units
Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon University¿s Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industry¿s need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: https://luimagroup.github.io/appliedlegalanalytics/

11-630 MCDS Practicum Internship
Fall
The MCDS Practicum course is used for recording CDS students summer internships for the MCDS Program. Section A is used for 7-month internship opportunities Section B is used for Returning Fall Analytic students who DO NOT attain a 7-mo Internships. Section R is used to record MCDS students Internship Requirements

11-646 Applied Legal Analytics & Artificial Intelligence
Spring: 12 units
Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon University¿s Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industry¿s need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: https://luimagroup.github.io/appliedlegalanalytics/

11-661 Language and Statistics
Fall: 12 units
Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob&stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI & SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: http://www.cs.cmu.edu/~roni/11661/

11-696 MIIS Capstone Planning Seminar
Spring: 6 units
The MIIS Capstone Planning Seminar prepares students to complete the MIIS Capstone Project in the following semester. Students are organized into teams that will work together to complete the capstone project. They define project goals, requirements, success metrics, and deliverables; and they identify and acquires data, software, and other resources required for successful completion of the project. The planning seminar must be completed in the semester prior to taking the capstone project.

11-711 Algorithms for NLP
All Semesters: 12 units
Algorithms for NLP is an introductory graduate-level course on the computational properties of natural languages and the fundamental algorithms for processing natural languages. The course will provide an in-depth presentation of the major algorithms used in NLP, including Lexical, Morphological, Syntactic and Semantic analysis, with the primary focus on parsing algorithms and their analysis.

11-716 Graduate Seminar on Dialog Processing
All Semesters: 6 units
Dialog systems and processes are becoming an increasingly vital area of interest both in research and in practical applications. The purpose of this course will be to examine, in a structured way, the literature in this area as well as learn about ongoing work. The course will cover traditional approaches to the problem, as exemplified by the work of Grosz and Sidner, as well as more recent work in dialog, discourse and evaluation, including statistical approaches to problems in the field. We will select several papers on a particular topic to read each week. While everyone will do all readings, a presenter will be assigned to overview the paper and lead the discussion. On occasion, a researcher may be invited to present their own work in detail and discuss it with the group. A student or researcher taking part in the seminar will come away with a solid knowledge of classic work on dialog, as well as familiarity with ongoing trends.

11-721 Grammars and Lexicons
All Semesters: 12 units
Grammars and Lexicons is an introductory graduate course on linguistic data analysis and theory, focusing on methodologies that are suitable for computational implementations. The course covers major syntactic and morphological phenomena in a variety of languages. The emphasis will be on examining both the diversity of linguistic structures and the constraints on variation across languages. Students will be expected to develop and defend analyses of data, capturing linguistic generalizations and making correct predictions within and across languages. The goal is for students to become familiar with the range of phenomena that occur in human languages so that they can generalize the insights into the design of computational systems. The theoretical framework for syntactic and lexical analysis will be Lexical Functional Grammar. Grades will be based on problem sets and take-home exams.

11-722 Grammar Formalisms
Intermittent: 12 units
The goal of this course is to familiarize students with grammar formalisms that are commonly used for research in computational lingusitics, language technologies, and lingusitics. We hope to have students from a variety disciplines (linguistics, computer science, psychology, modern languages, philosophy) in order to cover a broad perspective in class discussions. Comparison of formalisms will lead to a deeper understanding of human language and natural language processing algorithms. The formalisms will include: Head Driven Phrase Structure Grammar, Lexical Functional Grammar, Tree Adjoining Grammar and Categorial Grammar. If time permits, we will cover Penn Treebank, dependency grammar, and Construction Grammar. We will cover the treatment of basic syntactic and semantic phenomena in each formalism, and will also discuss algorithms for parsing and generating sentences for each formalism. If time permits, we may discuss formal language theory and generative capacity. The course is taught jointly by the following faculty of the Language Technologies Institute: Alan Black Alon Lavie Lori Levin (main coordinator)

11-731 Machine Translation and Sequence-to-Sequence Models
Spring: 12 units
Instructors: Graham Neubig. Prerequisites: This course has no official pre-requisites, although 11-711 "Algorithms for NLP" or 10-701 "Machine Learning" would be helpful. Course Description: Machine Translation and Sequence-to-Sequence Models is an introductory graduate-level course surveying the primary approaches and methods for developing systems to translate between human languages, or other sequential data. The main objective of the course is to obtain basic understanding and implementation skills for modern methods for MT and sequence transduction, including how to design models, how to learn the model parameters, how to search for the best output, and how to create training data. The course will focus on machine translation, but also briefly cover tasks such as dialog response generation, image caption generation, and others.

11-741 Machine Learning for Text Mining
Fall and Spring: 12 units
This course studies the theory, design, and implementation of text-based information systems. The Information Retrieval core components of the course include statistical characteristics of text, representation of information needs and documents, several important retrieval models (Boolean, vector space, probabilistic, inference net, language modeling), clustering algorithms, automatic text categorization, and experimental evaluation. The software architecture components include design and implementation of high-capacity text retrieval and text filtering systems. A variety of current research topics are also covered, including cross-lingual retrieval, document summarization, machine learning, topic detection and tracking, and multi-media retrieval. Prerequisites: Programming and data-structures at the level of 15-212 or higher. Algorithms comparable to the undergraduate CS algorithms course (15-451) or higher. Basic linear algebra (21-241 or 21-341). Basic statistics (36-202) or higher.

11-751 Speech Recognition and Understanding
All Semesters: 12 units
The technology to allow humans to communicate by speech with machines or by which machines can understand when humans communicate with each other is rapidly maturing. This course provides an introduction to the theoretical tools as well as the experimental practice that has made the field what it is today. We will cover theoretical foundations, essential algorithms, major approaches, experimental strategies and current state-of-the-art systems and will introduce the participants to ongoing work in representation, algorithms and interface design. This course is suitable for graduate students with some background in computer science and electrical engineering, as well as for advanced undergraduates. Prerequisites: Sound mathematical background, knowledge of basic statistics, good computing skills. No prior experience with speech recognition is necessary. This course is primarily for graduate students in LTI, CS, Robotics, ECE, Psychology, or Computational Linguistics. Others by prior permission of instructor.

11-752 Speech II: Phonetics, Prosody, Perception and Synthesis
Spring: 12 units
The goal of the course is to give the student basic knowledge from several fields that is necessary in order to pursue research in automatic speech processing. The course will begin with a study of the acoustic content of the speech signal. The students will use the spectrographic display to examine the signal and discover its variable properties. Phones in increasingly larger contexts will be studied with the goal of understanding coarticulation. Phonological rules will be studied as a contextual aid in understanding the spectrographic display. The spectrogram will then serve as a first introduction to the basic elements of prosody. Other displays will then be used to study the three parts of prosody: amplitude, duration, and pitch. Building on these three elements, the student will then examine how the three interact in careful and spontaneous speech. Next, the students will explore perception. Topics covered will be: physical aspects of perception, psychological aspects of perception, testing perception processes, practical applications of knowledge about perception. The second part of this course will cover all aspects of speech synthesis. Students need only have a basic knoweldge of speech and language processing. Some degree of programming and statistical modelling will be beneficial, but not required. Taught every other year

11-755 Machine Learning for Signal Processing
Fall: 12 units
Signal Processing is the science that deals with extraction of information from signals of various kinds. This has two distinct aspects — characterization and categorization. Traditionally, signal characterization has been performed with mathematically-driven transforms, while categorization and classification are achieved using statistical tools. Machine learning aims to design algorithms that learn about the state of the world directly from data. A increasingly popular trend has been to develop and apply machine learning techniques to both aspects of signal processing, often blurring the distinction between the two. This course discusses the use of machine learning techniques to process signals. We cover a variety of topics, from data driven approaches for characterization of signals such as audio including speech, images and video, and machine learning methods for a variety of speech and image processing problems.

11-761 Language and Statistics
Fall: 12 units
Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob&stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI & SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: http://www.cs.cmu.edu/~roni/11761/

11-762 Language and Statistics II
Fall: 12 units
This course will cover modern empirical methods in natural language processing. It is designed for language technologies students who want to understand statistical methodology in the language domain, and for machine learning students who want to know about current problems and solutions in text processing. Students will, upon completion, understand how statistical modeling and learning can be applied to text, be able to develop and apply new statistical models for problems in their own research, and be able to critically read papers from the major related conferences (EMNLP and ACL). A recurring theme will be the tradeoffs between computational cost, mathematical elegance, and applicability to real problems. The course will be organized around methods, with concrete tasks introduced throughout. The course is designed for SCS graduate students. Prerequisite: Language and Statistics (11-761) or permission of the instructor. Recommended: Algorithms for Natural Language Processing (11-711), Machine Learning (15-681, 15-781, or 11-746).
Prerequisite: 11-761

11-763 Structured Prediction for Language and other Discrete Data
Fall: 12 units
This course seeks to cover statistical modeling techniques for discrete, structured data such as text. It brings together content previously covered in Language and Statistics 2 (11-762) and Information Extraction (10-707 and 11-748), and aims to define a canonical set of models and techniques applicable to problems in natural language processing, information extraction, and other application areas. Upon completion, students will have a broad understanding of machine learning techniques for structured outputs, will be able to develop appropriate algorithms for use in new research, and will be able to critically read related literature. The course is organized around methods, with example tasks introduced throughout.

Course Website: http://www.cs.cmu.edu/~nasmith/SPFLODD/

11-777 Multimodal Machine Learning
Fall: 12 units
Multimodal machine learning (MMML) is a vibrant multi-disciplinary research field which addresses some of the original goals of artificial intelligence by integrating and modeling multiple communicative modalities, including linguistic, acoustic and visual messages. With the initial research on audio-visual speech recognition and more recently with language vision projects such as image and video captioning, this research field brings some unique challenges for multimodal researchers given the heterogeneity of the data and the contingency often found between modalities. The course will present the fundamental mathematical concepts in machine learning and deep learning relevant to the five main challenges in multimodal machine learning: (1) multimodal representation learning, (2) translation & mapping, (3) modality alignment, (4) multimodal fusion and (5) co-learning. These include, but not limited to, multimodal auto-encoder, deep canonical correlation analysis, multi-kernel learning, attention models and multimodal recurrent neural networks. We will also review recent papers describing state-of-the-art probabilistic models and computational algorithms for MMML and discuss the current and upcoming challenges. The course will discuss many of the recent applications of MMML including multimodal affect recognition, image and video captioning and cross-modal multimedia retrieval. This is a graduate course designed primarily for PhD and research master students at LTI, MLD, CSD, HCII and RI; others, for example (undergraduate) students of CS or from professional master programs, are advised to seek prior permission of the instructor. It is required for students to have taken an introduction machine learning course such as 10-401, 10-601, 10-701, 11-663, 11-441, 11-641 or 11-741. Prior knowledge of deep learning is recommended."

Course Website: https://piazza.com/cmu/fall2018/11777/home

11-792 Intelligent Information Systems Project
Spring: 12 units
The Software Engineering for IS sequence combines classroom material and assignments in the fundamentals of software engineering (11-791) with a self-paced, faculty-supervised directed project (11-792). The two courses cover all elements of project design, implementation, evaluation, and documentation. Students may elect to take only 11-791; however, if both parts are taken, they should be taken in proper sequence. Prerequisite: 11-791. The course is required for VLIS students.
Prerequisites: 11-791 or 15-393

11-927 MIIS Capstone Project
Fall: 36 units
The capstone project course is a group-oriented demonstration of student skill in one or more areas covered by the degree. Typically the result of the capstone project is a major software application. The capstone project course consists of two components. The classroom component guides students in project planning, team management, development of requirements and design specifications, and software tools for managing group-oriented projects. The lab component provides project-specific technical guidance and expertise, for example in the development of a question answering system, dialog, or sentiment analysis application. Thus, each project receives two types of supervision, often from two separate members of the faculty.

SCS: Machine Learning Courses

10-301 Introduction to Machine Learning
Fall and Spring: 12 units
Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10301 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation & the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets & Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam. 10301 is recommended for undergraduates who are not SCS majors. (SCS majors should instead take 10315.) Prerequisites (strictly enforced): strong quantitative aptitude, college probability & statistics course, and programming proficiency. For learning to apply ML practically & effectively, without the above prerequisites, consider 11344/05834 instead. You can evaluate your ability to take the course via a self-assessment exam (http://bit.ly/2fkddDN). Also, be sure to read the ML course comparison (http://bit.ly/2eV3UaD).
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (36-218 Min. grade C or 15-359 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 36-217 Min. grade C)

10-315 Introduction to Machine Learning (Undergrad)
Spring: 12 units
Machine learning is subfield of computer science with the goal of exploring, studying, and developing learning systems, methods, and algorithms that can improve their performance with learning from data. This course is designed to give undergraduate students a one-semester-long introduction to the main principles, algorithms, and applications of machine learning and is specifically designed for the SCS undergrad majors. The topics of this course will be in part parallel with those covered in the graduate machine learning courses (10-715, 10-701, 10-601), but with a greater emphasis on applications and case studies in machine learning. After completing the course, students will be able to: *select and apply an appropriate supervised learning algorithm for classification problems (e.g., naive Bayes, perceptron, support vector machine, logistic regression). *select and apply an appropriate supervised learning algorithm for regression problems (e.g., linear regression, ridge regression). *recognize different types of unsupervised learning problems, and select and apply appropriate algorithms (e.g., clustering, linear and nonlinear dimensionality reduction). *work with probabilities (Bayes rule, conditioning, expectations, independence), linear algebra (vector and matrix operations, eigenvectors, SVD), and calculus (gradients, Jacobians) to derive machine learning methods such as linear regression, naive Bayes, and principal components analysis. *understand machine learning principles such as model selection, overfitting, and underfitting, and techniques such as cross-validation and regularization. *implement machine learning algorithms such as logistic regression via stochastic gradient descent, linear regression (using a linear algebra toolbox), perceptron, or k-means clustering. *run appropriate supervised and unsupervised learning algorithms on real and synthetic data sets and interpret the results.
Prerequisites: 15-122 Min. grade C and (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C) and (15-359 Min. grade C or 36-218 Min. grade C or 36-217 Min. grade C or 21-325 Min. grade C or 36-225 Min. grade C)

10-335 Art and Machine Learning
Spring: 12 units
Ars, the Latin origin of the word art, means Art and Science. These two fields, which have been separated for a long time, are joining back together in many areas. One of those junctions is where Art and Machine Learning meet. Art in recent years has been moving forward along with the rise of new technologies and scientific discoveries. Machine Learning (ML) is one of the most cutting edge advancements in Computer Science. The popularity and accessibility of frameworks such as Google's Deep Dream system, Pikazo the neural style transfer, Kulitta AI Music Generation Framework, Deep Mind's WaveNet, Sony's Flow Machines, and recurrent neural network based language models brought great attention to the marriage of Art and ML methods. The number of ML applications that mimic famous artworks, e.g. The Next Rembrandt project, or even create original artworks such as the robot artist TAIDA's paintings, is rapidly growing. Increasing number of artists are also attempting to use ML methods in their artworks. This course is project-based and aims to introduce the crossroad of Art and Machine Learning to the broad range of students including both Art and Computer Science majors. We will offer the knowledge of examples, technologies, and issues that connect Art and Machine Learning to the students. Students will study example codes and produce creative applications/artworks using ML methods. Students do not need to have pre-existing knowledge of Machine Learning or experience of Art practice. Students are required to have basic understanding of Python and be open-minded, for example, open to learn the necessary mathematical background and open to discussions on conceptual development and artistic value of their projects.

10-401 Introduction to Machine Learning (Undergrad)
Fall and Spring: 12 units
Machine learning is subfield of computer science with the goal of exploring, studying, and developing learning systems, methods, and algorithms that can improve their performance with learning from data. This course is designed to give undergraduate students a one-semester-long introduction to the main principles, algorithms, and applications of machine learning. Topics. The topics of this course will be in part parallel with those covered in the graduate machine learning courses (10-715, 10-701, 10-601), but with a greater emphasis on applications and case studies in machine learning. After completing the course, students will be able to: *select and apply an appropriate supervised learning algorithm for classification problems (e.g., naive Bayes, perceptron, support vector machine, logistic regression). *select and apply an appropriate supervised learning algorithm for regression problems (e.g., linear regression, ridge regression). *recognize different types of unsupervised learning problems, and select and apply appropriate algorithms (e.g., clustering, linear and nonlinear dimensionality reduction). *work with probabilities (Bayes rule, conditioning, expectations, independence), linear algebra (vector and matrix operations, eigenvectors, SVD), and calculus (gradients, Jacobians) to derive machine learning methods such as linear regression, naive Bayes, and principal components analysis. *understand machine learning principles such as model selection, overfitting, and underfitting, and techniques such as cross-validation and regularization. *implement machine learning algorithms such as logistic regression via stochastic gradient descent, linear regression (using a linear algebra toolbox), perceptron, or k-means clustering. *run appropriate supervised and unsupervised learning algorithms on real and synthetic data sets and interpret the results.
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (36-218 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 15-359 Min. grade C)

10-403 Deep Reinforcement Learning & Control
Spring: 12 units
TBD
Prerequisites: 10-401 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

10-405 Machine Learning with Large Datasets (Undergraduate)
Intermittent: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-401, 10-601, or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and the introductory machine learning course concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Java and good programming skills.
Prerequisites: 15-210 or 15-214 or 15-211 or 17-214

10-417 Intermediate Deep Learning
Intermittent: 12 units
Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.
Prerequisites: 10-715 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

10-418 Machine Learning for Structured Data
Intermittent: 12 units
A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) — as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-401 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C

10-500 Senior Research Project
All Semesters
Register for this course if you are minoring in Machine Learning. This course is intended for research with a faculty member that would count towards the minor.

10-520 Independent Study
All Semesters
Independent Study intended to work on research with a Machine Learning faculty member.

10-600 Mathematical background for Machine Learning
Fall and Spring: 12 units
This course provides a place for students to practice the necessary mathematical background for further study in machine learning — particularly for taking 10-601 and 10-701. Topics covered include probability, linear algebra (inner product spaces, linear operators), multivariate differential calculus, optimization, and likelihood functions. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course supersedes the two mini-courses 10-606 and 10-607.

10-601 Introduction to Machine Learning (Master's)
Fall and Spring: 12 units
Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10601 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation & the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets & Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam. 10601 is recommended for CS Seniors & Juniors, quantitative Masters students, & non-MLD PhD students. Prerequisites (strictly enforced): strong quantitative aptitude, college probability & statistics course, and programming proficiency. For learning to apply ML practically & effectively, without the above prerequisites, consider 11344/05834 instead. You can evaluate your ability to take the course via a self-assessment exam (http://bit.ly/2fkddDN). Also, be sure to read the ML course comparison (http://bit.ly/2eV3UaD).
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (36-217 Min. grade C or 21-325 Min. grade C or 36-225 Min. grade C or 15-359 Min. grade C or 36-218 Min. grade C)

10-605 Machine Learning with Large Datasets
Spring: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and 10-601 concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Java and good programming skills.
Prerequisites: 15-210 or 15-214 or 17-214

Course Website: http://goo.gl/W2kPqO

10-606 Mathematical Foundations for Machine Learning
Fall and Spring: 6 units
This course provides a place for students to practice the necessary mathematical background for further study in machine learning. Topics covered include probability (random variables, modeling with continuous and discrete distributions), linear algebra (inner product spaces, linear operators), and multivariate differential calculus (partial derivatives, matrix differentials). The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning — particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-607 Computational Foundations for Machine Learning
Fall and Spring: 6 units
This course provides a place for students to practice the necessary computational background for further study in machine learning. Topics covered include computational complexity, analysis of algorithms, proof techniques, optimization, dynamic programming, recursion, and data structures. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above computational concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning — particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-608 Conversational Machine Learning
Intermittent: 12 units
Machine Learning today is largely about finding patterns in large amounts of data. But as personal devices that interact with us in natural language become ubiquitous (e.g., Siri, Google Now), they open an amazing possibility of letting users teach machines in natural language, similar to how we teach each other. Conversation, as an interface to machine learning systems, opens a new paradigm that both unifies several existing machine learning paradigms (e.g., active learning, supervised learning), but also brings a unique set of advantages and challenges that lie at the intersection of machine learning and natural language processing. This course will be structured as a well-defined mini-challenge (project) course. We will present you with several well-defined open problems and provide you with recently collected datasets that can get you started immediately! But you will be free to define your own problem using that data as well, or come up with your own problem entirely. There are no other constraints, and since this is a new area of research, you can (and should) be creative and as crazy in coming up with methods to tackle them. At the same time, we will provide guidance via readings and class-based hacking sessions. This course is a great way to get introduced to open problems in a collaborative and structured environment. Challenges Building a classifier with zero examples. Telling sequence to sequence models about their mistakes Letting machine learning models ask questions
Prerequisites: 10-401 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-715 Min. grade C

10-617 Intermediate Deep Learning
Intermittent: 12 units
Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.
Prerequisites: 10-601 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

10-618 Machine Learning for Structured Data
Intermittent: 12 units
A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) — as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-301 Min. grade C or 10-315 Min. grade C or 10-401 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C

10-701 Introduction to Machine Learning (PhD)
Fall and Spring: 12 units
Machine learning studies the question "How can we build computer programs that automatically improve their performance through experience?" This includes learning to perform many types of tasks based on many types of experience. For example, it includes robots learning to better navigate based on experience gained by roaming their environments, medical decision aids that learn to predict which therapies work best for which diseases based on data mining of historical health records, and speech recognition systems that learn to better understand your speech based on experience listening to you. This course is designed to give PhD students a thorough grounding in the methods, mathematics and algorithms needed to do research and applications in machine learning. Students entering the class with a pre-existing working knowledge of probability, statistics and algorithms will be at an advantage, but the class has been designed so that anyone with a strong numerate background can catch up and fully participate. You can evaluate your ability to take the course via a self-assessment exam that will be made available to you after you register. If you are interested in this topic, but are not a PhD student, or are a PhD student not specializing in machine learning, you might consider the master's level course on Machine Learning, 10-601." This class may be appropriate for MS and undergrad students who are interested in the theory and algorithms behind ML. You can evaluate your ability to take the course via a self-assessment exam at: https://qna-app.appspot.com/view.html?aglzfnFuYS1hcHByGQsSDFF1ZXN0aW9uTGlzdBiAgICgpO-KCgw ML course comparison: https://docs.google.com/document/d/1Y0Jx_tcINWQrWJx31WGEQSsUs059OUMmPIVSeyxNdeM/edit
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (36-225 Min. grade C or 15-259 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C or 15-359 Min. grade C or 36-217 Min. grade C)

10-702 Statistical Machine Learning
Spring: 12 units
Statistical Machine Learning is a second graduate level course in advanced machine learning, assuming that students have taken Machine Learning (10-701) or Advanced Machine Learning (10-715), and Intermediate Statistics (36-705). The term ?statistical? in the title reflects the emphasis on statistical theory and methodology. This course is mostly focused on methodology and theoretical foundations. It treats both the ?art? of designing good learning algorithms and the ?science? of analyzing an algorithm?s statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. Though computation is certainly a critical component of what makes a method successful, it will not receive the same central focus as methodology and theory. We will cover topics in statistical theory that are important for researchers in machine learning, including consistency, minimax estimation, and concentration of measure. We will also cover statistical topics that may not be covered in as much depth in other machine learning courses, such as nonparametric density estimation, nonparametric regression, and Bayesian estimation.
Prerequisites: (36-705 or 10-705) and (10-701 or 10-715)

Course Website: http://www.stat.cmu.edu/~larry/=sml/

10-703 Deep Reinforcement Learning & Control
Spring: 12 units
This course will cover latest advances in Reinforcement Learning and Imitation learning. This is a fast developing research field and an official textbook is available only for about one forth of the course material. The rest will be taught from recent research papers. This course brings together many disciplines of Artificial Intelligence to show how to develop intelligent agent that can learn to sense the world and learn to act imitating others or maximizing sparse rewards Particular focus will be given in incorporating visual sensory input and learning suitable visual state representations.
Prerequisites: 10-601 Min. grade B or 10-701 Min. grade B or 10-715 Min. grade B or 10-401 Min. grade B or 10-315 Min. grade B or 10-301 Min. grade B

10-707 Topics in Deep Learning
Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from high-dimensional data lies at the core of solving many AI related tasks. In the past few years, researchers across many different communities, from applied statistics to engineering, computer science and neuroscience, have developed deep (hierarchical) models — models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. This is an advanced graduate course, designed for Master's and Ph.D. level students, and will assume a reasonable degree of mathematical maturity. The goal of this course is to introduce students to the recent and exciting developments of various deep learning methods. Some topics to be covered include: restricted Boltzmann machines (RBMs) and their multi-layer extensions Deep Belief Networks and Deep Boltzmann machines; sparse coding, autoencoders, variational autoencoders, convolutional neural networks, recurrent neural networks, generative adversarial networks, and attention-based models with applications in vision, NLP, and multimodal learning. We will also address mathematical issues, focusing on efficient large-scale optimization methods for inference and learning, as well as training density models with intractable partition functions. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.
Prerequisites: 10-401 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C

10-708 Probabilistic Graphical Models
Spring: 12 units
Many of the problems in artificial intelligence, statistics, computer systems, computer vision, natural language processing, and computational biology, among many other fields, can be viewed as the search for a coherent global conclusion from local information. The probabilistic graphical models framework provides an unified view for this wide range of problems, enabling efficient inference, decision-making and learning in problems with a very large number of attributes and huge datasets. This graduate-level course will provide you with a strong foundation for both applying graphical models to complex problems and for addressing core research topics in graphical models. The class will cover three aspects: The core representation, including Bayesian and Markov networks, and dynamic Bayesian networks; probabilistic inference algorithms, both exact and approximate; and, learning methods for both the parameters and the structure of graphical models. Students entering the class should have a pre-existing working knowledge of probability, statistics, and algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. It is expected that after taking this class, the students should have obtain sufficient working knowledge of multi-variate probabilistic modeling and inference for practical applications, should be able to formulate and solve a wide range of problems in their own domain using GM, and can advance into more specialized technical literature by themselves. Students are required to have successfully completed 10701 or 10715, or an equivalent class.
Prerequisites: 10-715 or 10-701

Course Website: https://sailinglab.github.io/pgm-spring-2019/lectures/

10-715 Advanced Introduction to Machine Learning
Fall: 12 units
The rapid improvement of sensory techniques and processor speed, and the availability of inexpensive massive digital storage, have led to a growing demand for systems that can automatically comprehend and mine massive and complex data from diverse sources. Machine Learning is becoming the primary mechanism by which information is extracted from Big Data, and a primary pillar that Artificial Intelligence is built upon. This course is designed for Ph.D. students whose primary field of study is machine learning, and who intend to make machine learning methodological research a main focus of their thesis. It will give students a thorough grounding in the algorithms, mathematics, theories, and insights needed to do in-depth research and applications in machine learning. The topics of this course will in part parallel those covered in the general PhD-level machine learning course (10-701), but with a greater emphasis on depth in theory and algorithms. The course will also include additional advanced topics such as fairness in machine learning. Students entering the class are expected to have a pre-existing strong working knowledge of algorithms, linear algebra, probability, and statistics. If you are interested in this topic, but do not have the required background or are not planning to work on a PhD thesis with machine learning as the main focus, you might consider the general PhD-level Machine Learning course (10-701) or the Masters-level Machine Learning course (10-601). ML course comparison: https://goo.gl/mmR2eL
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (21-325 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 15-359 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C)

Course Website: http://www.cs.cmu.edu/~nihars/teaching/10715-Fa19/index.html

10-716 Advanced Machine Learning: Theory and Methods
Spring: 12 units
Advanced Machine Learning: Theory and Methods is a graduate level course introducing the theoretical foundations of modern machine learning, as well as advanced methods and frameworks used in modern machine learning. The course assumes that students have taken graduate level introductory courses in machine learning (Introduction to Machine Learning, 10-701 or 10-715), as well as Statistics (Intermediate Statistics, 36-700 or 36-705). The course treats both the art of designing good learning algorithms, as well as the science of analyzing an algorithm's computational and statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. We will cover theoretical foundation topics such as computational and statistical convergence rates, minimax estimation, and concentration of measure. We will also cover advanced machine learning methods such as nonparametric density estimation, nonparametric regression, and Bayesian estimation, as well as advanced frameworks such as privacy, causality, and stochastic learning algorithms.
Prerequisites: (10-715 or 10-701) and (36-705 or 36-700)

10-725 Convex Optimization
Intermittent: 12 units
Nearly every problem in machine learning can be formulated as the optimization of some function, possibly under some set of constraints. This universal reduction may seem to suggest that such optimization tasks are intractable. Fortunately, many real world problems have special structure, such as convexity, smoothness, separability, etc., which allow us to formulate optimization problems that can often be solved efficiently. This course is designed to give a graduate-level student a thorough grounding in the formulation of optimization problems that exploit such structure, and in efficient solution methods for these problems. The main focus is on the formulation and solution of convex optimization problems, though we will discuss some recent advances in nonconvex optimization. These general concepts will also be illustrated through applications in machine learning and statistics. Students entering the class should have a pre-existing working knowledge of algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. Though not required, having taken 10-701 or an equivalent machine learning or statistical modeling class is strongly encouraged, as we will use applications in machine learning and statistics to demonstrate the concepts we cover in class. Students will work on an extensive optimization-based project throughout the semester.

Course Website: http://www.stat.cmu.edu/~ryantibs/convexopt/

10-737 Creative AI
Intermittent: 12 units
Artificial intelligence (AI) systems now generate authentic paintings, compose music pieces, and find out-of-box solutions to real-life problems in our world. Creativity, which was considered to be a moon shot for AI, does not seem to be too far any more. Is that true? Are we close to see creative AI? The answer is yes and no. We are moving closer with meaningful developments in Machine Learning, however there are several questions to be explored further to achieve the creative AI. What kind of creativity we want to represent? How do we translate creativity into what machines can understand? How do we design ML algorithms to be more creative? This course is where we explore these questions through seminars and projects. Our goal is to design computational models that present the very possibility of the creative AI. The instructors who are specialized in Machine Learning Art and Robotics lead this course together. We introduce related examples and possible methods including multi-modal data-driven learning, learning from demonstration, and combined learning from data and human demonstrations. Students are welcome to bring in their expertise and passion from diverse backgrounds to explore this topic together.

Course Website: http://kangeunsu.com/creativeai19f/

10-745 Scalability in Machine Learning
Fall: 12 units
The goal of this course is to provide a survey into some of the recent advances in the theory and practice of dealing with scalability issues in machine learning. We will investigate scalability issues along the following dimensions: Challenges with i) large datasets, ii) high-dimensions, and iii) complex data structure. The course is intended to prepare students to write research papers about scalability issues in machine learning. This is an advanced-level, fast-paced course that requires students to already have a solid understanding of machine learning (e.g. by taking an intro to ML class), good programming skills in Python, and being comfortable with dealing with abstract mathematical concepts and reading research papers. The course will have significant overlap with 10-405/605/805, but 10-745 will be faster-paced and go deeper into the theoretical investigations of the methods. Some of the classes will be flipped that will require students to watch a video lecture or read a research paper before the class, and the content will be discussed during the class time. The class will include a course project, HW assignments, and two-in class exams.
Prerequisites: 10-701 Min. grade B or 10-601 Min. grade B or 10-401 Min. grade B or 10-315 Min. grade B or 10-715 Min. grade B or 10-301 Min. grade B

10-805 Machine Learning with Large Datasets
Spring: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. The class will include programming assignments, presentation of relevant research papers to the class, and a research project chosen by the student, to be presented to the class, and written up in a conference-paper format. 10-805 will share lectures with 10-605, but 10-805 students need to make class presentations and complete a research project, and will do fewer programming assignments, so 10-805 students are expected to be capable of surveying recent literature and conducting research. Four lecture sessions for 10-605 will also be reserved for 10-805 students' presentations. If there is sufficient interest we will introduce a mechanism for 10-605 students to collaborate of 10-805 students on projects.
Prerequisites: 15-214 or 15-210 or 17-214

Course Website: http://goo.gl/W2kPqO

10-806 Foundations of Machine Learning and Data Science
Fall: 12 units
This course will cover fundamental topics in Machine Learning and Data Science, including powerful algorithms with provable guarantees for making sense of and generalizing from large amounts of data. The course will start by providing a basic arsenal of useful statistical and computational tools, including generalization guarantees, core algorithmic methods, and fundamental analysis models. We will examine questions such as: Under what conditions can we hope to meaningfully generalize from limited data? How can we best combine different kinds of information such as labeled and unlabeled data, leverage multiple related learning tasks, or leverage multiple types of features? What can we prove about methods for summarizing and making sense of massive datasets, especially under limited memory? We will also examine other important constraints and resources in data science including privacy, communication, and taking advantage of limited interaction. In addressing these and related questions we will make connections to statistics, algorithms, linear algebra, complexity theory, information theory, optimization, game theory, and empirical machine learning research. Topics to be covered will include: - Fundamental measures of complexity for generalization, including VC-dimension and Rademacher complexity. - Core algorithmic tools including boosting, regularization, and online optimization with connections to game theory. - Spectral methods, streaming algorithms and other approaches for handling massive data. - Foundations and algorithms for addressing important constraints or externalities such as privacy, limited memory, and communication constraints. - Foundations for modern learning paradigms including semi-supervised learning, never-ending learning, interactive learning, and deep learning.

Course Website: http://www.cs.cmu.edu/~ninamf/courses/806/10-806-index.html

10-807 Topics in Deep Learning
Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from high-dimensional data lies at the core of solving many AI related tasks. In the past few years, researchers across many different communities, from applied statistics to engineering, computer science and neuroscience, have developed deep (hierarchical) models — models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. This is an advanced graduate course, designed for Master's and Ph.D. level students, and will assume a reasonable degree of mathematical maturity. The goal of this course is to introduce students to the recent and exciting developments of various deep learning methods. Some topics to be covered include: restricted Boltzmann machines (RBMs) and their multi-layer extensions Deep Belief Networks and Deep Boltzmann machines; sparse coding, autoencoders, variational autoencoders, convolutional neural networks, recurrent neural networks, generative adversarial networks, and attention-based models with applications in vision, NLP, and multimodal learning. We will also address mathematical issues, focusing on efficient large-scale optimization methods for inference and learning, as well as training density models with intractable partition functions. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.
Prerequisites: 10-701 Min. grade C or 10-715 Min. grade C

10-822 Presentation Skills
Fall and Spring: 6 units
This course provides a forum for students to learn and refine public speaking and technical reading skills. The course will include brief workshops embedded throughout the semester to cover such things as effective structure of presentations and papers, how to give a short talk (think NIPS spotlights), "elevator" talks, structure of a research paper, conference presentations, proposal writing (think thesis and beyond), slide crafting, posters, critical evaluation, and public communications for research. Students will be expected to prepare and present a number of practice talks throughout the semester.

10-830 Machine Learning in Policy
Spring: 12 units
Machine learning, a field derived primarily from computer science and statistics, has matured and gained wide adoption over past decades. Alongside exponential increases in data measurement and availability, the ability to develop appropriate and tailored analyses is in demand. As practitioners in the social sciences consider machine learning methods, however, we are identifying limitations and externalities of the applications of machine learning techniques, such as overconfidence in settings with concept drift, lack of generalizability due to selection bias, and magnification of inequities. Machine Learning and Policy seeks to (1) demonstrate motivations and successes of machine learning, to (2) contrast them with more classical methods, and to (3) investigate the promise and cautions of machine learning for public policy. The course will cover variety of topics, including: Basics of machine learning; probability/Bayes/likelihood/conjugacy, terminology, code/algorithm design, evaluation, mathematical formulations Popular and well-performing methods; random forests/trees/ensembles, neural networks/backpropagation/embeddings/generalized adversarial networks, generalized linear models/shrinkage/convexity/basis functions, support vector machines/kernels/optimization/Lagrangian Leveraging other data sources; natural language processing/topic modeling/relational (non-i.i.d.)/relational (Markov logic networks)/temporal data Additional topics: causality/confounding/propensity scoring/inverse weighting/causal directed acyclic graphs, fairness/ethics, interpretation/explanation/visualization, anomaly detection, semi-supervised and active learning, reinforcement learning.

Course Website: https://www.andrew.cmu.edu/user/jweiss2/mlp/

10-831 Special Topics in Machine Learning and Policy
Spring: 6 units
Special Topics in Machine Learning and Policy (90-921/10-831) is intended for Ph.D. students in Heinz College, MLD, and other university departments who wish to engage in detailed exploration of a specific topic at the intersection of machine learning and public policy. Qualified master's students may also enroll with permission of the instructor; all students are expected to have some prior background in machine learning and data mining (10-601, 10-701, 90-866, 90-904/10-830, or a similar course). We will explore state-of-the-art methods for detection of emerging events and other relevant patterns in massive, high-dimensional datasets, and discuss how such methods can be applied usefully for the public good in medicine, public health, law enforcement, security, and other domains. The course will consist of lectures, discussions on current research articles and future directions, and course projects. Specific topics to be covered may include: anomaly detection, change-point detection, time series monitoring, spatial and space-time scan statistics, pattern detection in graph data, submodularity and LTSS properties for efficient pattern detection, combining multiple data sources, scaling up pattern detection to massive datasets, applications to public health, law enforcement, homeland security, and health care. A sample syllabus is available at: http://www.cs.cmu.edu/~neill/courses/90921-S10.html
Course Website: http://www.cs.cmu.edu/~neill/courses/90921-S10.html

SCS: Robotics Courses

16-161 ROB Freshman Seminar: Artificial Intelligence and Humanity
Fall and Spring: 9 units
In 1965 British mathematician I.J. Good wrote, An ultraintelligent machine could design even better machines; there would then unquestionably be an intelligence explosion, and the intelligence of man would be left far behind. As we enter an age where companies like Uber are testing driverless cars in Pittsburgh and innovative interfaces like IBMs Watson can play jeopardy and learn techniques for medical diagnoses, how are we to negotiate an intelligence explosion that for many individuals might threaten the very notions of what it means to be human? The future of human-to-machine relationships will likely define our historical epoch and yet, many young technologists and humanists underestimate the downstream impact of technological innovations on human society. Presently, we have little choice but to attend to this rapidly anxiety-ridden question. This seminar will attend to the challenge of present existential questions on what it means to be human (read not machine) in the context of a rapidly advancing technological age. We will consider human narratives throughout history that exam how governments and individual citizens defined humanity in the context of slavery and colonialism as a framework for exploring and projecting what it means to be human in the age of rapidly advancing intelligent machines. We will trace the technological advancements of the recent five decades and identify historical precedents and speculative narratives that help us to consider issues like labor, economic disparity, negotiations of power, human dignity and ethical responsibility within the context of human relations with advancing technological tools that are now coined, artificial intelligence.

16-223 IDeATe Portal: Creative Kinetic Systems
Fall: 10 units
The art and science of machines which evoke human delight through physical movement is founded on a balance of form and computation. This introductory physical computing course addresses the practical design and fabrication of robots, interactive gadgets, and kinetic sculptures. The emphasis is on creating experiences for human audiences through the physical behavior of devices which embody computation with mechanism, sensing, and actuation. Specific topics include basic electronics, elementary mechanical design, embedded programming, and parametric CAD. A key objective is gaining an intuitive understanding of how information and energy move between the physical, electronic, and computational domains to create a compelling behavior. The final projects are tested in the field on children and adults. This interdisciplinary course is an IDeATe Portal Course open to students from all colleges. For students choosing to follow an IDeATe program it is an entry into either Physical Computing or Intelligent Environments. The structure of the class revolves around collaborative exercises and projects which introduce core physical computing and system engineering techniques in a human-centric context. Students apply system and design thinking across multiple domains, work together to make and test several devices, and participate in wide-ranging critique which considers both technical and artistic success.

Course Website: https://courses.ideate.cmu.edu/16-223

16-264 Humanoids
Spring: 12 units
This course surveys perception, cognition, and movement in humans, humanoid robots, and humanoid graphical characters. Application areas include more human-like robots, video game characters, and interactive movie characters.

Course Website: http://www.cs.cmu.edu/~cga/humanoids-ugrad/

16-299 Introduction to Feedback Control Systems
Spring: 12 units
This course is designed as a first course in feedback control systems for computer science majors. Course topics include classical linear control theory (differential equations, Laplace transforms, feedback control), linear state-space methods (controllability/observability, pole placement, LQR), nonlinear systems theory, and an introduction to control using computer learning techniques. Priorities will be given to computer science majors with robotics minor.
Prerequisites: 21-122 and 15-122

Course Website: https://piazza.com/class/j8unqbhmwa3t

16-311 Introduction to Robotics
Spring: 12 units
This course presents an overview of robotics in practice and research with topics including vision, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensors. In course projects, students construct robots which are driven by a microcontroller, with each project reinforcing the basic principles developed in lectures. Students nominally work in teams of three: an electrical engineer, a mechanical engineer, and a computer scientist. This course will also expose students to some of the contemporary happenings in robotics, which includes current robot lab research, applications, robot contests and robots in the news.
Prerequisites: 21-240 Min. grade C or 24-311 Min. grade C or 21-260 Min. grade C or 21-241 Min. grade C or 18-202 Min. grade C

Course Website: http://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/16311/www/current/

16-350 Planning Techniques for Robotics
Spring: 12 units
Planning is one of the core components that enable robots to be autonomous. Robot planning is responsible for deciding in real-time what should the robot do next, how to do it, where should the robot move next and how to move there. This class does an in-depth study of popular planning techniques in robotics and examines their use in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students learn the theory of these methods and also implement them in a series of programming-based projects. To take the class students should have taken an Intro to Robotics class and have a good knowledge of programming and data structures.

Course Website: http://www.cs.cmu.edu/~maxim/classes/robotplanning/

16-362 Mobile Robot Algorithms Laboratory
Fall: 12 units
This course is a comprehensive hands-on introduction to the concepts and basic algorithms needed to make a mobile robot function reliably and effectively. We will work in small groups with small robots that are controlled over wireless from your laptop computers. The robots are custom-designed mini forktrucks that can move pallets from place to place just like commercial automated guided vehicles do today. The robots are programmed in the modern MATLAB programming environment. It is a pretty easy language to learn, and a very powerful one for prototyping robotics algorithms. You will get a lot of experience in this course in addition to some theory. Lectures are focused on the content of the next lab. There is a lab every week and they build on each other so that a complete robot software system results. The course will culminate with a class-wide robot competition that tests the performance of all of your code implemented in the semester. In order to succeed in the course, students must have a 1) 2nd year science/engineering level background in mathematics (matrices, vectors, coordinate systems) and 2) have already mastered at least one procedural programming language like C or Java, and 3) have enough experience to be reasonably prepared to write a 5000 line software system in 13 weeks with the help of one or two others. When the course is over, you will have written a single software system that has been incrementally extended in functionality and regularly debugged throughout the semester.

Course Website: http://www.frc.ri.cmu.edu/~alonzo/teaching/16x62/16x62.html

16-371 Personalized Responsive Environments
Spring: 9 units
[IDeATe collaborative course]. Environmental factors have a significant impact on mood and productivity. Creating responsive environments necessitates the design of surroundings that are able to metamorphose in order to optimize user strengths and available resources and evolve in stride with user needs. This course will investigate the development of spaces that adapt to user preferences, moods, and task specific demands. Both the design and engineering of such personalized environments will be explored. Central course concepts will include, understanding the user, integrating various modalities (e.g., light, heat, sound) to support the changing needs of task and user, and the creation of adaptive environments that learn user preferences over time. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 18-090 Min. grade C or 15-104 Min. grade C or 62-150 Min. grade C or 60-223 Min. grade C

16-374 IDeATe: Art of Robotic Special Effects
Spring: 12 units
Inspired by the early "trick" films of George Melies, this project-oriented course brings together robotics and film production technique to infuse cinema with the wonder of live magic. Students will learn the basics of film production using animatronics, camera motion control, and compositing. The projects apply these techniques to create innovative physical effects for short films, all the way from concept to post-production. The course emphasizes real-time practical effects to explore the immediacy and interactivity of improvisation and rehearsal. The robotics topics include animatronic rapid prototyping and programming human-robot collaborative performance. The course includes a brief overview of the history of special effects and robotics to set the work in context.

Course Website: https://courses.ideate.cmu.edu/16-374

16-375 IDeATe: Robotics for Creative Practice
Fall: 10 units
Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include closed-loop motion control, expressive physical and computational behavior, machine choreography, and performance conceptualization. Discussion topics include both contemporary kinetic sculpture and robotics research. This interdisciplinary course is part of IDeATe Physical Computing but is open to any student.
Prerequisites: 62-150 or 60-223 or 15-104 or 16-223

Course Website: https://courses.ideate.cmu.edu/16-375

16-376 IDeATe: Kinetic Fabrics
Spring: 10 units
Kinetic Fabrics brings together the fields of robotics and textiles to explore their unified creative and expressive potential. It is a wide-open frontier for kinetic art, wearable art, and architectural installation. In this course students will build a variety of performative systems combining fabrics and robotic technologies. Students will apply modular actuation and sensing to textile artworks, using software designed to facilitate fluid explorations, rapid iterations, and playful experimentation. Students will learn basic textile skills, such as hand and machine sewing, as well as gain facility and familiarity with the characteristics of multiple type of fabrics. Historical precedents as well as contemporary examples of works will support students creative growth and knowledge of the field. Students' course work will include short-term and long-term projects, sampling and prototyping, critique, and documentation. Additionally, students will organize an end-of-semester event where they will perform a developed kinetic fabric work for a public audience.

Course Website: https://courses.ideate.cmu.edu/16-376

16-384 Robot Kinematics and Dynamics
Fall: 12 units
Foundations and principles of robotic kinematics. Topics include transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and basic equations of motion. Course also include programming on robot arms.
Prerequisites: 21-241 or 24-311 or 18-202 or 16-311 or 15-122 Min. grade C

16-385 Computer Vision
Fall and Spring: 12 units
This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision, sensing and perception, and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems. This course is for undergraduate students only.
Prerequisites: (18-202 Min. grade C and 15-122 Min. grade C) or (21-259 Min. grade C and 21-241 Min. grade C and 15-122 Min. grade C)

Course Website: http://www.cs.cmu.edu/~16385/

16-397 Art, Conflict and Technology in Northern Ireland
Spring: 12 units
Art, Conflict and Technology in Northern Ireland is a 12-unit course cross-listed between the School of Art, the Department of English, and the Robotics Institute. Throughout the term students will be introduced to a history of social strife in the North of Ireland from the 1960s to the present, and efforts to reconcile such differences in the contemporary period. We will consider the influence of advancing technology on how narratives are shared within a community and worldwide. We will reflect upon and analyze a variety of literary and visual art sources from the chosen time period, while also learning how to create mixed-media projects using Gigapan and Hear Me systems from Carnegie Mellon?s CREATE Lab in the Robotics Institute. If you have ever considered how artists explore societal strife through their writing or visual arts practice, if you are interested in the social and political influences of evolving technology, or if you are a practicing artist who uses advancing technology as a tool for individual expression, this integrative course is for you. Throughout the semester we will examine the practice of a range of visual artists that include Rita Duffy, John Kindness and Willie Doherty and writers and dramatists like Dermot Healy, Patrick McCabe, and Christina Reid. Students will learn how to use CREATE Lab?s Gigapan and Hear Me systems as platforms for exploring the content presented in the class for the development of final projects. We will travel to Belfast for spring break 2015, to meet a variety of writers and artists whose work we will study, and stakeholders in the reconciliation efforts throughout the region. In addition to weekly lectures on Thursdays throughout the term, students will have a six-week lab on Tuesdays. Lab sessions begin in the second week of classes (January 20).

16-421 Vision Sensors
Spring: 12 units
This course covers the fundamentals of vision cameras and other sensors - how they function, how they are built, and how to use them effectively. The course presents a journey through the fascinating five hundered year history of "camera-making" from the early 1500's "camera obscura" through the advent of film and lenses, to today's mirror-based and solid state devices (CCD, CMOS). The course includes a significant hands-on component where students learn how to use the sensors and understand, model and deal with the uncertainty (noise) in their measurements. While the first half of the course deals with conventional "single viewpoint" or "perspective" cameras, the second half of the course covers much more recent "multi-viewpoint" or "multi-perspective" cameras that includes a host of lenses and mirrors.
Prerequisites: 21-241 and 21-111

Course Website: http://www.cs.cmu.edu/~ILIM/courses/vision-sensors/

16-423 Designing Computer Vision Apps
Fall: 12 units
Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for students who are not familiar with computer vision, but want to come up to speed rapidly with the latest in environments, software tools and best practices for developing computer vision apps. No prior knowledge of computer vision or machine learning is required although a strong programming background is a must (at a minimum good knowledge of C/C++). Topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE), and development on iOS devices using mobile vision libraries such as GPUImage and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focussed on a single operating system, the knowledge gained from this class is intended to generalize to other mobile platforms such as Android etc.
Prerequisites: (15-213 and 21-240) or (21-241 and 15-213) or (18-213 and 18-202)

Course Website: http://16423.courses.cs.cmu.edu

16-425 Medical Image Analysis
Spring: 12 units
Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh.
In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

16-441 Advanced CP/SIS: Urban Intervention
Fall and Spring: 12 units
This course introduces students to theories, practices, and communities for critical investigation of urban spaces and play within them. The course unfolds along two parallel trajectories: research (literature review, lectures, readings, demonstrations) and design (three iterated individualized projects and a fourth larger scale final project). The first half of the course will introduce students to a wide range of theories and techniques within urban intervention that draw from fluxus, the situationist international, activism and hacktivism, as well as public policy, philosophy, psychology and economics. Students will study theoretical and practical frameworks for artistic intervention into public urban spaces, while concurrently researching actual sites and communities within Pittsburgh for experimentation. Students are required to conceptualized projects on larger (urban) scales, and find ways to implement their projects safely and legally by pursuing the necessary administrative, social, technical, financial steps required to create meaningful interventions in public spaces. This class will specifically explore three media for urban intervention: Sound Outdoor video projection Robotics, Autonomy and Mobility in the way of remote control vehicles (e.g. cars, quad-copters, etc.). For each theme, students are required to produce one project that is iterated twice or more. The undergraduate (60441) and graduate (60741) sections of the course meet concurrently and follow the same syllabus and assignments. In addition to the coursework documented in the syllabus, Graduate level students are expected to write a research paper suitable for submission to a notable relevant academic conference. This process includes a rough draft, revisions and a completed and formatted paper ready for submission

16-450 Robotics Systems Engineering
Fall: 12 units
Systems engineering examines methods of specifying, designing, analyzing and testing complex systems. In this course, principles and processes of systems engineering are introduced and applied to the development of robotic devices. The focus is on robotic system engineered to perform complex behavior. Such systems embed computing elements, integrate sensors and actuators, operate in a reliable and robust fashion, and demand rigorous engineering from conception through production. The course is organized as a progression through the systems engineering process of conceptualization, specification, design, and prototyping with consideration of verification and validation. Students completing this course will engineer a robotic system through its compete design and initial prototype. The project concept and teams can continue into the Spring-semester (16-474 Robotics Capstone) for system refinement, testing and demonstration.
Prerequisites: 16-311 Min. grade B and (18-370 Min. grade B or 16-299 Min. grade B or 24-451 Min. grade B)

16-455 IDeATe: Human-Machine Virtuosity
Spring: 12 units
[IDeATe course] Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

Course Website: https://courses.ideate.cmu.edu/16-455

16-456 Reality Computing Studio
Fall: 12 units
[IDeATe collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). Taught in collaboration with the school of architecture, this studio asks students to apply these technologies to real world problems such as residential design, sustainability, and infrastructure monitoring.

Course Website: http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/

16-457 Reality Computing II
Spring: 12 units
[IDeATe collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). This iteration of the reality computing course will focus on "design realization": the translation from digital design to fully realized tangible artifact. Collaborating with the UDBS design studio, and within the context of a full-scale residential prototype, students will investigate how reality computing technologies can be used to accelerate and advance the process of design realization by using reality computing to understand existing homes, map design data into the real world, and highlight conflicts between design and reality. Topics of special focus within the course are residential design (John Folan) and augmented reality and robotics (Pyry Matikainen).

Course Website: http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/

16-461 Experimental Capture
Fall: 9 units
Performance capture is used in applications as varied as special effects in movies, animation, sports training, physical rehabilitation, and human-robot/human-computer interaction. This course will survey state-of-the-art techniques and emerging ideas, in the industry and in academia, to capture, model, and render human performances. The course will be a mix between lectures and discussion of recent progress in human motion capture and analysis. The course evaluation will be project-based, in which students will capture their own body and face motion, and build projects around the data they collect individually and as a group. We will cover: 1. Capture Techniques: We will describe and use various systems including motion capture, video-based capture, depth sensors, scanners, and eye-gaze trackers; 2. Modeling and Representation: We will cover classic and contemporary representations of face and body pose and motion, including statistical and physics-based techniques; 3. Rendering Applications: As new rendering paradigms emerge, new applications continue to develop. We will study recent progress in animation, synthesis, classification, and rehabilitation on new forms of displays. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 60-422 or 15-365

16-465 Game Engine Programming
Spring: 10 units
This course is designed to help students understand, modify, and develop game engines. Game engines consist of reusable runtime and asset pipeline code. They provide game-relevant abstractions of low-level system services and libraries, making it easier to write bug-free games that work across multiple platforms. Game engines also handle artistic content, providing or integrating with authoring tools to ease the process of creating high-fidelity games. In this course, we will discuss the problems game engines attempt to solve, examine how current state-of-the-art engines address these problems, and create our own engines based on what we learn. We will cover both the content authoring and runtime aspects of engines. Coursework will consist of frequent, tightly-scoped programming and system design assignments; expeditions through game engine source code; and two group projects — one in an engine created from scratch, and one that requires modification of an existing engine. Prerequisites: Students will be expected to be fluent in at least one programming language. We will be working with C++, Javascript, and a smattering of Python. We will be using git for version control and code sharing. The assignments in the course will be designed to be completed on an OSX or Linux workstation (e.g. the IDeATe "virtual cluster"). Working with Windows will be possible, but might require extra effort. We will be building a 3D model pipeline around Blender, but no prior knowledge of the tool will be assumed.
Prerequisites: 62-150 Min. grade C or 15-213 Min. grade C or 15-104 Min. grade C or 15-112 Min. grade C

16-467 Human Robot Interaction
Spring: 12 units
The field of human-robot interaction (HRI) is fast becoming a significant area of research in robotics. The basic objective is to create natural and effective interactions between people and robots. HRI is highly interdisciplinary, bringing together methodologies and techniques from robotics, artificial intelligence, human-computer interaction, psychology, education, and other fields. This course is primarily lecture-based, with in-class participatory mini-projects, homework assignments, a group term project that will enable students to put theory to practice, and a final. The topics covered will include technologies that enable human-robot interactions, the psychology of interaction between people and robots, how to design and conduct HRI studies, and real-world applications such as assistive robots. This course has no prerequisites, but some basic familiarity with robots is recommended (programming knowledge is not necessary, but is useful for the term project).

Course Website: http://harp.ri.cmu.edu/courses

16-474 Robotics Capstone
Spring: 12 units
In this course students refine the design, build, integrate, test, and demonstrate the performance of the robot they designed in the pre-requisite Systems Engineering Course (16-450). The students are expected to continue to apply the process and methods of Systems Engineering to track requirements, evaluate alternatives, refine the cyberphysical architectures, plan and devise tests, verify the design, and validate system performance. In addition, the students learn and apply Project Management techniques to manage the technical scope, schedule, budget, and risks of their project. The course consists of lectures, class meetings, reviews, and a final demonstration. Lectures cover core topics in Project Management and special topics in Systems Engineering. During class meetings the students and instructor review progress on the project and discuss technical and project-execution challenges. There are three major reviews approximately at the end of each of the first three months of the semester. For each review, the students give a presentation and submit an updated version of the System Design and Development Document. The course culminates in a System Performance Validation Demonstration at the end of the semester. In addition to that the students hold a special demonstration of their robotic system for the broader Robotics community.
Prerequisite: 16-450 Min. grade C

16-595 Undergraduate Independent Study
All Semesters
For students to pursue an independent study with a Robotics Institute faculty member.

16-597 Undergraduate Reading and Research
Fall and Spring
Missing Course Description - please contact the teaching department.

16-621 MSCV Project I
Fall and Spring: 12 units
The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

16-622 MSCV Capstone
Fall: 12 units
The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

16-623 Advanced Computer Vision Apps.
Fall: 12 units
Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for graduate students who are familiar with computer vision, and are keen to learn more about the applying state of the art vision methods on smart devices and embedded systems. A strong programming background is a must (at a minimum good knowledge of C/C++), topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE, Torch 7), and development on iOS devices using mobile vision libraries such as GPUImage, Metal and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focused on a single operating system, the knowledge gained from this class will easily generalize to other mobile platforms such as Android etc.
Prerequisites: 16-385 or 16-720

Course Website: http://16623.courses.cs.cmu.edu

16-627 MSCV Seminar
Fall
(Only open to MSCV students.) MSCV students will be required to participate in this one-semester seminar course which will prepare them for the MSCV project starting in the Spring semester. The first part of this course will cover talks by computer vision and related faculty about the ongoing research, development programs related to Computer Vision at CMU. The second part of this course will include student/faculty tutorial on topics such as OpenCV, Dataset Creation, Mechanical Turk etc. The goal of this series is to get students acquainted with practical knowledge for a successful project. In the last month of the course, each lecture will cover upto four possible MSCV projects pitched by faculty or industrial sponsors. At the end of the course students will turn in their choices, and a faculty committee will assign them the final projects.

16-665 Robot Mobility on Air, Land, & Sea
Fall: 12 units
Many robots are designed to move through their environments. Three prevalent environments on earth are land, air, and water. This course will explore the modeling, control, and navigation of ground-based (wheeled and legged), air-based (rotorcraft such as quadcopters), and water-based robots.

16-720 Computer Vision
Fall and Spring: 12 units
This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include image formation and representation, camera geometry, and calibration, computational imaging, multi-view geometry, stereo, 3D reconstruction from images, motion analysis, physics-based vision, image segmentation and object recognition. The material is based on graduate-level texts augmented with research papers, as appropriate. Evaluation is based on homeworks and a final project. The homeworks involve considerable Matlab programming exercises. Texts recommended but not required: Title: "Computer Vision Algorithms and Applications" Author: Richard Szeliski Series: Texts in Computer Science Publisher: Springer ISBN: 978-1-84882-934-3 Title: "Computer Vision: A Modern Approach" Authors: David Forsyth and Jean Ponce Publisher: Prentice Hall ISBN: 0-13-085198-1

Course Website: http://www.andrew.cmu.edu/course/16-720/

16-725 (Bio)Medical Image Analysis
Spring: 12 units
Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

16-730 Robotics Business
Spring: 12 units
This course introduces and develops business concepts that will be useful to new and existing companies, while focusing on robotic technology exemplars. The concepts begin with how to identify a new idea to for a business that can be effectively started. Initial ideas often start as a grandiose plan to change the world and these plans are legitimately the fuel that drive new businesses forward. However, when a company starts (e.g., builds a prototype or writes a first line of code), what is the least product a company can produce that customers still want and need? This kernel — extracted from the "big plan"— is a Minimal Viable Product (MVP). Once an MVP business kernel is formulated, we will learn and study how to understand customer needs, how to market a new idea and how raise and manage money for a new business entity. These steps abridge information that can be found in an MBA curriculum, but engineers and scientists focused on the technical side will need this information to participate in the process of building companies. In parallel, we will investigate the marketplace through the stock market. The stock market is a powerful window into the world of business. In other words, when a new business is built it has to live inside the competitive environment of every other business. To understand this eco-system, we will follow several companies in-situ as they go through their own ups-and-downs within the business world. The course is project based. Each student will either build their own business concept, or they will build an improvement plan that would be targeted to improve an existing business. Professor Bourne is a founding member of the Robotics Institute(1979) and has taught business concepts within the Tepper Business School and the Robotics Institute since 1988. In addition, he is the President of his own company Design One Software.

16-735 Robotic Motion Planning
Intermittent: 12 units
The robot motion field and its applications have become incredibly broad and theoretically deep at the same time. The goal of the course is to provide an up-to-date foundation in the motion planning field, make the fundamentals of motion planning accessible to the novice and relate low-level implementation to high-level algorithmic concepts. We cover basic path planning algorithms using potential functions, roadmaps and cellular decompositions. We also look at the recent advances in sensor-based implementation and probabalistic techniques, including sample-based roadmaps, rapidly exploring random trees, Kalman filtering, and Bayesian estimation.

16-740 Learning for Manipulation
Spring: 12 units
Manipulation is the process of changing the state of objects through direct physical interactions. To perform manipulation tasks in unstructured environments, autonomous robots will need to learn about the objects in their surroundings as well as the skills required to manipulate and change the state of these objects. In this course, we explore the use of machine learning and data-driven algorithms for robot manipulation. The course introduces students to the wide variety of challenges posed by manipulation tasks, and how these challenges can be formulated as learning problems. Students are taught how these problems can be solved using machine learning techniques. The types of machine learning methods covered in this course include supervised, unsupervised, active, and reinforcement learning methods. The course includes both lectures and guided paper discussions.

16-741 Mechanics of Manipulation
Fall: 12 units
Kinematics, statics, and dynamics of robotic manipulator's interaction with a task, focusing on intelligent use of kinematic constraint, gravity, and frictional forces. Automatic planning based on mechanics. Application examples drawn from manufacturing and other domains.

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/index.html

16-742 Geometry of Locomotion
Fall: 12 units
This course introduces geometric methods for the analysis of locomoting systems. Focusing on the kinematics of locomoting systems, the course covers topics from differential geometry, geometric mechanics, and motion planning . Specific topics include configuration spaces, manifolds, groups, Lie groups, representations of velocity, holonomic and nonholonomic constraints, constraint curvature, response to cyclic inputs and distance metrics. The primary goal of this class is to develop an intuitive understanding of these concepts and how they are used in locomoting systems, rather than working through a set of formal proofs and derivations. We do, however, incorporate enough mathematical formalism for this class to serve as a starting point for further investigation into this topic area. We also call upon biological data, when available, and relate to the mathematical formalisms in the class.

16-745 Optimal Control and Reinforcement Learning
Spring: 12 units
This course surveys the use of optimization (especially optimal control) to design behavior. We will explore ways to represent policies including hand-designed parametric functions, basis functions, tables, and trajectory libraries. We will also explore algorithms to create policies including parameter optimization and trajectory optimization (first and second order gradient methods, sequential quadratic programming, random search methods, evolutionary algorithms, etc.). We will discuss how to handle the discrepancy between models used to create policies and the actual system being controlled (evaluation and robustness issues). The course will combine lectures, student-presented material, and projects. The goal of this course will be to help participants find the most effective methods for their problems.

Course Website: http://www.cs.cmu.edu/~cga/dynopt/

16-748 Underactuated Robots
Fall: 12 units
People and animals move through and interact with the world in a fundamentally dynamic way. In the vast majority of cases the same cannot be said for robots. In fact, many conventional approaches to motion planning and robot control attempt to explicitly cancel out the dynamics associated with different tasks. This class will consider underactuated robots, systems that do not have full control over their state and therefore cannot be planned for or controlled via conventional methods. Our goal will be to make novel locomoting robots act more "naturally." This class will highlight the relationship between conventional ideas from deterministic motion planning and control design (e.g., dynamic programming and linear-quadratic regulators) and their contemporary counterparts, many of which help form the analytical basis for the probabilisitic reasoning that underlies contemporary AI systems (e.g., POMDPs). Note that this course is inspired by and, for the most part, will follow the format of "Underactuated Robotics: Learning, Planning, and Control for Efficient and Agile Machines" created by Prof. Russ Tedrake at MIT. We will take several tangents, but the course materials provided by Prof. Tedrake through MIT Open Courseware are an incredible resource for this course (and really just in general).

16-761 Mobile Robots
Spring: 12 units
The course is targeted to senior undergraduates and graduate level students. The lectures will develop the fundamentals of this emerging sub-field of robotics by calling on the experience of practitioners, the common themes of the literature, and relevant material from more basic fields such as computer vision, mathematics, and physics.

Course Website: http://www.frc.ri.cmu.edu/~alonzo/teaching/16-761/16-761.html

16-778 Mechatronic Design
Spring: 12 units
Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. This course is a semester-long multidisciplinary capstone hardware project design experience in which small (typically four-person) teams of electrical and computer engineering, mechanical engineering and robotics students deliver an end-of-course demonstration of a final integrated system capable of performing a mechatronic task. Throughout the semester, the students design, configure, implement, test and evaluate in the laboratory devices and subsystems culminating in the final integrated mechatronic system. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, microcontroller, electronic, sensor, and control components.

Course Website: http://www.ece.cmu.edu/courses/items/18578.html

16-782 Planning and Decision-making in Robotics
Fall: 12 units
Planning and Decision-making are critical components of autonomy in robotic systems. These components are responsible for making decisions that range from path planning and motion planning to coverage and task planning to taking actions that help robots understand the world around them better. This course studies underlying algorithmic techniques used for planning and decision-making in robotics and examines case studies in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students will learn the algorithms and implement them in a series of programming-based projects.

16-785 Integrated intelligence in robotics: vision, language, and planning
Spring: 12 units
This course covers the topics on building cognitive intelligence for robotic systems. Cognitive capabilities constitute high-level, humanlike intelligence that exhibits reasoning or problem solving skills. Such capabilities as semantic perception, language understanding, and task planning can be built on top of low-level robot autonomy that enables autonomous control of physical platforms. The topics generally bridge across multiple technical areas, for example, vision-language intersection and language-action/plan grounding. This course is composed of 50% lectures and 50% seminar classes. There are no explicit prerequisites for this class, but a general background knowledge in AI and machine learning is assumed.

Course Website: http://www.cs.cmu.edu/~jeanoh/16-785/

16-791 Applied Data Science
Spring: 12 units
This course explores the rapidly developing field of data science in the context of its pragmatic applications. Applied Data Science strives to achieve three main goals. The first is to optimize the efficacy of decision making by human managers. The second is to maximize the utilization of available data, so that no important clue is ever missed. The third is to improve understanding of data and the underlying processes that produce it. This course aims at building skills required to systematically achieve those goals in practice. The students will gain and solidify awareness of the most prevalent contemporary methods of Data Science, and develop intuition needed for assessing practical utility of the studied topics in application scenarios. They will be able to learn how to formulate analytic tasks in support of project objectives, how to define successful analytic projects, and how to evaluate utility of existing and potential applications of the discussed technologies in practice.

16-823 Physics-based Methods in Vision (Appearance Modeling)
Intermittent: 12 units
Everyday, we observe an extraordinary array of light and color phenomena around us, ranging from the dazzling effects of the atmosphere, the complex appearances of surfaces and materials, and underwater scenarios. For a long time, artists, scientists, and photographers have been fascinated by these effects, and have focused their attention on capturing and understanding these phenomena. In this course, we take a computational approach to modeling and analyzing these phenomena, which we collectively call "visual appearance". The first half of the course focuses on the physical fundamentals of visual appearance, while the second half of the course focuses on algorithms and applications in a variety of fields such as computer vision, graphics and remote sensing and technologies such as underwater and aerial imaging.
Prerequisites: 15-385 or 16-720 or 15-462

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/16823-f06/

16-824 Visual Learning and Recognition
Spring: 12 units
A graduate seminar course in Computer Vision with emphasis on representation and reasoning for large amounts of data (images, videos and associated tags, text, gps-locations etc) toward the ultimate goal of Image Understanding. We will be reading an eclectic mix of classic and recent papers on topics including: Theories of Perception, Mid-level Vision (Grouping, Segmentation, Poselets), Object and Scene Recognition, 3D Scene Understanding, Action Recognition, Contextual Reasoning, Image Parsing, Joint Language and Vision Models, etc. We will be covering a wide range of supervised, semi-supervised and unsupervised approaches for each of the topics above.
Prerequisites: 16-720 Min. grade B or 15-781 Min. grade B or 10-701 Min. grade B or 16-722 Min. grade B

Course Website: http://graphics.cs.cmu.edu/courses/16-824/2017_spring/

16-831 Statistical Techniques in Robotics
Fall: 12 units
Data-driven learning techniques are now an essential part of building robotic systems designed to operate in the real world. These systems must learn to adapt to changes in the environment, learn from experience, and learn from demonstration. In particular we will cover three important sub-fields of Machine Learning applied to robotic systems: (1) We will cover Online Learning, which can be used to give robotic systems the ability to adapt to changing environmental conditions. (2) We will cover Reinforcement Learning, which takes into account the tradeoffs between exploration and exploitation to learn how to interact with the environment. We will also cover Deep Reinforcement Learning techniques in the context of real-world robotic systems. (3) We will cover Apprenticeship Learning (Imitation Learning and Inverse Reinforcement Learning) which is critical for teaching robotic systems to learn from expert behavior. Prerequisites: Linear Algebra, Multivariate Calculus, Probability theory.

16-833 Robot Localization and Mapping
Fall and Spring: 12 units
Robot localization and mapping are fundamental capabilities for mobile robots operating in the real world. Even more challenging than these individual problems is their combination: simultaneous localization and mapping (SLAM). Robust and scalable solutions are needed that can handle the uncertainty inherent in sensor measurements, while providing localization and map estimates in real-time. We will explore suitable efficient probabilistic inference algorithms at the intersection of linear algebra and probabilistic graphical models. We will also explore state-of-the-art systems.

Course Website: http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018

16-845 Insects and Robots
Fall: 12 units
This course will cover all facets of modeling, design, fabrication, and analysis of robots operating on the insect scale, with a microrobotics perspective. Insects can perform different tasks, such as manipulation or locomotion, with their small scale bodies varying from 200¿m to 16cm length. Similarly, we can define a micro-robotic system as an autonomous or semi-autonomous device with features on the micron scale or that make use of micron-scale physics for mobility or manipulation of objects. Due to their small size scales, microrobots will encounter difficulties unlike their macro-scale counterparts, in terms of fabrication and autonomy. In this project-based course, our aim will be on learning the physics of scaling, fabrication paradigms, actuation and sensing strategies, with numerous case studies, and to build an insect-inspired robotic system. We will also discuss multiple applications such as surgical robotics, mobile microrobots, multi-agent systems, and micro/nano manipulation.

16-848 Hands: Design and Control for Dexterous Manipulation
Spring: 12 units
Research related to hands has increased dramatically over the past decade. Hands are in focus in computer graphics and virtual reality, new robot hands have been popping up in great variety, and manipulation has been featured in widely publicized programs such as the DARPA Robotics Challenge. With all of this attention on hands, are we close to a breakthrough in dexterity, or are we still missing some things needed for truly competent manipulation? In this course, we will survey robotic hands and learn about the human hand with the goal of pushing the frontiers on hand design and control for dexterous manipulation. We will consider the necessary kinematics and dynamics for dexterity, what sensors are required to carry out dexterous interactions, the importance of reflexes and compliance, and the challenge of uncertainty. We will examine the human hand: its structure, sensing capabilities, human grasp choice and control strategies for inspiration and benchmarking. Students will be asked to present one or two research papers, participate in discussions and short research or design exercises, and carry out a final project.

Course Website: http://graphics.cs.cmu.edu/nsp/course/16899-s18/

16-881 Special Topics: Deep Reinforcement Learning for Robotics
Spring: 12 units
The format of the class will be: each class, 2 students will present (1 paper each); one paper will be an interesting new paper on deep RL; the other will be a paper on robotics, which will have an impressive robotics result, possibly using RL but not deep RL. The class will compare and contrast these papers and try to understand: - How did the robotics paper achieve its result without deep RL? - What are the strengths and limitations of the approach described in the robotics paper? - What insights can we take away from this paper? - What are the strengths and limitations of the method described in the deep RL paper? - How can the method described in each paper be improved? Students will also work on a class project related to deep RL, of their choosing. Grading will be based on the presentations and the class project. Prerequisites: Students are expected to have already have a basic understanding of reinforcement learning, such as from 10-703, 16-748, 16-831, or a similar course, prior to taking this course.

Course Website: https://sites.google.com/view/16-881-cmu/home?authuser=0

16-882 Special Topics: Systems Engineering and Project Management for Robotics
Spring: 12 units
This course covers in-depth topics in systems engineering and project management, addressing the application of such topics in robotic system development. Even though the course stands on its own content-wise, it assumes that students have some basic knowledge of systems engineering and project management from other related courses (such as 16450 or 16650) or work experience. The course is partitioned into three segments: in the first, the course covers methods for systematic implementation of systems engineering, a formal discipline that guides the development of a system throughout its life cycle. The course will focus on methods that apply especially in the engineering development phase of systems engineering, exposing students to detailed system architecting, requirements decomposition, engineering design in systems engineering, and operational feasibility (reliability, affordability, MANPRINT, etc.) In the second segment, the course covers techniques and strategies for managing projects in robotics specifically. To achieve a successful system within scope-of-work, budget, and time, engineers must pay attention to project management alongside systems engineering. The course will introduce students to models for project management, project structures with cost and schedule control, estimation, and constraint-based prioritization. In the third segment of the course, students will apply the concepts they have learned on a robotic system they are developing as part of a sponsored research project, another course, or as a personal or business endeavor.

16-883 Special Topics: Provably Safe Robotics
Intermittent: 12 units
Safe autonomy has become increasingly critical in many application domains. It is important to ensure not only the safety of the ego robot, but also the safety of other agents (humans or robots) that directly interact with the autonomy. For example, robots should be safe to human workers in human-robot collaborative assembly; autonomous vehicles should be safe to other road participants. For complex autonomous systems with many degrees of freedom, safe operation depends on the correct functioning of all system components, i.e., accurate perception, optimal decision making, and safe control. This course deals with both the design and the verification of safe robotic systems. From the design perspective, we will talk about how to assure safety through planning, prediction, learning, and control. From the verification perspective, we will talk about verification of deep neural networks, safety or reachability analysis for closed loop systems, and analysis of multi-agent systems.

Course Website: http://www.cs.cmu.edu/~cliu6/provably-safe-robotics.html

16-884 Special Topic: Engineering a Robotics Startup
Intermittent: 6 units
In this mini course, we'll cover all the major areas of new venture creation, with an emphasis on issues related to starting robotics companies. There are unprecedented opportunities for entrepreneurship in robotics, and substantial funding, talent, and resources are available to founders who combine solid technical innovation with a viable business model. Our focus will primarily be on examining and evaluating business models for robotics companies using a Business Model Canvas approach, along with issues related to evaluating market size, dealing with venture capital, and developing financial forecasts. We'll make use of case studies to examine successful and failed robotics companies. As follow-on to this class, Marketing For Entrepreneurship, taught in the Tepper School of Business, is suggested, especially for RI students who desire 6 additional units of credit. Students who take 16-884 may register for 45-908 in the second half of the semester where the focus there will be on marketing and sales strategies for new companies.

16-899 Special Topics
Fall and Spring: 12 units
Section D: Nuclear Robots

Course Website: https://sites.google.com/site/cmuunderactuatedrobotics/

SCS: Institute for Software Research Courses

17-200 Ethics and Policy Issues in Computing
Spring: 9 units
Note: Previously offered as 08-200. In this course, students will study the social impacts of computing technology and systems. The course will provide a brief introduction to ethics and to the new and difficult ethical questions modern computing technology presents us with. It will focus on a number of areas in which computers and information technology are having an impact on society including data privacy, social media, and autonomous technologies.

17-214 Principles of Software Construction: Objects, Design, and Concurrency
Fall and Spring: 12 units
Note: This course previously offered as 15-214. Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java.
Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C)

17-224 Influence, Persuasion, and Manipulation Online
Fall: 9 units
This course will introduce the fundamental behavioral science of influence, persuasion, and manipulation, and the application of these scientific principles to online campaigns to influence attitudes and behavior. In particular, we will discuss the psychology of persuasion, nudging, social influence, bias, persuasive design, and the ethics of persuasion. Against this background, we will analyze case studies drawn from recent, high profile events such as election campaigns, targeted advertising, sowing political division, memes and virality, impact of social media, and propagation of "fake news." Countermeasures to these tactics will be explored, including personal measures, technologies, and policy.

17-303 Cryptocurrencies, Blockchains and Applications
Spring
Note: Previously offered as 08-303. Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies. Prerequisites: 15-213 or equivalent strongly recommended

17-313 Foundations of Software Engineering
Fall: 12 units
Note: This course previously offered as 15313.Students gain exposure to the fundamental principles of software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software in real-world settings. Topics related to software artifacts include coding, software architecture, measurement, and quality assurance of various qualities (e.g., robustness, security, performance, maintainability) with static and dynamic analysis, testing, code review, and inspection. Topics related to software process include requirements engineering, process models and evaluation, personal and team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, a strong focus on developing team skills, and will include both written and programming assignments. Students will get experience with the latest software engineering tools and practices.

Course Website: https://www.cs.cmu.edu/~ckaestne/17313/

17-331 Information Security, Privacy, and Policy
Fall: 12 units
Note: This course previously offered as 15-421. As layers upon layers of technology mediate increasingly rich business processes and social interactions, issues of information security and privacy are growing more complex too. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile and pervasive computing as well as social networking. Format: Lectures, short student presentations on topics selected together with the instructor, and guest presentations. Target Audience: Primarily intended for motivated undergraduate and masters students with CS background. Also open to PhD students interested in a more practical, multi-disciplinary understanding of information security and privacy.

17-333 Privacy Policy, Law, and Technology
Fall and Spring: 9 units
Note: Previously offered as 08-533. This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-334 Usable Privacy and Security
Spring: 9 units
Note: Previously offered as 08-734. There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

17-340 Green Computing
Intermittent: 9 units
Note: Previously offered as 08-340. Energy is a key societal resource. However, our energy usage is rising at an alarming rate and therefore it has become critical to manage its consumption more efficiently for long term sustainability. This course introduces students to the exciting area of "Green Computing", and is organizationally divided into two tracks. The first track is "Energy-Efficient Computing", which considers the state of the art techniques for improving the energy efficiency of mobile devices, to laptop and desktop class computers and finally to data centers. We will cover energy efficiency across the hardware/software stack, starting from the individual components like processors and radio interfaces to system level architectures and optimizations. The second track is "Applying Computing towards Sustainability", covering topics that leverage computing to reduce the energy footprint of our society. In particular, we will focus on Smart Buildings and the Smart Grid, covering topics such as sensing, modeling and controlling the energy usage of buildings, new operating systems or software stacks for the smart infrastructure, as well as the privacy and security issues with the new "internet of things". The goal of this course is to help students acquire some of the knowledge and the skills needed to do research in this space of "Green Computing". Although the course is listed within SCS, it should be of interest to students in several departments, including ECE, MechE, CEE, EPP and Architecture.

17-350 Information Technology Policy: Evidence, Communication, & Advocacy
Spring: 9 units
In recent decades, developments in Information and Communication Technologies (ICTs) have rapidly moved from research environments to products and services used by billions of people. This rapid rate of change has often resulted in a public which does not understand the technologies shaping their lives and lawmakers who are poorly equipped to make sound policy. It is therefore incumbent upon specialists to communicate how ICTs work to the public and lawmakers so policy making is shaped by evidence and reflects public desires. This course will train students to be effective communicators and advocates in the ICT space. Students taking this course will learn about the broader scope of technology policymaking including formal lawmaking, agency rule-making, strategic litigation, and corporate social responsibility. Current ICT policy topics in privacy, free expression, net neutrality, and competition will be covered. Public communication strategies such as writing op-eds, interviewing with journalists, producing explanatory videos and interactive games will be explored. Finally, students will learn how to perform an expert role in areas such as writing policy briefs and providing testimony. The course is open to advanced undergraduate and graduate students. Graduate students whose research has public policy implications are encouraged to develop projects related to their research. There is no requirement for programming knowledge, but students with experience in developing interactive media and games will be encouraged to utilize such skills. The class will focus heavily on readings, critical evaluation of real ICT advocacy campaigns, and homework will provide hands-on experience with numerous strategies for public engagement. At the end of the semester students will have a portfolio of projects which they may release publicly.

17-355 Program Analysis
Spring: 12 units
This course covers both foundations and practical aspects of the automated analysis of programs, which is becoming increasingly critical to find software errors and assure program correctness. The theory of abstract interpretation captures the essence of a broad range of program analyses and supports reasoning about their correctness. Building on this foundation, the course will describe program representations, data flow analysis, alias analysis, inter-procedural analysis, dynamic analysis, Hoare Logic, and symbolic execution. Through assignments and projects, students will design and implement practical analysis tools that find bugs and verify properties of software. This course satisfies the Logic and Languages constrained elective category of the Computer Science major, and the Technical Software Engineering requirement for the Software Engineering minor.
Prerequisites: 15-251 Min. grade C and (15-214 Min. grade C or 15-150 Min. grade C)

Course Website: http://www.cs.cmu.edu/~aldrich/courses/17-355-18sp/

17-356 Software Engineering for Startups
Spring: 12 units
Startup engineering is critical to innovation. The skills required to effectively prototype, launch, and scale products are vital to engineers everywhere, from fledgling companies founded in dorm rooms to local mid-size companies to internal startups from multi-national tech giants. However, developing software in a startup environment poses unique engineering challenges. These challenges include making and justifying foundational architectural and technical decisions despite extreme uncertainty; rapidly prototyping and evaluating new ideas and features, while building minimum viable products; prioritizing engineering effort in severely constrained environments; and communicating effectively both within a small engineering team and with internal and external non-technical stakeholders. This course teaches the skills necessary to engineer successfully in a startup environment, through lectures, group projects, case study discussions, and guest speakers drawn from experienced, practicing startup engineers. This is an engineering-focused course; no entrepreneurship background is required or expected. Students do not need to have a startup idea to participate fully. Prerequisites: 15-214 OR 15-213
Prerequisites: 15-213 or 15-214

17-401 Software Engineering for AI-Enabled Systems
Fall: 12 units
New Course Need Description

Course Website: https://ckaestne.github.io/seai/

17-413 Software Engineering Practicum
Spring: 12 units
Note: This course previously offered as 15413. This course is a project-based course in which students conduct a semester-long project for a real client in small teams. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. After the course, students will have the teamwork, process, and product skills to be immediately competent in a software engineering organization, and will be able to evaluate the new processes and techniques they will encounter in the workplace.

17-415 Software Engineering Reflection
Fall: 6 units
Note: This course previously offered as 17-413. This course is an opportunity to reflect on a software engineering experience you have had in industry. It is structured as a writers workshop, in which you will work with the instructor and other students to identify and flesh out a software engineering theme that is illustrated by your industry experience. You will prepare a 10-page report on this theme, comparable to a practitioner's report at a conference like ICSE or OOPSLA, and a 30-minute presentation to match. This course fulfills a requirement of the Software Engineering Minor program, but students in other programs may take the course if they meet the prerequisite industry experience and if space is available.

17-422 Building User-Focused Sensing Systems
Fall and Spring: 12 units
Note: Previously offered as 08-421. These days we are surrounded by sensing and computation. Smart devices, such as smartphones, smartwatches, are packed with sensors. While they are already very useful devices, we have only started to scratch the surface here. The aim of this class will be to introduce the students to building and understanding smart sensing devices. The course will include discussion into contribution of various fields, including human-computer interaction, embedded computing, computer vision, distributed systems, machine learning, signal processing, security, and privacy. We will discuss how these various disciplines are coming together to form an end-to-end system that generates useful and user-actionable data. We will take a hands-on approach towards building and evaluating these systems. The students will gain practical experience in developing sensing systems in different application domains, such as activity recognition, health sensing, gestural interaction, etc. You will learn about embedded systems and understand the advantages and limitations of different platforms. You will learn about sensors and how to interface them with the real world to be able to get useful and actionable data. You will learn how to build a network of sensors that can communicate with each other. You will also learn about storing the sensor data for visualization, analysis and presentation both locally and to the cloud. The course will be a combination of lectures, tutorials, class discussions, and demonstrations. Students will be evaluated based on 5 mini-projects/assignments, class participation, weekly reading summaries, and a final project. All hardware resources will be provided to the students and they will be given an option to take their final prototypes with them for the cost of the hardware components. Students should have reasonable programming experience and an interest in tinkering.

17-428 Machine Learning and Sensing
Fall: 12 units
Machine learning and sensors are at the core of most modern computing devices and technology. From Amazon Echo to Apple Watch to Google Photos to self-driving cars, making sense of the data coming from powerful but noisy sensors is the key challenge. The aim of the course will be to explore this intersection of sensors and machine learning, understand the inner workings on modern computing technologies, and design the future ones. We will cover data collection, signal processing, data processing, data visualization, feature engineering, machine learning tools, and some prototyping technologies. The course will focus on class discussions, hands-on demonstrations, and tutorials. Students will be evaluated on their class participation, multiple mini projects, and a final team project.

17-437 Web Application Development
Fall and Spring: 12 units
Note: This course previously offered as 15-437. This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technologies introduced will be the Django framework for Python and Java Servlets, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, XML, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must be comfortable programming in Java and/or Python to register for this course. Students must provide their own computer hardware for this course. Please see the Related URL above for more information.
Prerequisites: 15-214 or 17-514 or 17-214 or 14-513 or 15-513 or 15-213 or 18-213

17-445 Software Engineering for AI-Enabled Systems
Fall: 12 units
The course takes a software engineering perspective on building software systems with a significant machine learning or AI component. It discusses how to take an idea and a model developed by a data scientist (e.g., scripts and Jupyter notebook) and deploy it as part of scalable and maintainable system (e.g., mobile apps, web applications, IoT devices). Rather than focusing on modeling and learning itself, this course assumes a working relationship with a data scientist and focuses on issues of design, implementation, operation, and assurance and how those interact with the data scientist's modeling. This course is aimed at software engineers who want to understand the specific challenges of working with AI components and at data scientists who want to understand the challenges of getting a prototype model into production; it facilitates communication and collaboration between both roles.

Course Website: https://ckaestne.github.io/seai/

17-480 API Design and Implementation
Fall: 12 units
This class focuses on the design of programming interfaces, the APIs, within larger real-world software and ecosystems. We discuss the history and importance of APIs, and the principles behind designing good APIs. This includes study of specific examples of APIs, both good and bad, for inspiration and precaution. Students gain experience with the major steps of API design: gathering requirements, documenting, testing, implementing, refining, evolving, and reimplementing APIs. The principles taught are largely language-independent, though most examples are in Java or C. Students may be able to do assignments in other languages, within reason.
Prerequisites: 15-214 or 15-213 or 17-214

17-514 Principles of Software Construction: Objects, Design, and Concurrency
Fall and Spring: 12 units
Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java.
Prerequisites: (15-121 Min. grade C or 15-122 Min. grade C) and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C)

17-536 Pervasive and Ubiquitous Computing
Intermittent: 12 units
Note: Previously offered as 08530. The aim of the class will be to explore the area of Ubiquitous Computing (ubicomp) and allow students to work on a variety of small technology projects. Students will be exposed to the basics of building ubicomp systems, emerging new research topics, and advanced prototyping techniques. This course will focus more on class discussions and hands on demonstrations, while formal lectures will be conducted only as needed. Students will be evaluated on their class participation, reading summaries, and mini projects.

17-537 Artificial Intelligence Methods for Social Good
Spring: 9 units
Note: Previously offered as 08-537. Optimization: mathematical programming, robust optimization, influence maximization Game Theory and Mechanism Design: security games, human behavior modeling, auction and market equilibrium, citizen science Machine Learning: classification, clustering, probabilistic graphical models, deep learning Sequential Decision Making: Markov Decision Processes (MDPs), partially observable MDPs, online planning, reinforcement learning In addition to providing a deep understanding of these methods, the course will introduce which societal challenges they can tackle and how, in the areas of (i) healthcare, (ii) social welfare, (iii) security and privacy, (iv) environmental sustainability. The course will also cover special topics such as AI and Ethics and AI and Humans. The course content is designed to not have too much overlap with other AI courses offered at CMU. Although the course is listed within SCS, it should be of interest to students in several other departments, including ECE, EPP and SDS. The students in this 9-unit course are expected to have taken at least three mathematics courses covering linear algebra, calculus, and probability. The students will work in groups on a systematic literature review or a project exploring the possibility of applying existing AI tools to a societal problem, with a survey paper or technical report and presentation delivered at the end of the semester.

17-562 Law of Computer Technology
Fall: 9 units
NOTE: Previously offered as 08-532. A survey of how legislatures and courts cope with rapidly advancing computer technologies and how scientific information is presented to, and evaluated by, civil authorities. The course is also an introduction to the legal process generally and the interaction between the legal system and technology organizations. Topics include: patents, copyrights in a networked world, law of the Internet, free speech, data security, technology regulation, international law, and trans-border crime. Open to juniors, seniors and graduate students in any school. Open to sophomores by permission of the instructor. Prerequisites: none.

17-615 Software Process Definition
Intermittent: 9 units
A software process definition is the cornerstone of implementing and improving a software process. The objective of this course is to prepare students to understand how processes work within the context of an operational, day-to-day engineering company, and most importantly how they can, as an individual within an engineering environment, change a process for the betterment of all. Although the focus is on software process, this course will be useful to all students who will be executing, improving, or defining most any type of process. An incremental methodology and modular approach to software process definition is used and covers: * guidelines for early success and building a sound foundation * organizing the process definition as it develops * approaches to avoid unnecessarily elaborate or formal notations * developing the process using organizational goals and constraints * using the environmental context that the process resides within and builds upon Although the focus is on software process, this course will be useful to all students who will be executing, improving, or defining most any type of process. Requirement: This course is intended for individuals who have operational software engineering experience or a comprehensive undergraduate coursework in software engineering.

17-619 Introduction to Real-Time Software and Systems
Intermittent: 12 units
Introduction to Real-Time Software and Systems presents an overview of time as it relates engineering complex systems. Any system that responds at the pace of relevant events has real-time constraints whether the timescale is short, like the flight controls for an aircraft, or longer, like the flight reservation system for an airline. Fundamental concepts, terminology, and issues of real-time systems are introduced in this course. The focus is on software solutions to real-time problems-solutions that must be both correct and timely. Software development is examined with emphasis on real-time issues during each phase of the software lifecycle. Real-time requirements analysis, architecting real-time systems, designing and modeling system timing, and implementation and testing strategies are studied. Modeling techniques using UML 2.0 are applied. Particular emphasis is placed on real-time scheduling to achieve desired timing, reliability, and robustness. Languages and operating systems for real-time computing, and real-time problems in concurrent and distributed systems are explored. This course provides a comprehensive view of real-time systems with theory, techniques and methods for the practitioner. After successfully completing this course, the student will be able to identify constraints and understand real-time issues in system development, and propose approaches to typical real-time problems. The aim of this course is to motivate and prepare students to pursue more in-depth study of specific problems in real-time computing and systems development. REQUIREMENT: Proficiency with a high-level programming language such as C or Ada and basic concepts of computing systems. Familiarity with software engineering concepts and system development lifecycle.

17-621 Computational Modeling of Complex Socio-Technical Systems
Intermittent: 12 units
NOTE: Previously offered as 08-621. Social and cultural systems are complex. Whether considering world transforming events such as the Arab Spring or the impact of health care reforms, the interactions among people, technology, and organizations can generate unanticipated outcomes. Computer simulation is a critical methodology for explaining and predicting these events. In this course, the basics of simulation modeling, design, testing and validation are covered. Different simulation approaches are contrasted such as agent-based modeling and system dynamics.

17-635 Software Measurement
Fall: 9 units
Sections D and PP are NOT available for on-campus students. The purpose of this course is to introduce students to software measurement — from need identification through analysis and feedback and into the process. Much of the course material demonstrates concepts of software measurement that are used by managers and practitioners in industry today. The course is taught within the framework of the software engineering process. Required text: Selected Readings handed out in class Requirement: This course is intended for individuals who have industrial software engineering experience with a large project, or a comprehensive undergraduate course in software engineering.

17-640 IoT, Big Data, and ML: A Hands-on Approach
Intermittent: 12 units
This course is designed to teach IoT concepts, big data, and machine learning techniques using a hands-on approach. An IoT system simulating an order fulfillment process is central to the hands-on learning of the concepts and techniques. Students will work in 4-5 person teams to enable the system and implement the requirements. In doing so, they will incorporate sound design principles of software engineering acquired in lectures. Students will capture the data generated during the execution of the system as it fulfills orders that are received from a front-end system developed by the students. Students will be expected to prepare, process, and model the data for statistical analysis applying techniques taught in class. They will then visualize, analyze and interpret the results, and implement improvements to obtain a 360-degree experience of a business application using the automated system. This course will provide insight into the ways in which business enterprises think about leveraging technology and software in the management of their production operations. The course prepares students for professional opportunities requiring such skills allowing them to identify use cases that facilitate innovation and promote competitiveness.

17-643 Hardware for Software Engineers
Intermittent
The goal of this course is to provide an understanding of electronics beyond the average computer organization course. Its purpose is to enable software engineers to be more effective in domains where software and hardware are closely coupled. Examples of such domains include robotics, avionics, automotive, process control, and many others. Students successfully completing this course will be better prepared to communicate with hardware-oriented engineers, understand the hardware environment, and the subtle regions where software and hardware meet. Requirement: Students need not have a hardware background, but they should have a solid computer science background including languages, data structures, discrete math, operating systems, and computer organization. It is highly desirable that students have project experience, preferably real-world experience, although project course work and/or internships will suffice. Undergraduates need instructor approval (lattanze@cs.cmu.edu).

17-648 Engineering Data Intensive Scalable Systems
Intermittent: 12 units
Internet services companies such as Google, Yahoo!, Amazon, and Facebook have pioneered systems that have achieved unprecedented scale while still providing high level availability and a high cost-performance. These systems differ from mainstream high performance systems in fundamental ways. They are data intensive rather than compute intensive as we see with mainstream super computers spending the bulk of their time performing data I/O and manipulation rather than computation. They need to inherently support scalability, typically having high reliability and availability demands as well. Given that they often operate in the commercial space the cost-performance of these systems needs to be such that the organizations dependent on such systems can turn a profit. Designing and building these systems require a specialized set of skills. This course will cover the set of topics needed in order to design and build data intensive scalable systems. In this domain engineers not only need to know how to architect systems that are inherently scalable, but to do so in a way that also supports high availability, reliability, and performance. Given the large distributed nature of these systems basic distributed systems concepts such as consistency and time and synchronization are also important. These systems largely operate around the clock, placing an emphasis on operational concerns. This course will introduce students to these concerns with the intent that they understand the extent to which things like deploying, monitoring, and upgrading impact the design. The course will be a hands-on project oriented course. The basic concepts will be given during the lectures and applied in the project. The students will gain exposure to the core concepts needed to design and build such systems as well as current technologies in this space. Class size will be limited.

17-649 Artificial Intelligence for Software Engineering
All Semesters: 12 units
Advances in artificial intelligence (AI) and machine learning (ML) offer new opportunities in software engineering to explore the design space and improve software quality. This includes discovering interactions among natural language requirements, prioritizing feature requests, and finding and fixing bugs. Consequently, software engineers must take on the role of data scientist, which entails curating datasets, understanding the trade-offs in statistical models, and learning to evaluate their models. This course aims to introduce students to advances in natural language processing (NLP), including symbolic and statistical NLP techniques, and in deep learning to analyze software artifacts. The course will emphasize algorithm setup and configuration, data preparation, analytic workflow, and evaluation. Datasets will be drawn from industrial requirements, mobile app reviews, bug reports and source code with documented vulnerabilities. At course end, students will understand terminology and have hands on experience to help guide their decisions in applying AI to contemporary engineering problems.

Course Website: http://relab.cs.cmu.edu/ai4se/

17-651 Models of Software Systems
Fall: 12 units
Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not MSE/MSIT-SE/MITS, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken an undergraduate discrete math course, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

17-652 Methods: Deciding What to Design
Fall: 12 units
Sections D and PP are NOT available for on-campus students. Practical development of software requires an understanding of successful methods for bridging the gap between a problem to be solved and a working software system. In this course you will study a variety of ways of understanding the problem to be solved by the system you're developing and of framing an appropriate solution to that problem. After completing this course, you will be able to: identify different classes of problems and their structures; analyze technical, organizational, usability, business, and marketing constraints on solutions; apply engineering approaches to frame solutions; understand how your understanding of the problem should be reflected in the software design. PREREQUISITE: minimum of 3 months hands-on software development experience in industry. Students not accepted into the MSE program must present a current resume showing relevant industrial experience to department coordinator. This course is offered to only MSE/MITS and MSIT-SE students for fall semester. This course is for graduate students only. This course is for letter grade only (no pass/fail grades). To register for Methods course, you will need a requirement of a minimum of 3 mos hands-on software development experience in industry. Please submit a statement that gives the company, the dates, and a sentence or two about what you were actually doing during that time (i.e. programming, testing, other things actually involved in software development)to jdh@cs.cmu.edu. This is a graduate course. Only undergrad SE minors may take this course.

Course Website: http://spoke.compose.cs.cmu.edu/methods-fall-05/res/bib.htm

17-653 Managing Software Development
Fall: 12 units
Sections D, F, PP and G are NOT available for on-campus students. Large scale software development requires the ability to manage resources - both human and computational - through control of the development process. This course provides the knowledge and skills necessary to lead a project team, understand the relationship of software development to overall product engineering, estimate time and costs, and understand the software process. After completing this course, students will: 1. be able to write a software project management plan, addressing issues of risk analysis, schedule, costs, team organization, resources, and technical approach 2. be able to define the key process areas of the Capability Maturity Model and the technology and practices associated with each and a variety of software development life cycle models and explain the strengths, weaknesses, and applicability of each 3. understand the relationship between software products and overall products (if embedded), or the role of the product in the organizational product line 4. understand the legal issues involved in liability, warranty, patentability, and copyright 5. understand the purpose and limitations of software development standards and be able to apply sensible tailoring where needed 6. be able to use software development standards for documentation and implementation 7. be able to apply leadership principles 8. be able to perform requirements elicitation REQUIREMENT: Students must have had industrial software engineering experience with a large project, or a comprehensive undergraduate course in software engineering. This course is for letter grade only. Contact the instructor (mirandae@andrew.cmu.edu) for permission to join the class. This is a course for graduate students. Only undergrad SE minors may take this course.

Course Website: http://mse.isri.cmu.edu/software-engineering/documents/syllabi/17-653_F15_MSD_Syllabus.pdf

17-654 Analysis of Software Artifacts
Spring: 12 units
Analysis is the systematic examination of an artifact to determine its properties. This course will focus on analysis of software artifacts—primarily code, but also including analysis of designs, architectures, and test suites. We will focus on functional properties, but also cover non-functional properties like performance and security. In order to illustrate core analysis concepts in some depth, the course will center on static program analysis; however, the course will also include a breadth of techniques such as testing, model checking, theorem proving, dynamic analysis, and type systems. The course will balance theoretical discussions with lab exercises in which students will apply the ideas they are learning to real artifacts. After completing this course, students will: * know what kinds of analyses are available and how to use them * understand their scope and power,when they can be applied and what conclusions can be drawn from their results * have a grasp of fundamental notions sufficient to evaluate new kinds of analysis when they are developed * have some experience selecting and writing analyses for a real piece of software, applying them and interpreting the results Ph.D. students taking the 17-754 version of the course will gain a broad overview of the analysis research literature and in-depth knowledge of a particular sub-area through a course project. Requirement: A recent discrete math course and programming experience. Strongly Recommended: Models of SW Development course (17-651) before taking this course. This course is for letter grade only (no pass/fail grades). This is a graduate course. Only undergrad SE minors may take this course with the instructor's permission.

Course Website: http://www-2.cs.cmu.edu/~aldrich/courses/654/

17-655 Architectures for Software Systems
Spring: 12 units
Successful design of complex software systems requires the ability to describe, evaluate, and create systems at an architectural level of abstraction. This course introduces architectural design of complex software systems. The course considers commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures. It teaches the skills and background students need to evaluate the architectures of existing systems and to design new systems in principled ways using well-founded architectural paradigms. After completing this course, students will be able to: 1. describe an architecture accurately 2. recognize major architectural styles in existing software systems 3. generate architectural alternatives for a problem and choose among them 4. construct a medium-sized software system that satisfies an architectural specification 5. use existing definitions and development tools to expedite such tasks 6. understand the formal definition of a number of architectures and be able to reason about the properties of those architectures 7. use domain knowledge to specialize an architecture for a particular family of applications. REQUIREMENT: Experience with at least one large software system, either through industrial software development experience or an undergraduate course in software engineering, compilers, operating sys., or the like. This course is for letter grade only. Instructor wants each student who wants to take his Architectures class to have worked on a significant software system in your courses or in industry. Write to (garlan@cs.cmu.edu) for admission into the course stating the experience you have had. This is a graduate course. Only undergrad SE minors may take this course

17-685 Dynamic Network Analysis
Spring: 12 units
Who knows who? Who knows what? Who communicates with whom? Who is influential? How do ideas, diseases, and technologies propagate through groups? How do social media, social, knowledge, and technology networks differ? How do these networks evolve? How do network constrain and enable behavior? How can a network be compromised or made resilient? Such questions can be addressed using Network Science. Network Science, a.k.a. social network analysis and link analysis, is a fast-growing interdisciplinary field aimed at understanding simple & high dimensional networks, from both a static and a dynamic perspective. Across an unlimited application space, graph theoretic, statistical, & simulation methodologies are used. An interdisciplinary perspective on network science is provided, with an emphasis on high-dimensional dynamic data. The fundamentals of network science, methods, theories, metrics & confidence estimation, constraints on data collection & bias, and key research findings & challenges are examined. Illustrative networks discussed include social media based (e.g., twitter), disaster response, organizational, semantic, political elite, crises, terror, & P2P networks. Critical procedures covered include: basic centralities and metrics, group and community detection, link inference, network change detection, comparative analytics, and big data techniques. Applications from business, science, art, medicine, forensics, social media & numerous other areas are explored. Key issues addressed: Conceptualization, measurement, comparison & evaluation of networks. Identification of influential nodes and hidden groups. Network emergence, evolution, change & destabilization. Graduate course taught every other year. Prerequisite: Undergraduate-level statistics course or instructor permission. Linear algebra is recommended. Students are encouraged to bring & use their own data, or to use provided data.

17-702 Current Topics in Privacy Seminar
Fall and Spring: 3 units
Note: Previously offered as 08-602. In this seminar course students will discuss recent papers and current public policy issues related to privacy. Privacy professionals from industry, government, and non-profits will deliver several guest lectures each semester.

17-731 Foundations of Privacy
Fall: 12 units
Note: Previously offered as 08-604. Privacy is a significant concern in modern society. Individuals share personal information with many different organizations - healthcare, financial and educational institutions, the census bureau, Web services providers and online social networks - often in electronic form. Privacy violations occur when such personal information is inappropriately collected, shared or used. We will study privacy in a few settings where rigorous definitions and enforcement mechanisms are being developed - statistical disclosure limitation (as may be used by the census bureau in releasing statistics), semantics and logical specification of privacy policies that constrain information flow and use (e.g., by privacy regulations such as the HIPAA Privacy Rule and the Gramm-Leach-Bliley Act), principled audit and accountability mechanisms for enforcing privacy policies, anonymous communication protocols - and other settings in which privacy concerns have prompted much research, such as in social networks, location privacy and Web privacy (in particular, online tracking & targeted advertising).

17-749 Artificial Intelligence for Software Engineering
All Semesters: 12 units
Advances in artificial intelligence (AI) and machine learning (ML) offer new opportunities in software engineering to explore the design space and improve software quality. This includes discovering interactions among natural language requirements, prioritizing feature requests, and finding and fixing bugs. Consequently, software engineers must take on the role of data scientist, which entails curating datasets, understanding the trade-offs in statistical models, and learning to evaluate their models. This course aims to introduce students to advances in natural language processing (NLP), including symbolic and statistical NLP techniques, and in deep learning to analyze software artifacts. The course will emphasize algorithm setup and configuration, data preparation, analytic workflow, and evaluation. Datasets will be drawn from industrial requirements, mobile app reviews, bug reports and source code with documented vulnerabilities. At course end, students will understand terminology and have hands on experience to help guide their decisions in applying AI to contemporary engineering problems.

Course Website: http://www.cs.cmu.edu/~sadeh/17%20749.html

17-781 Mobile and IoT Computing Services
Spring: 12 units
With over 6 billion mobile phone users worldwide, including well over a 2 billion smart phone users, new wireless and pervasive computing applications and services are changing the way enterprises interact with customers and employees. The explosion in smart phone ownership along with the deployment of 4G and soon 5G networks is leading to a slew of new mobile apps and services. They range from mobile commerce and enterprise apps, social networking apps, all the way to more Internet of Things technologies (e.g. smart homes, smart cars, smart glasses, health/fitness sensors). These apps and services are emerging as part of an increasingly rich ecosystem where context awareness and intelligent predictive technologies are used to offer increasingly personalized experiences to users. This same ecosystem has emerged as the engine behind increasingly targeted marketing and advertising scenarios that also raise challenging privacy issues. The course objective is to introduce participants to the technologies, services and business models associated with Mobile and Pervasive Commerce. It also provides an overview of future trends and ongoing research. You will learn to evaluate critical design tradeoffs associated with different mobile technologies, architectures, interfaces and business models and how they impact the usability, security, privacy and commercial viability of mobile and pervasive computing services and apps. Topics include Mobile Communications, Mobile OS, Mobile Web technologies including app development, Mobile Security, Mobile Payments, Mobile Web Apps and Services (e.g. Mobile Entertainment, Mobile Banking, Mobile, Mobile Social Networking, Mobile Health, etc.), Location-Based Services, RFID, Mobile Enterprise Apps, Pervasive Computing Applications, Context awareness, intelligent assistant technologies, and privacy.

Course Website: http://www.normsadeh.com/ms-course-overview

17-801 Dynamic Network Analysis
Spring: 12 units
Note: Previously offered as 08-801. Who knows who? Who knows what? Who communicates with whom? Who is influential? How do ideas, diseases, and technologies propagate through groups? How do social media, social, knowledge, and technology networks differ? How do networks evolve? How do networks constrain and enable behavior? How can a network be destroyed or made resilient? Such questions can be addressed using network science. Network Science, also referred to as social network analysis and link analysis, is an interdisciplinary field aimed at understanding complex behavior using networks. Graph theoretic, statistical and simulation techniques are used. Applications areas are limited only be your imagination. This course covers the basics of network science from an interdisciplinary perspective. Key methods, theories, constraints on data collection, research findings and challenges are examined. Application areas discussed include: social media (e.g. twitter), disaster response, organizational networks, citation networks, semantic networks, political elite networks and crises, terror networks, disease and health networks, nation-state networks, and cyber networks. Methods covered include: basic centralities, group and community detection, link inference, network change detection, comparative analytics and big data techniques. Questions addressed include:How do we conceptualize, measure, compare and evaluate various types of networks? How do we evaluate the impact of policies and technology on networks? What nodes, relations, groups, or motifs stand out or are influential in a network? How do networks emerge, evolve, and change? Prerequisite: Undergraduate-level statistics course or permission of instructor. Linear algebra is recommended but not required. Students are encouraged to bring and use their own data, or to use publicly available network dataset for assignments.

Course Website: http://lorrie.cranor.org/courses/sp04/

17-821 Computational Modeling of Complex Socio-Technical Systems
Spring: 12 units
NOTE: Previously offered as 08-810. Social and cultural systems are complex. Whether considering world transforming events such as the Arab Spring or the impact of health care reforms, the interactions among people, technology, and organizations can generate unanticipated outcomes. Computer simulation is a critical methodology for explaining and predicting these events. In this course, the basics of simulation modeling, design, testing and validation are covered. Different simulation approaches are contrasted such as agent-based modeling and system dynamics.

SCS Concentrations

The School of Computer Science (SCS) offers concentrations for SCS students in various aspects of computing to provide greater depth to their education. Computer Science majors can substitute an SCS concentration for the minor requirement. Artificial Intelligence and Computational Biology majors can complete an SCS concentration if they wish, but it is not required for these degrees.

Note: At the present time, concentrations are not shown on official transcripts.

SCS Concentrations are currently available to SCS students only and assume these students have taken most/all of the CS core: 15-122/15-150/15-210/15-213/15-251. For SCS students entering in Fall 2018 or later, these students may not pursue a minor within SCS; instead they can pursue the related concentration. For example, instead of pursuing the Software Engineering minor, these SCS students could pursue the new Software Engineering concentration.

Consult the SCS undergraduate concentrations website (https://www.cs.cmu.edu/undergraduate-concentrations) for information about these concentrations as they are approved. For SCS students, consult with your academic advisor for more information about available concentrations and requirements.

- Algorithms and Complexity
- Computational Biology
- Computer Systems
- Human-Computer Interaction
- Language Technologies (to be approved in late 2019)
- Machine Learning
- Principles of Programming Languages
- Robotics
- Security and Privacy
- Software Engineering

Algorithms and Complexity Concentration

This concentration is available to SCS students only.

Ryan O'Donnell, *Concentration Director*
Location: GHC 7213

The goal of the Algorithms and Complexity concentration is to give SCS students a deep background in the theory of computation as it relates to algorithms and computational complexity. The expectation is that students who complete this concentration will have the background to pursue topics at the PhD level at any top program in the country. Furthermore we expect the reasoning skills gained as part of this concentration could be a significant help in a wide variety of positions in industry.

The concentration is designed to be reasonably flexible covering a wide area of topics within the area of algorithms and complexity. This includes central topics within the area such as complexity theory, and algorithms, but also includes theory as used in areas such as Computational Geometry, Graph Theory, Cryptography, Machine Learning, Algorithms for Large Data, Error Correcting Codes, and Parallel Algorithms.

Common themes of all courses covered by the concentration are the following:

- Clearly defined formalisms of the subject matter.
- A substantial component involving rigorous mathematical analysis, including proofs.
- Abstracting away from specific applications to a more general context.
- Relating algorithms and/or complexity of computation to a variety of complexity measures such as time, space, communication, or information content.

Any given course does not have to exclusively cover these themes and can, for example, also cover experimental aspects of algorithms, or examples applied to quite specific applications.

Learning Objectives

We do not expect students to have high proficiency in all the examples listed, but to gain at least some proficiency from each category.

- The ability to take a loosely defined problem and clearly pose it as a well defined problem specification.
- The understanding of several advanced algorithms beyond what is covered in the core.
- The appreciation a variety of models for bounding resources, such as information theory, space complexity, parallel complexity, communication complexity, proof complexity, query complexity, and hardness of approximation.
- The ability to understand and apply a variety of advanced algorithmic techniques and proof techniques, such as Lovasz Local Lemma, Johnson Lindenstrauss, Chernoff Bounds, sparsification, expanders, probabilistic method, regret bounds, spectral graph theory, fixed parameter tractability and semi-indefinite programming.
- The ability to recognize flaws in ill-formed proofs.
- The ability to formulate new questions about the field.

Prerequisites

The following courses must be completed before the concentration can be completed:

15-210	Parallel and Sequential Data Structures and Algorithms	12
15-251	Great Ideas in Theoretical Computer Science	12
15-259	Probability and Computing	12
or 21-325	Probability	
or 36-218	Probability Theory for Computer Scientists	
15-451	Algorithm Design and Analysis	12

It is expected that all students will start the concentration after having finished all but 15-451.

Course Requirements

The curriculum consists of one required course and at least three elective courses. The three elective courses must sum to at least 30 units. The elective courses will vary from year to year.

Required:

15-455	Undergraduate Complexity Theory	9

Electives (at least three courses with a total of 30 units or more):

15-354	Computational Discrete Mathematics	12
15-356	Introduction to Cryptography	12
15-456	Computational Geometry	9
15-458	Discrete Differential Geometry	12
15-483	Truth, Justice, and Algorithms	9
21-301	Combinatorics	9
21-484	Graph Theory	9
Special permission required:		
47-834	Linear Programming	6
47-835	Graph Theory	6
47-836	Advanced Graph Theory	6
Other graduate-level courses as approved by the concentration director		

A student can also use a senior thesis or research-based independent study as one of the elective courses (for 12 units). The topic must be related to algorithms and complexity, and approved by the director. An independent study must be for at least 12 units, and there must be a substation paper writeup on the research topic, and a poster or other presentation.

The choice of available elective courses will be posted prior to registration each semester.

Double Counting

The concentration will require that 3 courses (at least 27 units) are not double counted with any other requirements of any Major, Minor, or other concentration the student is pursuing.

Advising and Management

Courses in the list of electives will be approved by the director on a yearly basis under consultation of the algorithms and complexity group (to help evaluate the relevance of the courses) and the Assistant Dean (to help flag any logistical issues). Any special requests by a student for counting a course out of the list, will go to the director. The director will also approve any research units.

Students interested in this concentration should contact the concentration director for an initial advising consultation.

Computational Biology Concentration

This concentration is available to SCS students only.

Phillip Compeau, *Concentration Director*
Location: GHC 7403

Samantha Mudrinich, *Concentration Coordinator*
Location: GHC 7414

The general goal of the Computational Biology Concentration is to provide foundational coursework in computational biology that will allow undergraduate students in the Carnegie Mellon University School of Computer Science to start building a skillset useful for understanding many of the modern technologies developed by researchers as well as companies in the biotech and biomedical arenas.

This concentration consists of four core courses providing breadth in computational biology across laboratory methods, machine learning, genomics, and modeling of biological systems, as well as one elective that allows students to complete depth coursework in an area of interest, including undergraduate research.

Learning Objectives

Students will, by way of completing this concentration:

- model biological systems at the molecular and cellular levels using a variety of approaches;
- generate their own high throughput molecular biology data in a laboratory setting, and apply computational techniques to analyze the data they generate;
- transform hazy biological problems involving genomic data into well-defined computational problems, design algorithms to solve these problems, and adapt them to biological data;
- explore additional coursework of interest in genomics, biological research automation, biological image analysis, or computational biology research.

This concentration also provides students completing a computational degree other than the major in computational biology (http://www.cbd.cmu.edu/education/bs-in-computational-biology) with the opportunity to make a transition toward a career in computational biology. We have compiled information on over 250 companies working on computational biology into a unique web resource for students both inside and outside of Carnegie Mellon (http://careers.cbd.cmu.edu). These companies work on diverse topics from the automation of biological research to drug discovery to wearable medical devices to genetic diagnostics. Increasingly, when we interact with these companies, they want computationally minded candidates with as much knowledge of standard approaches in computational biology as possible.

Prerequisites

Note that not all of the prerequisites below are required to take every course in this concentration (for example, 02-251 does not have any of the pre-requisites below), but these courses are required to complete all of the required coursework and should be completed early within this concentration.

15-122	Principles of Imperative Computation	10
15-151	Mathematical Foundations for Computer Science	10
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-241	Matrices and Linear Transformations	10
36-218	Probability Theory for Computer Scientists	9

Further, the following two courses are not technically required as prerequisites to the courses in this concentration, but they are strongly suggested prerequisites because they provide students with helpful surveys of fundamental topics in biology and computational biology.

02-251	Great Ideas in Computational Biology	12
03-121	Modern Biology	9

Requirements

Five courses in total are required for this concentration. The following four courses are required as part of a central core of coursework; they consist of three computational biology courses as well as an introductory machine learning course, which today is fundamental for even an introductory understanding of the field.

		Units
02-261	Quantitative Cell and Molecular Biology Laboratory (03-343, Experimental Techniques in Molecular Biology, may be taken if 02-261 is not offered)	Var.
02-510	Computational Genomics	12
02-512	Computational Methods for Biological Modeling and Simulation	9
10-315	Introduction to Machine Learning (Undergrad)	12

In addition to these four courses above, one elective course is required. Any 02-listed (Computational Biology Department) undergraduate course of at least 9 units at the 300-level or above may satisfy this requirement; graduate courses may be applied to this category with permission. The Computational Biology Department is growing quickly, but at the time of writing, the courses that are regularly offered by the department that would satisfy this requirement are the following:

02-317	Algorithms in Nature	9
02-319	Genomics and Epigenetics of the Brain	9
02-425	Computational Methods for Proteogenomics and Metabolomics	9
02-450	Automation of Scientific Research	9
02-499	Independent Study in Computational Biology	Var.
02-500	Undergraduate Research in Computational Biology (03-441/03-541 may be taken if 02-500 is not offered)	Var.
02-514	String Algorithms	12
02-515	Advanced Topics in Computational Genomics	12
02-518	Computational Medicine	12

Double Counting

At most two courses can double count with all program requirements for majors, minors and other concentrations being pursued by the student. Courses used as free electives for a major are not considered double counted.

Accordingly, this concentration is expressly closed to majors and additional majors in computational biology.

CS and AI majors completing this concentration are encouraged to double-count 10-315 as well as 02-261 as their lab science course. Suggested prerequisites 03-121 and 02-251 also count as requirements for these degrees (as a Science & Engineering course and CS Domains course, respectively).

Advising and Management

The day-to-day management of this concentration (including declaration of the concentration, exception requests, overseeing student audits, advising, etc.) is handled by Phillip Compeau, Assistant Department Head for Education in the Computational Biology Department. Administrative support for the concentration is provided by Samantha Mudrinich. Curricular organization and annual review will be managed by the Computational Biology Undergraduate Review Committee.

SCS students interested in this concentration should set up an appointment with Phillip Compeau for a brief interview.

Computer Systems Concentration

This concentration is available to SCS students only.

Brian Railing, *Concentration Director and Advisor*
Location: GHC 6005

The goal of the Computer Systems concentration is to give students a broad background in the practical understanding of designing and building systems. Students who complete this concentration are expected to be able to both pursue topics at the Ph.D. level at top programs, as well as industry work, either applying these concepts or directly working within the areas of kernel development, compiler improvements, designing distributed systems, et cetera.

The concentration is designed to be flexible in covering the wide area of systems topics. Two courses from the Computer Science major's "systems" constrained elective are required (List A below). The other courses come from a larger list of related courses (List B below). A limited amount of research credit can count toward the requirements.

Typically, systems courses include three aspects:

- A systems course educates students about how a class of computer systems works, both at a conceptual level and in practice. This includes the study of concrete problems faced in building a particular class of systems and successful solutions to these problems.
- Systems courses address how properties of modern hardware (e.g., processors, net- works, storage hierarchies) influence the design and implementation of a class of soft- ware systems. This typically includes reasoning about concurrency, and understanding and measuring performance.
- To solidify the key systems organization principles, there is a significant project/system implementation aspect to the course, both to reinforce understanding of how these systems work, and to learn system building skills (i.e., not just programming, but also design, debugging, testing, etc.). The size of the programming tasks is course dependent, but a significant fraction of the course grade (e.g., at least 40%) is derived from project work.

Learning Objectives

Students completing this concentration will be able to demonstrate the following skills and learning:

- Students will be able to design, develop and deploy large computer systems and justify their design decisions.
- Students will synthesize the interaction and tradeoffs between different layers and components in computer systems.
- Students will demonstrate debugging expertise on complex and diverse bugs and issues during software development.
- Students will recognize diverse granularities of parallelism, apply them toward solving problems, and implement solutions that achieve correct execution while accounting for reliability, fault tolerance, performance, security, and scalability.

Prerequisites

All students will start the concentration after having finished 15-213 Introduction to Computer Systems (or its cross-listed equivalents) with a C or better, as 15-213 is a prerequisite either directly or indirectly for all courses in the concentration.

Course Requirements

The curriculum will consist of at least four courses: two courses from List A and at least two elective courses from List B. The courses taken from list A and B must sum to at least 51 units, where each course must be passed with a C or better. The courses in List A will follow the Systems constrained elective list as part of the degree requirements for a B.S. in Computer Science. The elective courses on List B may vary from year to year, with a plan to review these requirements every three years.

List A (select two):

15-410	Operating System Design and Implementation	15
15-411	Compiler Design	15
15-418	Parallel Computer Architecture and Programming	12
15-440	Distributed Systems	12
15-441	Computer Networks	12
15-445	Database Systems	12

List B (select at least two):

Anything from List A, plus...		
15-319	Cloud Computing	12
15-330	Introduction to Computer Security	12
15-348	Embedded Systems	9
15-412	Operating System Practicum	Var.
15-415	Database Applications	12
17-422	Building User-Focused Sensing Systems	12
18-341	Logic Design and Verification	12
18-349	Introduction to Embedded Systems	12
18-447	Introduction to Computer Architecture	12
Special permission required for:		
15-719	Advanced Cloud Computing	12
Other graduate-level courses in CSD as approved by the concentration director		

Students can also apply a senior thesis (or other significant research for credit) in a topic related to Systems, as approved by the concentration advisor, as one of the elective courses for List B. Any significant research credit will include an identifiable output, such as paper or technical report. Any research course counts for at most 12 units, and can be done once.

Double Counting

The concentration will require that 3 courses (at least 27 units) are not double counted with any other requirements of any major, minor, or other concentration.

Advising and Management

The courses on the list of electives will be reviewed yearly by the concentration advisor through consultation with the Systems group (to help evaluate the relevance of the courses) and the Assistant Dean for undergraduate studies (to help flag any logistical issues). Any special requests by a student for counting a course outside of the list will go to the concentration advisor. The concentration advisor will also approve any research units.

Students interested in this concentration should set up an initial advising consultation with Brian Railing.

Human-Computer Interaction Concentration

This concentration is available to SCS students only.

Vincent Aleven, *Concentration Coordinator*
Location: Newell-Simon Hall 3531

Andrea Gnessin, *Concentration Manager*
Location: Newell-Simon Hall 3607

In this concentration, students learn techniques, processes, principles, and theory of Human-Computer Interaction (HCI). This interdisciplinary field aims at understanding how interactions with digital technologies and services can augment what humans do. It also aims at understanding what design, prototyping, and evaluation processes lead to innovative digital technologies and services that fulfill human needs. The concentration enhances what is learned in the SCS majors by addressing how digital products and services can be designed and evaluated so they benefit individuals, small groups, organizations, larger networks, and societies. It is synergistic with SCS majors in that envisioning, designing, and implementing innovative digital interactions benefit from superior technical skill. The concentration consists of 5 courses (2 required courses and 3 electives).

The concentration helps prepare students for jobs as technically-skilled specialists in design and development of interactive systems. The concentration will give students a broader perspective on how technologies impact humans, which may help them move faster into product management positions. It also lays a foundation for graduate study in the field of Human-Computer Interaction.

Learning Objectives

Students will learn skills and methods for:

- Eliciting and understanding human objectives, preferences, and needs through qualitative and quantitative methods for data collection and analysis
- Generating and imagining possible solutions and design concepts that involve human/technology partnerships
- Basic visual design, including typography, grids, color and the use of images
- Design of interactive systems, experiences, and technologies
- Developing and evaluating interactive prototypes as a way of iteratively refining designs
- Evaluating interactive technologies to assess and improve their functioning through data-driven redesign, including discount and empirical evaluation methods

Students will also learn knowledge about

- Digital technologies, including, possibly, web and mobile platforms, conversational technologies, wearable computing, gadgets, digital fabrication, virtual reality and mixed reality

- Human psychology, regarding individuals, groups, organizations, societies, and cultures, as it relates to interactions with digital products and services

Prerequisites

For this concentration, students should have completed the following courses prior to starting the concentration:

15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10

Course Requirements

Students in an SCS major wanting to complete a concentration in HCI must complete 5 courses, namely, 2 required courses and 3 electives. The student will be required to get a grade of “C” or better in each course in order for it to count as part of the concentration.

Required courses (2 courses)

05-391	Designing Human Centered Software	12
05-392	Interaction Design Overview	9

Electives (3 courses)

1. At least one of the electives must have strong technical content and must be selected from the following list:

05-434	Machine Learning in Practice	12
05-499	Special Topics in HCI	12
05-839	Interactive Data Science	12
10-315	Introduction to Machine Learning (Undergrad)	12
11-411	Natural Language Processing	12
15-237	Special Topic: Cross-Platform Mobile Web Apps	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-365	Experimental Animation	12
15-388	Practical Data Science	9
15-462	Computer Graphics	12
15-464	Technical Animation	12
15-466	Computer Game Programming	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-467	Human Robot Interaction	12
17-422	Building User-Focused Sensing Systems	12
17-428	Machine Learning and Sensing	12
17-437	Web Application Development	12
17-537	Artificial Intelligence Methods for Social Good	9
Other courses as approved by the concentration director		

2. At least one of the electives must have strong design content and must be selected from the following list:

05-317	Design of Artificial Intelligence Products	12
05-418	Design Educational Games	12
05-452	Service Design	12
05-499	Special Topics in HCI (Game Design Studio)	12
15-465	Animation Art and Technology	12
51-327	Design Center: Introduction to Web Design	9

3. The remaining elective must be a course in HCI offered by the Human-Computer Interaction Institute, meaning it has a 05 number, and is included in the pre-approved list of electives maintained on the HCII website.

Students interested in doing research or project work in the field of Human-Computer Interaction can do an independent study with an HCII faculty member. The independent study (05-589) will count as an elective for the HCI concentration.

Double Counting

At most 2 courses can be double counted with any major, minor or other concentration being pursued by the student.

Advising and Management

Management will fall on the HCII Undergraduate Program Director and the HCII Undergraduate Program Manager. The requirements for the courses will be reviewed annually by the HCII Curriculum Committee, in consultation with the URC.

Students in the HCI concentration will be advised by the HCII Undergraduate Program Director and/or the HCII Undergraduate Program Manager, who also oversee and direct the HCI second major and the HCI minor. They will meet once a semester will each student in the concentration.

SCS Students interested in this concentration should contact the program director for an initial advising consultation.

Machine Learning Concentration

This concentration is available to SCS students only.

Matt Gormley, *Concentration Director/Advisor*
Location: GHC 8103

Dorothy Holland-Minkley, *Concentration Coordinator*
Location: GHC 8008

ml-concentration@cs.cmu.edu

Machine learning and statistical methods are increasingly used in many application areas including natural language processing, speech, vision, robotics, and computational biology. The Concentration in Machine Learning allows undergraduates to learn about the core principles of this field. The Concentration requires five courses (two core courses and three electives) from the School of Computer Science (SCS) and the Department of Statistics & Data Science. The electives primarily focus on core machine learning skills that could be broadly applicable to either industry or graduate work. A CS Senior Honors Thesis or two semesters of Senior Research may be used to satisfy part of the electives requirement, which could provide excellent research experience for students interested in pursuing a PhD.

Learning Objectives

Upon completion of this concentration, students should be able to:

- Formulate real-world problems involving data such that they can be solved by machine learning
- Implement and analyze existing learning algorithms
- Employ probability, statistics, calculus, linear algebra, and optimization in order to develop new predictive models or learning methods
- Select and apply an appropriate supervised learning algorithm for problems of different kinds, including classification, regression, structured prediction, clustering, and representation learning
- Describe the the formal properties of models and algorithms for learning and explain the practical implications of those results
- Compare and contrast different paradigms for learning

Prerequisites

The following courses are expected to be completed before the Core courses in the ML Concentration:

Computer Science:		
15-122	Principles of Imperative Computation	10
Calculus:		
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
Probability and Statistics:		
36-218	Probability Theory for Computer Scientists	9
or 36-225	Introduction to Probability Theory	
or 15-259	Probability and Computing	
or 21-325	Probability	
36-226	Introduction to Statistical Inference	9
or 36-326	Mathematical Statistics (Honors)	
(Students with a B or higher in 36-218 do not need to take 36-226 or 36-326)		

Course Requirements

The ML Concentration requires that students complete two core courses and their choice of three elective courses of at least 9 units each. The electives can be through a combination of coursework in Machine Learning and optionally senior research.

Core Courses (24 units):

Students must take two core courses:

10-315	Introduction to Machine Learning (Undergrad)	12
Plus one of:		
10-403	Deep Reinforcement Learning & Control	12
10-405	Machine Learning with Large Datasets (Undergraduate)	12
10-417	Intermediate Deep Learning	12
10-418	Machine Learning for Structured Data	12

Electives (minimum 33 units):

Students need to take three courses from the following list. Students may substitute one of these courses with one semester of an SCS Senior Honors Thesis or equivalent senior research credit.

10-403	Deep Reinforcement Learning & Control	12
10-405	Machine Learning with Large Datasets (Undergraduate)	12
or 10-745	Scalability in Machine Learning	
10-417	Intermediate Deep Learning	12
or 11-485	Introduction to Deep Learning	
or 10-707	Topics in Deep Learning	
10-418	Machine Learning for Structured Data	12
or 10-708	Probabilistic Graphical Models	
10-716	Advanced Machine Learning: Theory and Methods	12
10-725	Convex Optimization	12
36-401	Modern Regression	9

Important Notes:

- To avoid excessive overlap in covered material, at most one of the core Deep Learning courses may be used to fulfill concentration course requirements: 10-417, 10-617, 11-485, 10-707. In general, students are discouraged from taking more than one of these.
- 15-281 Artificial Intelligence: Representation and Problem Solving covers several topics (i.e. reinforcement learning and Bayesian networks) that are complementary to 10-315. While not part of the ML Concentration curriculum, this course is also one to consider.
- Students should note that some of these elective courses (those at the 600-level and higher) are primarily aimed at graduate students, and so should make sure that they are adequately prepared for them before enrolling. Graduate-level cross-listings of these courses can also be used for the ML Concentration, if the student is adequately prepared for the more advanced version and the home department approves the student's registration.
- Please be aware that not all graduate-level courses in the Machine Learning Department may be used as electives. In particular, 10-606/10-607 Computational Foundations for Machine Learning may not be used as electives for the Machine Learning Concentration.

CS Senior Honors Thesis

The CS Senior Honors Thesis consists of 36 units of academic credit for this work. Up to 12 units may be counted towards the ML Concentration. Students must consult with the Computer Science Department for information about the CS Senior Honors Thesis. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

Senior Research

Senior Research consists of 2 semesters of 10-500 Senior Research Project, totaling 24 units. Up to 12 units may be counted towards the ML Concentration. The research must be a year-long senior project, supervised or co-supervised by a Machine Learning Core Faculty member. It is almost always conducted as two semester-long projects, and must be done in senior year. Some samples of available Machine Learning Senior Projects are available on the Machine Learning Department webpage. Interested students should contact the faculty they wish to advise them to discuss the research project, before the semester in which research will take place. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration. The student will present the work and submit a year-end write-up to the Concentration Director at the end of Senior year.

Double Counting

At least 3 courses (each being at least 9 units) must be used for only the Machine Learning Concentration, not for any other major, minor, or concentration. (These double counting restrictions apply specifically to the Core Courses and the Electives. Prerequisites may be counted towards other majors, minors, and concentrations and do not count towards the 3 courses that must be used for only the Machine Learning Concentration.)

Advising and Management

The ML Concentration Director will hold advising office hours leading up to registration week each semester. In addition, the ML Concentration Program Coordinator will hold regular office hours to address general questions. All office hours will be detailed on the ML Concentration website.

SCS Students interested in pursuing this concentration should contact Matt Gormley for an initial advising consultation.

Principles of Programming Languages Concentration

This concentration is available to SCS students only.

Robert Harper, *Concentration Director and Advisor*
Location: GHC 9229

Programming languages play a central role in computer science. All programs are written in a language, and it is obvious that some are better than others, at least for some purposes. The constant demand for new languages reflects the changing demands for constructing reliable and maintainable software systems. Academic research in programming language principles has led to numerous advances in language design, language implementation, and program verification intended to meet these changing expectations through the development of a rigorous theory of programming languages.

Carnegie Mellon is a recognized leader in programming languages, characterized by a strong emphasis on the centrality of type theory, a consolidation of ideas in mathematical semantics, programming logics, and programming language design and implementation. The purpose of the PoPL concentration is to teach the comprehensive view of the field that has been developed here over many decades. Type theory teaches how to define a language, and how to show that it is well-defined, free of internal contradictions. It teaches the mathematical foundations for abstraction and modularity, concepts that are fundamental to building maintainable systems. It teaches how to use a rigorous language definition as the basis for building a compiler that correctly implements the definition, and provides the tools necessary to achieve it. It teaches the logical foundations of program development, how to precisely specify the intended behavior of a program, and how to use machine tools to verify that a program meets those expectations. It gives precise meaning to language concepts, relating them to one another, and distinguishing concepts that are often confused or conflated. It teaches how to specify and verify the resource usage of a program (such as its sequential and parallel time and space complexity) without resorting to a model of how it is implemented on a machine; it supports using actual code, rather than pseudo-code, for defining and analyzing algorithms.

The PoPL concentration is of value to a broad range of students. For the practically minded it will provide the foundation for structuring and validating programs, using type systems or more advanced forms of specification. For the theoretically minded it will provide the foundation for understanding the close relationship between specification and programs on one hand and mathematical conjecture and proof on the other. The elegance of the PoPL lies in their unification of these two perspectives: the theory applies directly to the practice, and the practice informs the theory.

Learning Objectives

The PoPL concentration is characterized by a collection of learning outcomes that it seeks to achieve. These may be summarized by the knowledge that students may expect to gain by concentrating in the area. By their choice of electives each student will choose an emphasis within the area; the required courses ensure that this includes at least the first five objectives:

- Specify the concrete and abstract syntax of a programming language, including a precise specification of the binding and scope of declarations.
- Define the static semantics (compile-time constraints) of a programming language using typing judgments, and how to state and prove that it properly defined.
- Define the dynamics semantics (run-time behavior) of a language using operational and denotational methods.
- Verify rigorously that the statics and dynamics of a language are coherent, a property commonly called type safety.
- Understand the propositions-as-types principle, which relates programs to proofs and specifications to theorems, and know how to apply it in language design and program verification.

- Formulate type and assertion languages for specifying the behavior of a program, and how to verify that a program satisfies such a specification.
- Specify the cost (sequential and parallel time and space complexity) for a program written in a precisely defined language, and how to verify that a given program meets stated cost bounds.
- Use software tools to verify both the properties of languages and the specifications of programs written in well-defined languages.
- Use the static and dynamic semantics of a language to derive a compiler for it that complies with these definitions, and how to use types and verification tools to ensure compiler correctness.
- Relate a language definition to its implementation, both in terms of the run-time structures required, but also to validate abstract cost measures in an implementation.

Prerequisites

This concentration requires students to complete the following courses before the concentration can be completed:

15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
15-151	Mathematical Foundations for Computer Science	10
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Course Requirements

This concentration requires two courses along with two additional electives.

Required Courses (complete all of the following):

15-312	Foundations of Programming Languages	12
15-317	Constructive Logic	9

Electives (complete two of the following):

15-314	Programming Language Semantics	12
15-316	Software Foundations of Security and Privacy	9
15-414	Bug Catching: Automated Program Verification	9
15-417	HOT Compilation	12
15-424	Logical Foundations of Cyber-Physical Systems	12
Any graduate-level Programming Languages course(s), with prior permission of the concentration advisor and the course instructor(s).		

Students may use one semester of a senior thesis supervised by a member of the Principles of Programming faculty in the Computer Science Department as a replacement for one of the two electives.

Transfer of credit for courses taken outside of Carnegie Mellon University toward this concentration will not be allowed.

Double Counting

Either 15-312 or 15-317 (but not both) may be double counted towards any major, minor or other concentration being pursued by the student. No other double counting is permitted.

Advising and Management

Participation in this concentration is supervised by the concentration coordinator in cooperation with the students academic advisor, course instructors, and, as appropriate, thesis supervisor. The current coordinator is Robert Harper. Content for this concentration will be reviewed yearly by the Principles of Programming faculty in the Computer Science Department.

Students interested in pursuing this concentration should contact Robert Harper for an initial advising consultation.

Robotics Concentration

This concentration is available to SCS students only.

Howie Choset, *Concentration Director/Advisor*
Location: NSH 3205

Barbara ("B.J.") Fecich, *Concentration Administrator*
Location: NSH 4121

The SCS Robotics Concentration provides an opportunity for SCS undergraduate students at Carnegie Mellon to learn the principles and practices of robotics through theoretical studies and hands-on experience with robots. Students initially learn the basics of robotics in an introductory robotics overview course. Additional required courses teach control systems and robotic kinematics. Students also choose from a wide selection of electives in mobile systems, machine learning, computer vision, cognition and cognitive science, or computer graphics. Students have a unique opportunity to undertake independent research projects, working under the guidance of Robotics Institute faculty members; this provides an excellent introduction to robotics practice, for those considering industry and research for those considering graduate studies.

Learning Objectives

Students completing this concentration will be able to demonstrate the following skills and learning:

- construct robots which are driven by a microcontroller through several projects, with each project reinforcing the basic principles of: vision, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensing
- apply feedback control theory to the development of robotic systems, including the principles of classical linear control theory, linear state-space methods, nonlinear systems theory, and elementary control using computer learning techniques
- program a robot arm using the principles of kinematics and dynamics: transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and the basic equations of motion
- apply related fields of computing to the construction and testing of robotic solutions: machine learning, AI, graphics and computer vision, cognitive science and learning models, cyber-physical and embedded systems
- work effectively in a team include computer and mechanical engineers to solve challenging robotics problems

Prerequisites

The following courses are expected to be completed before the Core courses in the Robotics Concentration:

CS background:		
15-122	Principles of Imperative Computation	10
15-213	Introduction to Computer Systems	12
One year of calculus:		
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
Matrix Algebra (one of the following):		
21-241	Matrices and Linear Transformations	10
21-242	Matrix Theory	10
Probability (one of the following):		
15-259	Probability and Computing	12
21-325	Probability	9
36-218	Probability Theory for Computer Scientists	9
36-225	Introduction to Probability Theory	9

The probability course can be taken concurrently with the concentration requirements. Depending on specific electives chosen, additional prerequisites may be required (e.g. 21-259).

Course Requirements

The Robotics Concentration requires that students complete three core courses and their choice of two elective courses of at least 9 units each. The electives can be chosen from a specific set of stand-alone courses. Students can opt to do an undergraduate research project as one of their electives.

Required core courses (36 units)

16-311	Introduction to Robotics	12
plus the following two courses:		
16-299	Introduction to Feedback Control Systems	12
16-384	Robot Kinematics and Dynamics	12

Electives (minimum 18 units)

Students must complete 2 electives from the following list of courses for a minimum of 18 units. At least one of the two electives courses must be from the Robotics Institute (16-xxx). A maximum of 12 units of research (16-597) can be used toward this requirement.

16-264	Humanoids	12
16-362	Mobile Robot Algorithms Laboratory	12
16-385	Computer Vision	12
16-421	Vision Sensors	12
16-423	Designing Computer Vision Apps	12
16-597	Undergraduate Reading and Research	Var.
10-315	Introduction to Machine Learning (Undergrad)	12
11-344	Machine Learning in Practice	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-348	Embedded Systems	9
15-424	Logical Foundations of Cyber-Physical Systems	12
15-462	Computer Graphics	12
15-463	Computational Photography	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
85-370	Perception	9
85-395	Applications of Cognitive Science	9
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-426	Learning in Humans and Machines	9

Note: Graduate level Robotics courses may be used to meet the elective requirement with permission from the Concentration Advisor. Graduate level Mechanical Engineering and Electrical and Computer Engineering courses that are relevant to robotics may be used to meet the elective requirement with permission from the Concentration Advisor.

Double Counting

Courses being used to satisfy the requirements for the Robotics Concentration may not be counted towards another minor or concentration. A minimum of 27 units must be completed that is not double counted with any other program. This allows a maximum of 2 courses that can double count with other programs.

Advising and Management

The Robotics Concentration will always have a Robotics faculty member as its Advisor. There will also be a Robotics Concentration Administrator who will track progress for any SCS student pursuing this concentration. Curriculum changes will be discussed with the Robotics Institute faculty and SCS academic deans.

Students interested in this concentration should set up an initial advising consultation with Howie Choset to assess interest and preparation.

Security & Privacy Concentration (SCS)

This concentration is available to SCS students only.
(ECE students should consult their department for an equivalent concentration.)

Lujo Bauer, *Concentration Director and Advisor*
Location: CIC 2203

In a world where data breaches and cyber-attacks are ever-present, the need for technologists who have a solid understanding of the principles that underlie strong security and privacy practices is greater than ever.

The Security & Privacy concentration is designed to expose students to the key facets of and concerns about computer security and privacy that drive practice, research, and legislation. On completing the curriculum, students will be well prepared to continue developing their interests in security or privacy through graduate study; to take jobs in security or privacy that will provide further training in applicable areas; and to be informed participants in public and other processes that shape how organizations and society develop to meet new challenges related to computer security or privacy.

Learning Objectives

After completing this concentration, students should:

- Understand how to reason about the adversary in computer systems.
- Be familiar with common security vulnerabilities, from buffer overflows and return oriented programming to cross-site scripting, and widely deployed defenses against these vulnerabilities.
- Be familiar with and understand how to apply the basic concepts in cryptography and secure system design and analysis.
- Understand the key properties of commonly used cryptographic primitives and properties commonly desired of cryptographic protocols.
- Be familiar with current and upcoming research directions in secure system design, software analysis, and cryptography.
- Be familiar with the breadth of concerns and topics relevant to computer security and privacy, ranging from technical topics to ethics, regulation, usability, and economics.
- Be familiar with the key concepts in privacy, ranging from conceptions of privacy to privacy algorithms to regulation and policy.
- Gain a more in-depth understanding of one “context” area: usable security and privacy, or policy.

Prerequisites

Students interested in pursuing this concentration should have the following courses completed before starting the concentration:

15-151	Mathematical Foundations for Computer Science	10
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Curriculum

A distinguishing feature of this field is the ubiquitous need to consider an adversary, and the resulting interplay between attack and defense that routinely advances both theory and practice. In order to understand widely-deployed defensive techniques and secure-by-design approaches, students must also understand the attacks that motivate them and the “adversarial mindset” that leads to new forms of attack. The curriculum is designed around this principle

Students in the Security & Privacy concentration will take courses that cover the basic principles *(Introduction and Basics Course Area)*, the underlying theory *(Theoretical Foundations Course Area)*, and the practical application *(System Design Course Area)* of security and privacy. Additionally, they will be required to select a course which covers either usability or policy *(Context Course Area)*. Finally, students will have the opportunity to dive deep on a particular security & privacy topic by completing an elective of their choosing *(Depth Course Area)*.

Requirements (5 courses, minimum 48 units):

Introduction/Portal Entry course		Units
15-330	Introduction to Computer Security	12

Theoretical Foundations course (choose one option):		Units
15-356	Introduction to Cryptography	12
Other graduate-level courses as approved by the concentration director		

System Design course (choose one):		Units
15-316	Software Foundations of Security and Privacy	9
18-335	Secure Software Systems	12

Usability or Policy course (select one):		Units
17-334	Usable Privacy and Security	9
or one of:		
17-333	Privacy Policy, Law, and Technology	9
Other graduate-level courses as approved by the concentration director		

Depth course (complete one option below):	Units
Complete an elective course or at least 9 units of independent study in the security or privacy area. Consult with the concentration coordinator for elective options.	9
Complete five, rather than four, courses from the list above to satisfy the requirements described above (this might be achieved by taking both a policy and a usability course, or taking the two-course foundations alternative).	9-12

Anti-requisites

When two (or more) courses overlap significantly in the material they cover, only one can count toward the security and privacy concentration. An example pair is 15-316 Software Foundations of Security and Privacy and 18-335 Secure Software Systems. Other such anti-requisites may occur; please consult the concentration director when scheduling courses.

Excluded Courses

Some security and privacy courses may not be counted towards concentration requirements. These courses all serve specific important different purposes, but do not fit into the concentration as currently designed. For example, 17-331 is more suitable for students who are interested in a broader single-course introduction to information security, but has too much overlap with the concentration's required intro course to be able to count toward the concentration. For other excluded courses, please consult the concentration director.

Double Counting

Only two of the courses that are counted toward concentration requirements can also be counted towards core course requirements of other majors and minors being pursued by the student.

Advising and Management

The concentration is open to all undergraduates in the School of Computer Science. There is no formal admissions process. Students intending to pursue the concentration should contact the concentration coordinator to register their intention. Curriculum for the concentration will be reviewed by the coordinator annually in consultation with faculty in supporting departments.

Software Engineering Concentration

This concentration is available to SCS students only.

Michael Hilton, *Concentration Director and Advisor*
Location: Wean Hall 5122

Effectively building modern software systems at scale requires not just programming skills, but also engineering skills. These skills include the ability to interact effectively with customers to gather the requirements for a system in a precise way; to develop a design that resolves competing quality attributes; to make tradeoffs among schedule, cost, features, and quality to maximize value to stakeholders; to work effectively with other engineers; and to assure the quality of the delivered software system. We hear regularly from industry that these skills are crucial to them, and that they are interested in students with a strong software engineering background.

Learning Objectives

The software engineering concentration is designed to teach the fundamental tools, techniques, and processes of software engineering. Through internships and a mentored project experience, students gain an understanding of the issues of scale and complexity that motivate software engineering tools and techniques. The core curriculum includes material both on engineering the software product and on the process, teamwork, and management skills that are essential to successful engineering. Graduates of the program should have the technical, process, and teamwork skills to be immediately productive in a mature engineering organization.

Prerequisites

SCS students should have completed the following courses before completing this concentration:

15-122	Principles of Imperative Computation	10
15-151	Mathematical Foundations for Computer Science	10
15-213	Introduction to Computer Systems	12

In addition, students must ensure they have larger-scale software development experience which can be gained by taking the following course:

17-214	Principles of Software Construction: Objects, Design, and Concurrency	12

Students can have the 17-214 prerequisite waived by the director if the student can show significant development experience.

Course Requirements

Overall, the concentration requires five (5) courses and an internship. One of the five courses consists of a 6-credit course that serves as a writing workshop in which the student reflects upon and integrates the lessons of the internship.

Required Courses (complete all of the following):

17-313	Foundations of Software Engineering	12
17-413	Software Engineering Practicum	12

Electives (complete one from each category):

A domain-independent course focused on technical software engineering material:

15-414	Bug Catching: Automated Program Verification	9
17-355	Program Analysis	12
17-356	Software Engineering for Startups	12
17-615	Software Process Definition	9
17-651	Models of Software Systems	12
17-652	Methods: Deciding What to Design	12
17-653	Managing Software Development	12
17-654	Analysis of Software Artifacts	12
17-655	Architectures for Software Systems	12
Other courses, with prior approval from the Director of the Software Engineering Program.		

A course that explores computer science problems related to existing and emerging technologies and their associated social, political, legal, business, and organizational contexts:

15-390	Entrepreneurship for Computer Science	9
17-200	Ethics and Policy Issues in Computing	9
17-331	Information Security, Privacy, and Policy	12
17-333	Privacy Policy, Law, and Technology	9
17-334	Usable Privacy and Security	9
17-562	Law of Computer Technology	9
17-781	Mobile and IoT Computing Services	12
17-801	Dynamic Network Analysis	12
17-821	Computational Modeling of Complex Socio-Technical Systems	12
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
70-311	Organizational Behavior	9
70-415	Introduction to Entrepreneurship	9
70-421	Entrepreneurship for Computer Scientists	9
70-471	Supply Chain Management	9

Internship and Reflection

The concentration requires a software engineering internship of a minimum of 8 full-time weeks in an industrial setting (i.e., integrated into a team and exposed to industry pressures). The student may work in development, management, quality assurance, or other relevant positions. Students should confirm with the director that an internship is appropriate, but internships that fulfill the criteria will be accepted after the fact. Students must further complete:

17-415	Software Engineering Reflection	6

Double Counting

No more than two of the courses used to fulfill the concentration requirements may be counted towards any other degree or concentration. This rule does not apply to 17-214 (a prerequisite for the concentration) or courses counted for general education requirements.

Advising and Management

The concentration coordinator, Michael Hilton, is responsible for academic advising, handling exceptions and updating the curriculum each year, in consultation with faculty in the Institute for Software Research.

Students who are interested in pursuing this concentration should contact Michael Hilton for an initial advising consultation.

School of Computer Science Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

Institute for Software Research Courses

08-200 Ethics and Policy Issues in Computing
Spring: 9 units
In this course, students will study the social impacts of computing technology and systems. The course will provide a brief introduction to ethics and to the new and difficult ethical questions modern computing technology presents us with. It will focus on a number of areas in which computers and information technology are having an impact on society including data privacy, social media, and autonomous technologies.

08-722 Data Structures for Application Programmers
Fall and Spring: 6 units
This course is an introduction to Data Structures and a few fundamental algorithms for students with some prior programming experience (functions, loops and arrays mainly in Java). It covers the conceptual and implementation views of some common data structures and algorithms. It also goes over the Java Collections (such as List, ArrayList, LinkedList, Set, HashSet, TreeSet, Map, HashMap, TreeMap, PriorityQueue) to solidify the understanding of the data structures. There is an introduction to the analysis of algorithms that operate on them. Following learning-by-doing methodology, there will be many repetitions of writing code and reviews of the items covered in lectures. Students are required to be familiar with Java Programming before taking this course. Those who are not are encouraged to take 08-671 in mini 1 before taking this course. Students are required to have a reasonably modern laptop computer on which install the Java software used for this course.

SCS Interdisciplinary Courses

07-128 Freshman Immigration Course
Fall: 1 unit
The Freshman Immigration Course is taken by first-semester Computer Science majors on the Pittsburgh campus. The course is designed to acquaint incoming majors with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS Freshmen ONLY.

07-129 Freshmen Immigration Course
All Semesters: 3 units
The Freshman Immigration Course is taken by first-semester Computer Science majors on the Doha campus. The course is designed to acquaint incoming majors with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS Freshmen ONLY.

07-131 Great Practical Ideas for Computer Scientists
Fall: 2 units
THIS COURSE IS OPEN TO CS FIRST YEAR ONLY. Throughout your education as a Computer Scientist at Carnegie Mellon, you will take courses on programming, theoretical ideas, logic, systems, etc. As you progress, you will be expected to pick up the so-called "tools of the trade." This course is intended to help you learn what you need to know in a friendly, low-stress, high-support way. We will discuss UNIX, LaTeX, debugging and many other essential tools. Laptop required. (Laptops will be available for those without their own laptops.)

07-180 Concepts in Artificial Intelligence
Spring: 5 units
The course will introduce students to the main foundational concepts and techniques used in Artificial Intelligence (AI), including heuristic search, machine learning, automated decision making, and interaction with the physical world. The course will present a range of real-world applications in which AI is currently used. Students will be introduced to the history of AI, as well as the potential future of a world in which AI is commonplace. Programming-based assignments will enable students to get a feel for AI techniques.
Prerequisites: 15-122 or 15-112

Course Website: https://canvas.cmu.edu/courses/8266

07-599 SCS Honors Undergraduate Research Thesis
Fall and Spring
Available only to students registered in the CS Senior Research Thesis Program.

SCS: Computational Biology Courses

02-201 Programming for Scientists
Fall and Spring: 10 units
Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required. Course not open to CS majors.

02-223 Personalized Medicine: Understanding Your Own Genome
Fall: 9 units
Do you want to know how to discover the tendencies hidden in your genome? Since the first draft of a human genome sequence became available at the start of this century, the cost of genome sequencing has decreased dramatically. Personal genome sequencing will likely become a routine part of medical exams for patients for prognostic and diagnostic purposes. Personal genome information will also play an increasing role in lifestyle choices, as people take into account their own genetic tendencies. Commercial services such as 23andMe have already taken first steps in this direction. Computational methods for mining large-scale genome data are being developed to unravel the genetic basis of diseases and assist doctors in clinics. This course introduces students to biological, computational, and ethical issues concerning use of personal genome information in health maintenance, medical practice, biomedical research, and policymaking. We focus on practical issues, using individual genome sequences (such as that of Nobel prize winner James Watson) and other population-level genome data. Without requiring any background in biology or CS, we begin with an overview of topics from genetics, molecular biology, stats, and machine learning relevant to the modern personal genome era. We then cover scientific issues such as how to discover your genetic ancestry and how to learn from genomes about migration and evolution of human populations. We discuss medical aspects such as how to predict whether you will develop diseases such as diabetes based on your own genome, how to discover disease-causing genetic mutations, and how genetic information can be used to recommend clinical treatments.

02-250 Introduction to Computational Biology
Spring: 12 units
This 12-unit class provides a general introduction to computational tools for biology. The course is divided into two modules. Module 1 covers computational molecular biology/genomics. It examines important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research. In the process, it covers basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. Module 2 covers computational cell biology, including biological modeling and image analysis. It includes homework assignments requiring modification of scripts to perform computational analyses. The modeling component includes computer models of population dynamics, biochemical kinetics, cell pathways, neuron behavior, and stochastic simulations. The imaging component includes basics of machine vision, morphological image analysis, image classification and image-derived models. Lectures and examinations are joint with 03-250, but recitations are separate. Recitations for this course are intended primarily for computational biology majors as well as computer science, statistics or engineering majors at the undergraduate or graduate level who have had significant prior experience with computer science or programming. Students may not take both 02-250 and 03-250 for credit.
Prerequisites: (02-201 or 15-110 or 15-112) and (03-151 or 03-121) and 21-122

02-251 Great Ideas in Computational Biology
Spring: 12 units
This 12-unit course provides an introduction to many of the great ideas that have formed the foundation for the transformation of life sciences into a fully-fledged computational discipline. This gateway course is intended as a first exposure to computational biology for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded students who are interested in exploring the field. By completing this course, students will encounter a handful of fundamental algorithmic approaches deriving straight from very widely cited primary literature, much of which has been published in recent years. The course also introduces basic concepts in statistics, mathematics, and machine learning necessary to understand these approaches. Many of the ideas central to modern computational biology have resulted in widely used software that is applied to analyze (often very large) biological datasets; an important feature of the course is that students will be exposed to this software in the context of compelling biological problems.
Prerequisites: (15-112 or 02-201) and (15-151 or 21-127 or 21-128)

02-261 Quantitative Cell and Molecular Biology Laboratory
Fall and Spring
This is an introductory laboratory-based course designed to teach basic biological laboratory skills used in exploring the quantitative nature of biological systems and the reasoning required for performing research in computational biology. Over the course of the semester, students will design and perform multiple modern experiments and quantitatively analyze the results of these experiments. During this course students will also have an opportunity to use techniques learned during the course to experimentally answer an open question. Designing the experiments will require students to think critically about the biological context of the experiments as well as the necessary controls to ensure interpretable experimental results. During this course students will gain experience in many aspects of scientific research, including: sequencing DNA, designing and performing PCR for a variety of analyses, maintaining cell cultures, taking brightfield and fluorescent microscopy images, developing methods for automated analysis of cell images, communicating results to peers and colleagues. As space is limited, laboratory sections will be small. Additional sections will be added to accommodate all students on the waitlist. Course Outline: (1) 3-hour lab per week, (1) 1-hour lecture per week.

02-317 Algorithms in Nature
Intermittent: 9 units
Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. No prior biological knowledge required.
Prerequisites: 15-251 and 15-210

Course Website: http://www.algorithmsinnature.org

02-319 Genomics and Epigenetics of the Brain
Fall: 9 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in genomic technology are in the process of revolutionizing how we conduct molecular biology research. These new techniques have given us an appreciation for the role that epigenetics modifications of the genome play in gene regulation, development, and inheritance. In this course, we will cover the biological basis of genomics and epigenetics, the basic computational tools to analyze genomic data, and the application of those tools to neuroscience. Through programming assignments and reading primary literature, the material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: (03-151 or 03-121) and (03-220 or 03-221) and (15-112 or 15-110 or 02-201 or 15-121)

02-402 Computational Biology Seminar
Fall and Spring: 3 units
This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Students will be expected to digest what they have learned in the seminar by writing short summaries on each speaker's topic.

02-403 Special Topics in Bioinformatics and Computational Biology
Intermittent: 6 units
A decade ago, mass spectrometry (MS) was merely a qualitative research technique allowing the analysis of samples regarding the presence of specific biomolecules. However, as MS has turned quantitative, more sophisticated experiments can be performed, such as the recording of signal transduction kinetics and the analysis of the composition of protein complexes and organelles. This makes MS-based proteomics a powerful method to study spatiotemporal protein dynamics. The development of relative quantification approaches, which generally use 2H, 13C or 15N isotope labels, has especially led to an increase in quantification accuracy and set off numerous new experimental approaches to study protein regulation. In this mini-course, we will cover mass spectrometry principles, discuss classical as well as current primary literature addressing method development and quantitative analysis, and highlight state-of-the-art biological studies that employ MS. A combination of lectures, student presentations, and written exercises will establish a thorough knowledge of current bio-analytical MS approaches.
Prerequisites: (03-250 Min. grade C or 02-250 Min. grade C) and 03-121 Min. grade C

02-421 Algorithms for Computational Structural Biology
Intermittent: 12 units
Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-425 Computational Methods for Proteogenomics and Metabolomics
Spring: 9 units
Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.
Prerequisites: 02-250 or 02-604

02-450 Automation of Scientific Research
Spring: 9 units
Biology is increasingly becoming a "big data" science, as biomedical research has been revolutionized by automated methods for generating large amounts of data on diverse biological processes. Integration of data from many types of experiments is required to construct detailed, predictive models of cell, tissue or organism behaviors, and the complexity of the systems suggests that these models need to be constructed automatically. This requires iterative cycles of acquisition, analysis, modeling, and experimental design, since it is not feasible to do all possible biological experiments. This course will cover a range of automated biological research methods and a range of computational methods for automating the acquisition and interpretation of the data (especially active learning, proactive learning, compressed sensing and model structure learning). Grading will be based on class participation, homeworks, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of biology, statistics, and programming. Experience with Machine Learning is useful but not mandatory.
Prerequisites: (10-701 or 10-315) and 15-122

Course Website: https://sites.google.com/site/automationofbiologicalresearch/

02-499 Independent Study in Computational Biology
Fall and Spring
The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-500 Undergraduate Research in Computational Biology
Fall and Spring
This course is for undergraduate students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator who will enroll you in the course. 02-250 is a suggested pre-requisite.

02-510 Computational Genomics
Fall and Spring: 12 units
Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. In this course we will discuss classical approaches and latest methodological advances in the context of the following biological problems: 1) sequence analysis, focusing on gene finding and motifs detection, 2) analysis of high throughput molecular data, such as gene expression data, including normalization, clustering, pattern recognition and classification, 3) molecular and regulatory evolution, focusing on phylogenetic inference and regulatory network evolution, 4) population genetics, focusing on how genomes within a population evolve through recombination, mutation, and selection to create various structures in modern genomes and 5) systems biology, concerning how to combine diverse data types to make mechanistic inferences about biological processes. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course may be taken for 12 units, which requires completion of a course project, or for 9 units, which does not.
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C)

02-512 Computational Methods for Biological Modeling and Simulation
Fall: 9 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.
Prerequisites: 15-110 or 15-112 or 02-201

02-514 String Algorithms
Fall: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Burrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.
Prerequisite: 15-251

02-515 Advanced Topics in Computational Genomics
Spring: 12 units
Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for ciritiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-518 Computational Medicine
Fall: 12 units
Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.

Course Website: https://sites.google.com/site/computationalmedicinecmu/

02-530 Cell and Systems Modeling
Fall: 12 units
This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed.
Prerequisites: (03-151 or 33-121 or 03-121) and (03-232 or 03-231) and 21-112 and 09-105

02-601 Programming for Scientists
Fall and Spring: 12 units
Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed, and students will have the opportunity to design their own programming project on a scientific topic of their choice. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required. Course not open to CS majors.

Course Website: http://compeau.cbd.cmu.edu/programming-for-scientists/

02-602 Professional Issues for Computational and Automated Scientists
Fall and Spring: 3 units
This course gives Master's in Computational Biology and Master's in Automated Science students the opportunity to develop the professional skills necessary for a successful career in either academia or industry. This course, required in the first semester of both programs, will include assistance with elevator pitches, interview preparation, resume and cover letter writing, networking, and presentation skills. The course will also include opportunities to connect with computational biology professionals as part of industry outreach. The course will meet once a week and is pass/fail only.

02-604 Fundamentals of Bioinformatics
Spring: 12 units
How do we find potentially harmful mutations in your genome? How can we reconstruct the Tree of Life? How do we compare similar genes from different species? These are just three of the many central questions of modern biology that can only be answered using computational approaches. This 12-unit course will delve into some of the fundamental computational ideas used in biology and let students apply existing resources that are used in practice every day by thousands of biologists. The course offers an opportunity for students who possess an introductory programming background to become more experienced coders within a biological setting. As such, it presents a natural next course for students who have completed 02-601. 02-250 is a suggested pre-requisite for undergraduates.

02-605 Professional Issues in Automated Science
Fall
This course gives MS in Automated Science students an opportunity to develop professional skills necessary for a successful career in computational biology. This course will include assistance with resume writing, interview preparation, presentation skills, and job search techniques. This course will also include opportunities to network with computational biology professionals and academic researchers.

02-613 Algorithms and Advanced Data Structures
Fall and Spring: 12 units
The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. 02-250 is a suggested pre-requisite.

02-651 New Technologies and Future Markets
Fall: 12 units
This course focuses on technological trends and how these trends can help shape or disrupt new and existing markets. Students will learn to identify, analyze, and synthesize emerging trends and perform detailed research on how these trends can influence and create markets. By understand the drivers behind these trends students will be able to identify key market opportunity inflection points in biotechnology as well as the relationship between business processes and information technology (IT). Students will also learn to assess some information technologies and the potential of applying them to solve problems and create commercially viable solutions. The course is designed for the student interested in finding new venture opportunities on the cutting edge of technology and finding and evaluating the opportunities for further development. For MS Biotechnology Innovation and Computation students only.
Prerequisite: 11-695

02-654 Biotechnology Enterprise Development
Fall: 12 units
In this course students learn how to develop a biotech start-up, create a Minimum Viable Product (MVP), business model and strategy for the product. Students will learn about business modeling, customer development, customer validation, proposal, product branding, and marketing for their product. The course will require students to spend most time to validate their start up concept and prototypes with potential customers and adapt to critical feedback and revise their respective value propositions accordingly. Students learn to balance technical product development with customer requirements, business strategy and budget constraints. This course provides real world, hands-on learning on what it is like to start a company. Different business modeling will be covered. By understand customer discovery and validation concepts will aid students to effectively modify their original concepts to meet market demands. Student teams will learn how to revise, improve their prototype by the end of the term. This is a fast paced course in which students are expected to spend most of the time outside of the classroom to interact with potential customers to validate, test, verify, and integrate essentials elements for their start-up business proposal. Up to now, students have been learning some technologies and methods for solving problems in the life science industry and build a prototype for their start-up. However, a new venture proposal is not a collection of isolated bits. It should be thorough validated via customer's inputs and market needs to tell a single story of how the venture will reach its end goals. Final deliverable is creation and presentation of a well explicated, business proposal in addition to a product prototype corresponding to the business proposal.
Prerequisites: 02-651 and 11-695

02-680 Essential Mathematics and Statistics for Scientists
Fall: 9 units
This course is for first year master's students looking for a rigorous introduction to mathematics and statistics as preparation for more advanced coursework in computational courses. Closed to enrollment for undergraduates.

02-699 Independent Study in Computational Biology
Fall and Spring
The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-703 Special Topics in Bioinformatics and Computational Biology
Intermittent: 6 units
A decade ago, mass spectrometry (MS) was merely a qualitative research technique allowing the analysis of samples regarding the presence of specific biomolecules. However, as MS has turned quantitative, more sophisticated experiments can be performed, such as the recording of signal transduction kinetics and the analysis of the composition of protein complexes and organelles. This makes MS-based proteomics a powerful method to study spatiotemporal protein dynamics. The development of relative quantification approaches, which generally use 2H, 13C or 15N isotope labels, has especially led to an increase in quantification accuracy and set off numerous new experimental approaches to study protein regulation. In this mini-course, we will cover mass spectrometry principles, discuss classical as well as current primary literature addressing method development and quantitative analysis, and highlight state-of-the-art biological studies that employ MS. A combination of lectures, student presentations, and written exercises will establish a thorough knowledge of current bio-analytical MS approaches.

02-710 Computational Genomics
Spring: 12 units
Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. In this course we will discuss classical approaches and latest methodological advances in the context of the following biological problems: 1) sequence analysis, focusing on gene finding and motifs detection, 2) analysis of high throughput molecular data, such as gene expression data, including normalization, clustering, pattern recognition and classification, 3) molecular and regulatory evolution, focusing on phylogenetic inference and regulatory network evolution, 4) population genetics, focusing on how genomes within a population evolve through recombination, mutation, and selection to create various structures in modern genomes and 5) systems biology, concerning how to combine diverse data types to make mechanistic inferences about biological processes. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc.

02-711 Computational Molecular Biology and Genomics
Spring: 12 units
An advanced introduction to computational molecular biology, using an applied algorithms approach. The first part of the course will cover established algorithmic methods, including pairwise sequence alignment and dynamic programming, multiple sequence alignment, fast database search heuristics, hidden Markov models for molecular motifs and phylogeny reconstruction. The second part of the course will explore emerging computational problems driven by the newest genomic research. Course work includes four to six problem sets, one midterm and final exam.
Prerequisites: (03-151 or 03-121) and 15-122

02-712 Computational Methods for Biological Modeling and Simulation
Fall: 12 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.
Prerequisites: (15-112 or 15-110) and (02-613 or 02-201)

02-714 String Algorithms
Fall: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.
Prerequisite: 15-251

02-715 Advanced Topics in Computational Genomics
Spring: 12 units
Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for ciritiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-717 Algorithms in Nature
Fall: 12 units
Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. See also: www.algorithmsinnature.org no prior biological knowledge required.

02-718 Computational Medicine
Fall: 12 units
Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.
Prerequisites: 10-401 or (10-601 and 10-701)

Course Website: https://sites.google.com/site/computationalmedicinecmu/

02-719 Genomics and Epigenetics of the Brain
Fall: 12 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in genomic technology are in the process of revolutionizing how we conduct molecular biology research. These new techniques have given us an appreciation for the role that epigenetics modifications of the genome play in gene regulation, development, and inheritance. In this course, we will cover the biological basis of genomics and epigenetics, the basic computational tools to analyze genomic data, and the application of those tools to neuroscience. Through programming assignments and reading primary literature, the material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: (03-121 or 03-151) and 03-220 and (15-110 or 02-201 or 15-121)

02-721 Algorithms for Computational Structural Biology
Intermittent: 12 units
Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-725 Computational Methods for Proteogenomics and Metabolomics
Spring: 12 units
Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.
Prerequisites: 02-604 or 02-250 or 02-251

02-730 Cell and Systems Modeling
Fall: 12 units
This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed. *THIS COURSE WILL BE AT PITT
Prerequisites: (33-121 or 03-121 or 03-151) and (03-232 or 03-231) and 21-112 and 09-105

Course Website: https://sites.google.com/site/cellandsystemsmodeling/

02-740 Bioimage Informatics
Intermittent: 12 units
With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.

02-750 Automation of Scientific Research
Spring: 12 units
Biology is increasingly becoming a "big data" science, as biomedical research has been revolutionized by automated methods for generating large amounts of data on diverse biological processes. Integration of data from many types of experiments is required to construct detailed, predictive models of cell, tissue or organism behaviors, and the complexity of the systems suggests that these models need to be constructed automatically. This requires iterative cycles of acquisition, analysis, modeling, and experimental design, since it is not feasible to do all possible biological experiments. This course will cover a range of automated biological research methods and a range of computational methods for automating the acquisition and interpretation of the data (especially active learning, proactive learning, compressed sensing and model structure learning). Grading will be based on class participation, homeworks, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of biology, statistics, and programming.
Prerequisites: 10-601 or 10-701

Course Website: https://sites.google.com/site/automationofbiologicalresearch/?pli=1

02-760 Laboratory Methods for Computational Biologists
Fall and Spring: 6 units
Computational biologists frequently focus on analyzing and modeling large amounts of biological data, often from high-throughput assays or diverse sources. It is therefore critical that students training in computational biology be familiar with the paradigms and methods of experimentation and measurement that lead to the production of these data. This one-semester laboratory course gives students a deeper appreciation of the principles and challenges of biological experimentation. Students learn a range of topics, including experimental design, structural biology, next generation sequencing, genomics, proteomics, bioimaging, and high-content screening. Class sessions are primarily devoted to designing and performing experiments in the lab using the above techniques. Students are required to keep a detailed laboratory notebook of their experiments and summarize their resulting data in written abstracts and oral presentations given in class-hosted lab meetings. With an emphasis on the basics of experimentation and broad views of multiple cutting-edge and high-throughput techniques, this course is appropriate for students who have never taken a traditional undergraduate biology lab course, as well as those who have and are looking for introductory training in more advanced approaches. Grading: Letter grade based on class participation, laboratory notebooks, experimental design assignments, and written and oral presentations. 02-250 is a suggested pre-requisite.

02-761 Laboratory Methods for Automated Biology I
Fall: 12 units
In order to rapidly generate reproducible experimental data, many modern biology labs leverage some form of laboratory automation to execute experiments. In the not so distant future, the use of laboratory automation will continue to increase in the biological lab to the point where many labs will be fully automated. Therefore, it is critical for automation scientists to be familiar with the principles, experimental paradigms, and techniques for automating biological experimentation with an eye toward the fully automated laboratory. In this laboratory course, students will learn about various automatable experimental methods, design of experiments, hardware for preparing samples and executing automated experiments, and software for controlling that hardware. These topics will be taught in lectures as well as through laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on liquid handling, plate control, plate reading, and remote control of the automated system based on experimental data. The second project will be focused on the design, implementation, and analysis of a high content screening campaign using fluorescence microscopy, image analysis, and tissue culture methods.

02-801 Computational Biology Internship
Fall and Summer: 3 units
This course is for students participating in an internship or co-op.

02-900 Ph.D. Thesis Research
All Semesters
This course is for Ph.D students doing supervised research for academic credit.

SCS: Computer Science Courses

15-050 Study Abroad
All Semesters
Students who are interested in studying abroad should first contact the Office of International Education. More information on Study Abroad is available on OIE's Study Abroad page and at the CS Undergraduate Office.

15-075 Computer Science Co-Op
Fall and Spring
This course is meant for CS undergraduate students with a full-time internship that encompasses a summer and a contiguous semester, either Spring-Summer or Summer-Fall who wish to have this recorded on their academic transcript. Units posted for this course do not count toward any requirement for the CS undergraduate degree including free elective units. This course is not available to international students; consult with the Office for International Education for more information.

15-090 Computer Science Practicum
All Semesters: 3 units
This course is for Computer Science students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their CS curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their CS education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

Course Website: https://csd.cs.cmu.edu/course-profiles/15-090-Computer-Science-Practicum

15-104 Introduction to Computing for Creative Practice
Fall: 10 units
An introduction to fundamental computing principles and programming techniques for creative cultural practices, with special consideration to applications in music, design and the visual arts. Intended for students with little to no prior programming experience, the course develops skills and understanding of text-based programming in a procedural style, including idioms of sequencing, selection, iteration, and recursion. Topics include data organization (arrays, files, trees), interfaces and abstraction (modular software design, using sensor data and software libraries), basic algorithms (searching and sorting), and computational principles (randomness, concurrency, complexity). Intended for students participating in IDeATe courses or minors who have not taken 15-112.

Course Website: https://csd.cs.cmu.edu/course-profiles/15-104-Introduction-to-Computing-for-Creative-Practice

15-106 Introduction to Computing for Data Analysis
Spring: 5 units
[Course Pilot] An introductory course in programming for students in statistics-related disciplines using R. Fundamental data types and data structures: booleans, numbers, characters, vectors, matrices, data frames, and lists. Programming constructs: assignment, conditionals, loops, function calls. Processing data: vectorization, "apply" functions, text processing, plotting tools. Additional topics, time permitting: writing functions, using data files, random number generation and simulation. This course is not for credit for SCS majors.

15-110 Principles of Computing
All Semesters: 10 units
A course in fundamental computing principles for students with minimal or no computing background. Programming constructs: sequencing, selection, iteration, and recursion. Data organization: arrays and lists. Use of abstraction in computing: data representation, computer organization, computer networks, functional decomposition, and application programming interfaces. Use of computational principles in problem-solving: divide and conquer, randomness, and concurrency. Classification of computational problems based on complexity, non-computable functions, and using heuristics to find reasonable solutions to complex problems. Social, ethical and legal issues associated with the development of new computational artifacts will also be discussed.

Course Website: https://www.cs.cmu.edu/~15110/

15-112 Fundamentals of Programming and Computer Science
All Semesters: 12 units
A technical introduction to the fundamentals of programming with an emphasis on producing clear, robust, and reasonably efficient code using top-down design, informal analysis, and effective testing and debugging. Starting from first principles, we will cover a large subset of the Python programming language, including its standard libraries and programming paradigms. We will also target numerous deployment scenarios, including standalone programs, shell scripts, and web-based applications. This course assumes no prior programming experience. Even so, it is a fast-paced and rigorous preparation for 15-122. Students seeking a more gentle introduction to computer science should consider first taking 15-110. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.

Course Website: https://www.cs.cmu.edu/~112/

15-121 Introduction to Data Structures
Fall: 10 units
A continuation of the process of program design and analysis for students with some prior programming experience (functions, loops, and arrays, not necessarily in Java). The course reinforces object-oriented programming techniques in Java and covers data aggregates, data structures (e.g., linked lists, stacks, queues, trees, and graphs), and an introduction to the analysis of algorithms that operate on those data structures.
Prerequisite: 15-112

Course Website: http://www.cs.cmu.edu/~mjs/121/index.html

15-122 Principles of Imperative Computation
Fall and Spring: 10 units
For students with a basic understanding of programming (variables, expressions, loops, arrays, functions). Teaches imperative programming and methods for ensuring the correctness of programs. Students will learn the process and concepts needed to go from high-level descriptions of algorithms to correct imperative implementations, with specific application to basic data structures and algorithms. Much of the course will be conducted in a subset of C amenable to verification, with a transition to full C near the end. This course prepares students for 15-213 and 15-210. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisite: 15-112 Min. grade C

Course Website: http://www.cs.cmu.edu/~15122/home.shtml

15-128 Freshman Immigration Course
Fall: 1 unit
The Freshman Immigration Course is taken by first-semester Computer Science majors on the Pittsburgh campus. The course is designed to acquaint incoming majors with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS Freshmen ONLY.

15-129 Freshman Immigration II
Fall: 3 units
This course is ONLY offered at Carnegie Mellon in Qatar. Students and instructors will solve different problems each week by searching the Web and other likely places for answers. The problems will be submitted by other faculty who will grade the quality of the answers. Students will learn strategies and techniques for finding information on the Web more efficiently; learn when to start with a search engine, a subject-oriented directory, or other tools; explore and practice using advanced search syntax for major search engines; experience specialized search engines for images, sound, multimedia, newsgroups, and discussion lists as well as subject-specific search engines; discover valuable resources to help keep you up-to-date in this fast-changing environment.

15-131 Great Practical Ideas for Computer Scientists
Fall: 2 units
THIS COURSE IS OPEN TO CS FRESHMAN ONLY. Throughout your education as a Computer Scientist at Carnegie Mellon, you will take courses on programming, theoretical ideas, logic, systems, etc. As you progress, you will be expected to pick up the so-called "tools of the trade." This course is intended to help you learn what you need to know in a friendly, low-stress, high-support way. We will discuss UNIX, LaTeX, debugging and many other essential tools. Laptop required. (Laptops will be available for those without their own laptops.)

Course Website: https://www.cs.cmu.edu/~15131/f17/

15-150 Principles of Functional Programming
Fall and Spring: 10 units
An introduction to programming based on a "functional" model of computation. The functional model is a natural generalization of algebra in which programs are formulas that describe the output of a computation in terms of its inputs—-that is, as a function. But instead of being confined to real- or complex-valued functions, the functional model extends the algebraic view to a very rich class of data types, including not only aggregates built up from other types, but also functions themselves as values. This course is an introduction to programming that is focused on the central concepts of function and type. One major theme is the interplay between inductive types, which are built up incrementally; recursive functions, which compute over inductive types by decomposition; and proof by structural induction, which is used to prove the correctness and time complexity of a recursive function. Another major theme is the role of types in structuring large programs into separate modules, and the integration of imperative programming through the introduction of data types whose values may be altered during computation. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisites: (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C) and 15-112 Min. grade C

Course Website: http://www.cs.cmu.edu/~15150/

15-151 Mathematical Foundations for Computer Science
Fall: 10 units
CS majors only This course is offered to incoming Computer Science freshmen and focuses on the fundamental concepts in Mathematics that are of particular interest to Computer Science such as logic, sets,induction, functions, and combinatorics. These topics are used as a context in which students learn to formalize arguments using the methods of mathematical proof. This course uses experimentation and collaboration as ways to gain better understanding of the material. Open to CS freshmen only. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.

Course Website: http://www.cs.cmu.edu/~15150/

15-199 Special Topics: Discovering Logic
Intermittent: 3 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course has the purpose of introducing first-year Computer Science students to elements of formal logic as well as to the historical context in which this discipline developed. As all subsequent courses in the CS curriculum rely on students having mastered basic logical notions and skills, it will test and enhance your preparation, thereby putting you in a better position to succeed in the program. It will also help you understand and appreciate how CS came about since Computer Science grew out of logic. The specific knowledge and skills you will learn in is course include: an enhanced ability to research topics, give presentations and write technical prose, some elementary logic, some historical depth into Computer Science, mathematics and logic itself. This course is open to Computer Science freshmen only.

15-210 Parallel and Sequential Data Structures and Algorithms
Fall and Spring: 12 units
Teaches students about how to design, analyze, and program algorithms and data structures. The course emphasizes parallel algorithms and analysis, and how sequential algorithms can be considered a special case. The course goes into more theoretical content on algorithm analysis than 15-122 and 15-150 while still including a significant programming component and covering a variety of practical applications such as problems in data analysis, graphics, text processing, and the computational sciences. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisites: 15-150 Min. grade C and 15-122 Min. grade C

Course Website: http://www.cs.cmu.edu/~15210/

15-213 Introduction to Computer Systems
Fall and Spring: 12 units
This course provides a programmer's view of how computer systems execute programs, store information, and communicate. It enables students to become more effective programmers, especially in dealing with issues of performance, portability and robustness. It also serves as a foundation for courses on compilers, networks, operating systems, and computer architecture, where a deeper understanding of systems-level issues is required. Topics covered include: machine-level code and its generation by optimizing compilers, performance evaluation and optimization, computer arithmetic, memory organization and management, networking technology and protocols, and supporting concurrent computation. NOTE FOR GRADUATE STUDENTS: This course is not open to graduate students beginning Spring 2015. Graduate students must register for 15-513 instead.
Prerequisite: 15-122 Min. grade C

Course Website: https://www.cs.cmu.edu/~213/

15-214 Principles of Software Construction: Objects, Design, and Concurrency
Fall and Spring: 12 units
Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, program structures, and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object oriented programming, (3) static and dynamic analysis for programs, and (4) concurrent and distributed software. Student assignments involve engagement with complex software such as distributed massively multi-player game systems and frameworks for graphical user interaction.
Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C)

15-237 Special Topic: Cross-Platform Mobile Web Apps
Intermittent: 12 units
An introduction to writing cross-platform mobile web apps. Using a tool chain based on HTML5, CSS3, JavaScript, and a variety of supporting frameworks, we will write apps that are effectively designed both for desktop and mobile browsers, and which can be converted into native apps for Android, iOS, and Windows Phone 7 devices. Additional topics will include designing user interfaces for mobile devices, accessing mobile device API's (such as accelerometer, GPS, compass, or camera), and power management issues. While this course focuses on browser-side technologies, we will briefly explore JavaScript-based server-side technologies (though students should consider 15-437 for extensive treatment of server-side topics). Note that we will not be writing native apps in Objective-C for iOS nor in Java for Android, though we may include some brief exposure to these technologies near the end of the course.
Prerequisite: 15-112 Min. grade C

15-251 Great Ideas in Theoretical Computer Science
Fall and Spring: 12 units
This course is about how to use theoretical ideas to formulate and solve problems in computer science. It integrates mathematical material with general problem solving techniques and computer science applications. Examples are drawn from algorithms, complexity theory, game theory, probability theory, graph theory, automata theory, algebra, cryptography, and combinatorics. Assignments involve both mathematical proofs and programming. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisites: (15-122 Min. grade C or 15-150 Min. grade C) and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C)

Course Website: http://www.cs.cmu.edu/~15251/

15-259 Probability and Computing
Spring: 12 units
Probability theory is indispensable in computer science today. In areas such as artificial intelligence and computer science theory, probabilistic reasoning and randomization are central. Within networks and systems, probability is used to model uncertainty and queuing latency. This course gives an introduction to probability as it is used in computer science theory and practice, drawing on applications and current research developments as motivation. The course has 3 parts: Part I is an introduction to probability, including discrete and continuous random variables, heavy tails, simulation, Laplace transforms, z-transforms, and applications of generating functions. Part II is an in-depth coverage of concentration inequalities, like the Chernoff bound and SLLN bounds, as well as their use in randomized algorithms. Part III covers Markov chains (both discrete-time and continuous-time) and stochastic processes and their application to queuing systems performance modeling. This is a fast-paced class which will cover more material than the other probability options and will cover it in greater depth.
Prerequisites: 21-259 and 15-251 Min. grade C and 21-241

15-281 Artificial Intelligence: Representation and Problem Solving
Fall and Spring: 12 units
This course is about the theory and practice of Artificial Intelligence. We will study modern techniques for computers to represent task-relevant information and make intelligent (i.e. satisficing or optimal) decisions towards the achievement of goals. The search and problem solving methods are applicable throughout a large range of industrial, civil, medical, financial, robotic, and information systems. We will investigate questions about AI systems such as: how to represent knowledge, how to effectively generate appropriate sequences of actions and how to search among alternatives to find optimal or near-optimal solutions. We will also explore how to deal with uncertainty in the world, how to learn from experience, and how to learn decision rules from data. We expect that by the end of the course students will have a thorough understanding of the algorithmic foundations of AI, how probability and AI are closely interrelated, and how automated agents learn. We also expect students to acquire a strong appreciation of the big-picture aspects of developing fully autonomous intelligent agents. Other lectures will introduce additional aspects of AI, including natural language processing, web-based search engines, industrial applications, autonomous robotics, and economic/game-theoretic decision making.
Prerequisites: 15-122 Min. grade C and 21-241 Min. grade C and (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C)

15-292 History of Computing
Spring: 5 units
This course traces the history of computational devices, pioneers and principles from the early ages through the present. Topics include early computational devices, mechanical computation in the 19th century, events that led to electronic computing advances in the 20th century, the advent of personal computing and the Internet, and the social, legal and ethical impact of modern computational artifacts. This course also includes a history of programming languages, operating systems, processors and computing platforms. Students should have an introductory exposure to programming prior to taking this course.
Prerequisites: (76-106 or 76-102 or 76-101 or 76-107 or 76-108) and (15-150 or 15-110 or 15-122 or 15-112)

15-294 Rapid Prototyping Technologies
Intermittent: 5 units
This mini-course introduces students to rapid prototyping technologies with a focus on laser cutting and 3D printing. The course has three components: 1) A survey of rapid prototyping and additive manufacturing technologies, the maker and open source movements, and societal impacts of these technologies; 2) An introduction to the computer science behind these technologies: CAD tools, file formats, slicing algorithms; 3) Hands-on experience with SolidWorks, laser cutting, and 3D printing, culminating in student projects (e.g. artistic creations, functional objects, replicas of famous calculating machines, etc.). Please note that there will be a usage/materials fee for this course.
Prerequisites: 15-104 Min. grade C or 15-112 Min. grade C

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/15394u-s18/

15-295 Competition Programming and Problem Solving
Fall and Spring: 5 units
Each year, Carnegie Mellon fields two teams for participation in the ACM-ICPC Regional Programming Contest. During many recent years, one of those teams has earned the right to represent Carnegie Mellon at the ACM-ICPC World Finals. This course is a vehicle for those who consistently and rigorously train in preparation for the contests to earn course credit for their effort and achievement. Preparation involves the study of algorithms, the practice of programming and debugging, the development of test sets, and the growth of team, communication, and problem solving skills. Neither the course grade nor the number of units earned are dependent on ranking in any contest. Students are not required to earn course credit to participate in practices or to compete in ACM-ICPC events.
Prerequisite: 15-122 Min. grade C

Course Website: https://contest.cs.cmu.edu/295/

15-300 Research and Innovation in Computer Science
Fall: 9 units
This Fall course is the first part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Course topics will include the following: an overview of important things to know about how research and innovation works in the field of computer science; a survey of the current cutting- edge of computer science research, both here at Carnegie Mellon and elsewhere; critical thinking skills when reading research publications that disagree with each other; strategies for coping with open-ended problems; and technical communication skills for computer scientists. Students will also match up with a faculty mentor for a potential Technology Innovation Project (to be performed in the Spring), put together a detailed plan of attack for that project, and start to get up to speed (including background reading, etc.). This course can be used to satisfy the Technical Communications requirement for the CS major.
Prerequisites: (15-210 Min. grade C and 76-101 Min. grade C and 15-213 Min. grade C) or (15-213 Min. grade C and 76-101 Min. grade C and 15-251 Min. grade C) or (15-210 Min. grade C and 15-251 Min. grade C and 76-101 Min. grade C)

15-312 Foundations of Programming Languages
Spring: 12 units
This course discusses in depth many of the concepts underlying the design, definition, implementation, and use of modern programming languages. Formal approaches to defining the syntax and semantics are used to describe the fundamental concepts underlying programming languages. A variety of programming paradigms are covered such as imperative, functional, logic, and concurrent programming. In addition to the formal studies, experience with programming in the languages is used to illustrate how different design goals can lead to radically different languages and models of computation.
Prerequisites: 15-150 Min. grade C and (15-251 Min. grade C or 21-228 Min. grade C)

15-313 Foundations of Software Engineering
Fall: 12 units
Students gain exposure to the fundamentals of modern software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software. Topics related to software artifacts include design models, patterns, coding, static and dynamic analysis, testing and inspection, measurement, and software architecture and frameworks. Topics related to software process include modeling, requirements engineering, process models and evaluation, team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, and will include both written and programming assignments. Students will get experience with modern software engineering tools.
Prerequisite: 15-214

15-314 Programming Language Semantics
Spring: 12 units
This course is designed for advanced undergraduates with interests in the mathematical and logical foundations of programming languages. The course introduces the foundational concepts and fundamental techniques of the most prominent and successful approaches to programming language semantics that have been developed. Broadly speaking, semantics is concerned with the provision of mathematical meanings to programs, at an appropriate level of abstraction, to allow formalization of program behavior and facilitate proofs of correctness. Our aim is to demonstrate the utility of a scientific approach to programming and languages. We focus on the most important and most general frameworks for semantic description: denotational and operational semantics. These frameworks are widely applicable and offer complementary approaches to language definition, with various advantages. We also discuss formal specifications, and logics of program correctness. We make extensive use of mathematical and structural induction, and computational induction. We use semantics to describe program behavior, guide the development of correct programs, specify and prove the correctness of a compiler, validate program logics, and derive laws of program equivalence. We discuss imperative and functional languages, sequential and parallel, high-level and low-level, as time permits.
Prerequisites: 15-150 Min. grade C and 15-251 Min. grade C

15-316 Software Foundations of Security and Privacy
Spring: 9 units
Security and privacy issues in computer systems continue to be a pervasive issue in technology and society. Understanding the security and privacy needs of software, and being able to rigorously demonstrate that those needs are met, is key to eliminating vulnerabilities that cause these issues. Students who take this course will learn the principles needed to make these assurances about software, and some of the key strategies used to make sure that they are correctly implemented in practice. Topics include: policy models and mechanisms for confidentiality, integrity, and availability, language-based techniques for detecting and preventing security threats, mechanisms for enforcing privacy guarantees, and the interaction between software and underlying systems that can give rise to practical security threats. Students will also gain experience applying many of these techniques to write code that is secure by construction.
Prerequisite: 15-213 Min. grade C

15-317 Constructive Logic
Fall: 9 units
This multidisciplinary junior-level course is designed to provide a thorough introduction to modern constructive logic, its roots in philosophy, its numerous applications in computer science, and its mathematical properties. Some of the topics to be covered are intuitionistic logic, inductive definitions, functional programming, type theory, realizability, connections between classical and constructive logic, decidable classes.
Prerequisite: 15-150 Min. grade C

Course Website: http://symbolaris.com/course/constlog16.html

15-319 Cloud Computing
Fall and Spring: 12 units
This course gives students an overview of Cloud Computing, which is the delivery of computing as a service over a network, whereby distributed resources are rented, rather than owned, by an end user as a utility. Students will study its enabling technologies, building blocks, and gain hands-on experience through projects utilizing public cloud infrastructures. Cloud computing services are widely adopted by many organizations across domains. The course will introduce the cloud and cover the topics of data centers, software stack, virtualization, software defined networks and storage, cloud storage, and programming models. We will start by discussing the clouds motivating factors, benefits, challenges, service models, SLAs and security. We will describe several concepts behind data center design and management, which enable the economic and technological benefits of the cloud paradigm. Next, we will study how CPU, memory and I/O resources, network (SDN) and storage (SDS) are virtualized, and the key role of virtualization to enable the cloud. Subsequently, students will study cloud storage concepts like data distribution, durability, consistency and redundancy. We will discuss distributed file systems, NoSQL databases and object storage using HDFS, CephFS, HBASE, MongoDB, Cassandra, DynamoDB, S3, and Swift as case studies. Finally, students will study the MapReduce, Spark and GraphLab programming models. Students will work with Amazon Web Services and Microsoft Azure, to rent and provision compute resources and then program and deploy applications using these resources. Students will develop and evaluate scaling and load balancing solutions, work with cloud storage systems, and develop applications in several programming paradigms. 15619 students must complete an extra team project which entails designing and implementing a cost- and performance-sensitive web-service for querying big data.
Prerequisite: 15-213 Min. grade C

Course Website: https://csd.cs.cmu.edu/course-profiles/15-319-619-Cloud-Computing

15-322 Introduction to Computer Music
Fall: 9 units
Computers are used to synthesize sound, process signals, and compose music. Personal computers have replaced studios full of sound recording and processing equipment, completing a revolution that began with recording and electronics. In this course, students will learn the fundamentals of digital audio, basic sound synthesis algorithms, and techniques for digital audio effects and processing. Students will apply their knowledge in programming assignments using a very high-level programming language for sound synthesis and composition. In a final project, students will demonstrate their mastery of tools and techniques through music composition or by the implementation of a significant sound-processing technique.
Prerequisites: 15-122 Min. grade C or 15-112 Min. grade C

Course Website: https://courses.ideate.cmu.edu/15-322

15-323 Computer Music Systems and Information Processing
Spring: 9 units
This course presents concepts and techniques for representing and manipulating discrete music information, both in real time and off line. Representations of music as explicitly timed event sequences will be introduced, and students will learn how to build efficient run-time systems for event scheduling, tempo control, and interactive processing. The MIDI protocol is used to capture real-time performance information and to generate sound. The course will also cover non-real-time processing of music data, including Markov models, style recognition, computer accompaniment, query-by-humming, and algorithmic composition. This course is independent of, and complementary to 15-322, Introduction to Computer Music, which focuses on sound synthesis and signal processing.
Prerequisite: 15-122 Min. grade C

15-330 Introduction to Computer Security
Fall: 12 units
Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.
Prerequisite: 15-213

15-346 Special Topic: Perspectives in Computer Architecture
Intermittent: 6 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course will provide various perspectives in the field of computer architecture by world renowned scientists. The course will bring together basic architecture principles and designs of uniprocessor and multicore computers. First, we introduce the Von-Neuman architecture and the major hardware components of a modern computer. Students will learn how to describe an architecture design using a Hardware Description Language such as Verilog. Second, we will learn basic architectural techniques including instruction level parallelism, pipelining and cache memory. An overview of multicore architectures, specifically on how they differ from uniprocessor ones, the promises they offer, and the serious challenges they bring, will be provided. We will also discuss cache organization techniques in multicores. Students will gain insight into the designing principles that dominated past processor architectures and how they will continue to change for future processor design targeting emerging technologies such as mobile and wearable computing. The concepts delivered in the lectures will be reinforced and extended through student presentations on multiple directions in computer architecture.
Prerequisite: 15-213

15-348 Embedded Systems
Spring: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. This course covers the broad range of foundational skills that apply across all embedded computer system application areas, from thermostats to self-driving vehicles. The emphasis is at the layer where hardware meets software. Topics include microcontroller hardware, assembly language, embedded C programming, analog I/O, timers, code optimization, interrupts, and concurrency. Real world engineering practices, constraints, and example applications are integrated throughout the course. Weekly hands-on hardware and software experiences with an industry-strength automotive embedded controller are coordinated with the lecture content to reinforce core skills.
Prerequisite: 15-122

15-349 Introduction to Computer and Network Security
Fall: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course is meant to offer Computer Science undergraduate students in their junior or senior year a broad overview of the field of computer security. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, applied cryptography, as well as ethical, legal, social and economic facets of security. Students will also learn the fundamental methodology for how to design and analyze security critical systems.
Prerequisite: 15-122

15-351 Algorithms and Advanced Data Structures
Fall: 12 units
The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. THIS COURSE IS NOT OPEN TO COMPUTER SCIENCE MAJORS OR MINORS.
Prerequisites: 15-121 or 15-122

Course Website: https://www.csd.cs.cmu.edu/course-profiles/15-351-Algorithms-and-Advanced-Data-Structures

15-354 Computational Discrete Mathematics
Fall: 12 units
This course is about the computational aspects of some of the standard concepts of discrete mathematics (relations, functions, logic, graphs, algebra, automata), with emphasis on efficient algorithms. We begin with a brief introduction to computability and computational complexity. Other topics include: iteration, orbits and fixed points, order and equivalence relations, propositional logic and satisfiability testing, finite fields and shift register sequences, finite state machines, and cellular automata. Computational support for some of the material is available in the form of a Mathematica package.
Prerequisites: 21-228 Min. grade C or 15-251 Min. grade C

Course Website: http://www.cs.cmu.edu/~cdm/

15-355 Modern Computer Algebra
Spring: 9 units
The goal of this course is to investigate the relationship between algebra and computation. The course is designed to expose students to algorithms used for symbolic computation, as well as to the concepts from modern algebra which are applied to the development of these algorithms. This course provides a hands-on introduction to many of the most important ideas used in symbolic mathematical computation, which involves solving system of polynomial equations (via Groebner bases), analytic integration, and solving linear difference equations. Throughout the course the computer algebra system Mathematica will be used for computation.
Prerequisites: 21-228 Min. grade C or 15-251 Min. grade C

Course Website: http://www.andrew.cmu.edu/course/15-355/

15-356 Introduction to Cryptography
Fall: 12 units
This course is aimed as an introduction to modern cryptography. This course will be a mix of applied and theoretical cryptography. We will cover popular primitives such as: pseudorandom functions, encryption, signatures, zero-knowledge proofs, multi-party computation, and Blockchains. In addition, we will cover the necessary number-theoretic background. We will cover formal definitions of security, as well as constructions based on well established assumptions like factoring. Please see the course webpage for a detailed list of topics.
Prerequisites: 15-251 Min. grade C or 21-128 Min. grade C

Course Website: http://www.cs.cmu.edu/~goyal/15356/

15-359 Probability and Computing
Intermittent: 12 units
Probability theory has become indispensable in computer science. In areas such as artificial intelligence and computer science theory, probabilistic methods and ideas based on randomization are central. In other areas such as networks and systems, probability is becoming an increasingly useful framework for handling uncertainty and modeling the patterns of data that occur in complex systems. This course gives an introduction to probability as it is used in computer science theory and practice, drawing on applications and current research developments as motivation and context. Topics include combinatorial probability and random graphs, heavy tail distributions, concentration inequalities, various randomized algorithms, sampling random variables and computer simulation, and Markov chains and their many applications, from Web search engines to models of network protocols. The course will assume familiarity with 3-D calculus and linear algebra.
Prerequisites: 21-241 and 15-251 Min. grade C and 21-259

Course Website: http://www.cs.cmu.edu/~harchol/15359/class.html

15-365 Experimental Animation
Spring: 12 units
This class will explore animation from the student's perspective with a sense of investigation toward both form and content. Topics in the class will include non-linear narrative, visual music, puppet and non-traditional materials, manipulation of motion and performance capture data, immersive environments.
Prerequisite: 15-213 Min. grade C

15-369 Special Topics: Perceptual Computing
Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. What can today's computers see, hear, and feel? This project-based course is designed to provide students exposure to the state-of-the-art in machine perception and the algorithms behind them. Student groups will design a perceptual computing project around Intel's Creative Camera or Microsoft's Kinect. Students will learn to use tools in face detection and recognition, hand and finger tracking, and speech recognition, along with algorithms to make decisions based on these input modalities.
Prerequisites: 15-122 and 21-241

15-381 Artificial Intelligence: Representation and Problem Solving
Fall: 9 units
This course is about the theory and practice of Artificial Intelligence. We will study modern techniques for computers to represent task-relevant information and make intelligent (i.e. satisficing or optimal) decisions towards the achievement of goals. The search and problem solving methods are applicable throughout a large range of industrial, civil, medical, financial, robotic, and information systems. We will investigate questions about AI systems such as: how to represent knowledge, how to effectively generate appropriate sequences of actions and how to search among alternatives to find optimal or near-optimal solutions. We will also explore how to deal with uncertainty in the world, how to learn from experience, and how to learn decision rules from data. We expect that by the end of the course students will have a thorough understanding of the algorithmic foundations of AI, how probability and AI are closely interrelated, and how automated agents learn. We also expect students to acquire a strong appreciation of the big-picture aspects of developing fully autonomous intelligent agents. Other lectures will introduce additional aspects of AI, including natural language processing, web-based search engines, industrial applications, autonomous robotics, and economic/game-theoretic decision making.
Prerequisite: 15-122 Min. grade C

15-382 Collective Intelligence
Spring: 9 units
This course is about the study of distributed control and intelligence systems involving a large number of autonomous components that interact with each other, dynamically adapting to their changing environment as a result of mutual interactions. Examples of such components include cars in city traffic, pedestrians moving in crowds, firms competing in a market, ants foraging for food, or mobile robots in a swarm or multi-robot system. Under certain conditions, such systems can produce useful system-level behaviors, display self-organized spatial-temporal patterns, effectively perform computations, information dissemination, and decision-making. Loosely speaking, when this happens we can say that the system is displaying a form of "collective intelligence". Collective intelligence will expose students to relevant mathematical and computational models from following fields and domains: Cellular automata and Random boolean networks, Social choice, Game theory, Distributed consensus, Task allocation, Swarm intelligence, Social networks, Pattern formation, and Self-organizing maps. The course will also help bridge the gap between theory and practice via assignments where students will implement system models and explore their properties in application domains of practical interest.
Prerequisite: 15-122 Min. grade C

15-383 Introduction to Text Processing
Fall: 6 units
Text processing is a mini-course about text basic techniques of processing human language in text format. The course has theoretical and hands-on components. In the theoretical component, the course will discuss challenges in processing human languages, and review the basics of statistics and probability theory and their application to language problems. In the hands-on part, students will learn about Python programming and use it to process large volumes of text using various techniques. The processing will range from simple steps such as tokenization and part-of-speech tagging to full-fledged applications such as statistical machine translation, search and document/topic classification. The course is suited for junior and senior students in CS and IS.
Prerequisites: 15-121 Min. grade C or 15-122 Min. grade C

15-385 Introduction to Computer Vision
Spring: 6 units
An introduction to the science and engineering of computer vision, i.e. the analysis of the patterns in visual images with the view to understanding the objects and processes in the world that generate them. Major topics include image formation and sensing, fourier analysis, edge and contour detection, inference of depth, shape and motion, classification, recognition, tracking, and active vision. The emphasis is on the learning of fundamental mathematical concepts and techniques and applying them to solve real vision problems. The discussion will also include comparison with human and animal vision from psychological and biological perspectives. Students will learn to think mathematically and develop skills in translating ideas and mathematical thoughts into programs to solve real vision problems.
Prerequisites: 15-122 Min. grade C and 21-241

15-386 Neural Computation
Spring: 9 units
Computational neuroscience is an interdisciplinary science that seeks to understand how the brain computes to achieve natural intelligence. It seeks to understand the computational principles and mechanisms of intelligent behaviors and mental abilities — such as perception, language, motor control, and learning — by building artificial systems and computational models with the same capabilities. This course explores how neurons encode and process information, adapt and learn, communicate, cooperate, compete and compute at the individual level as well as at the levels of networks and systems. It will introduce basic concepts in computational modeling, information theory, signal processing, system analysis, statistical and probabilistic inference. Concrete examples will be drawn from the visual system and the motor systems, and studied from computational, psychological and biological perspectives. Students will learn to perform computational experiments using Matlab and quantitative studies of neurons and neuronal networks.
Prerequisites: (15-122 Min. grade C or 15-112 Min. grade C) and 21-122

15-387 Computational Perception
Fall and Spring: 9 units
In this course, we will first cover the biological and psychological foundational knowledge of biological perceptual systems, and then apply computational thinking to investigate the principles and mechanisms underlying natural perception. The course will focus on vision this year, but will also touch upon other sensory modalities. You will learn how to reason scientifically and computationally about problems and issues in perception, how to extract the essential computational properties of those abstract ideas, and finally how to convert these into explicit mathematical models and computational algorithms. Topics include perceptual representation and inference, perceptual organization, perceptual constancy, object recognition, learning and scene analysis. Prerequisites: First year college calculus, some basic knowledge of linear algebra and probability and some programming experience are desirable.
Prerequisites: 15-112 Min. grade C and 21-241 and 21-122

15-388 Practical Data Science
Intermittent: 9 units
Data science is the study and practice of how we can extract insight and knowledge from large amounts of data. This course provides a practical introduction to the "full stack" of data science analysis, including data collection and processing, data visualization and presentation, statistical model building using machine learning, and big data techniques for scaling these methods. Topics covered include: collecting and processing data using relational methods, time series approaches, graph and network models, free text analysis, and spatial geographic methods; analyzing the data using a variety of statistical and machine learning methods include linear and non-linear regression and classification, unsupervised learning and anomaly detection, plus advanced machine learning methods like kernel approaches, boosting, or deep learning; visualizing and presenting data, particularly focusing the case of high-dimensional data; and applying these methods to big data settings, where multiple machines and distributed computation are needed to fully leverage the data.Students will complete weekly programming homework that emphasize practical understanding of the methods described in the course. In addition, students will develop a tutorial on an advanced topic, and will complete a group project that applies these data science techniques to a practical application chosen by the team; these two longer assignments will be done in lieu of a midterm or final.
Prerequisites: 15-112 Min. grade C or 15-122 Min. grade C

Course Website: http://www.datasciencecourse.org

15-390 Entrepreneurship for Computer Science
Fall: 9 units
This course is designed to develop skills related to entrepreneurship and innovation for non-business undergraduate and graduate students in the School of Computer Science. The course assumes no background courses in business and is appropriate for those who are interested in bringing innovations to market either through new companies or existing companies. The course provides an overview of entrepreneurship and innovation, develops an entrepreneurial frame of mind, and provides a framework for learning the rudiments of how to generate ideas. Students come up with or are presented with potential ideas and learn how to develop these ideas into opportunities, and to explore their potential for becoming viable businesses. They learn how to do market research, to develop go-to-market strategies, value propositions and to differentiate their products or services from potential competitors. The focus is on understanding and developing strategies for approaching the key elements of the entrepreneurial process...opportunity, resources and team. The course consists of a balance of lectures, case studies and encounters with entrepreneurs, investors and business professionals. The students are exposed to financial and intellectual property issues, and encounter a real world perspective on entrepreneurship, innovation and leadership. The output of the course is a mini-business plan or venture opportunity screening document that can be developed into a business plan in a subsequent course entitled New Venture Creation or through independent study.

15-392 Special Topic: Secure Programming
Spring: 9 units
This course provides a detailed explanation of common programming errors in C and C++ and describes how these errors can lead to software systems that are vulnerable to exploitation. The course concentrates on security issues intrinsic to the C and C++ programming languages and associated libraries. It does not emphasize security issues involving interactions with external systems such as databases and web servers, as these are rich topics on their own. Topics to be covered include the secure and insecure use of integers, arrays, strings, dynamic memory, formatted input/output functions, and file I/O.
Prerequisite: 15-213 Min. grade C

Course Website: https://www.securecoding.cert.org/confluence/display/sci/15392+Secure+Programming

15-394 Intermediate Rapid Prototyping
Intermittent: 5 units
This course covers additional topics in rapid prototyping beyond the content of 15-294. Example topics include mechanism design, procedural shape generation using Grasshopper, 3D scanning and mesh manipulation, and advanced SolidWorks concepts. The only prerequisite is basic familiarity with SolidWorks, which can be obtained via 15-294, from other CMU courses, or from online tutorials.
Prerequisites: 15-112 Min. grade C or 15-104 Min. grade C

Course Website: https://csd.cs.cmu.edu/course-profiles/15-394-Intermediate-Rapid-Prototyping

15-400 Research Practicum in Computer Science
Spring: 12 units
This Spring course is the second part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Building directly upon 15-300 (the prerequisite for this course), students will conduct a semester-long independent research project, under the guidance of both the course staff and a faculty project mentor. The course does not meet for lecture or recitations. Instead, the students will spend their time working on their research projects, and will also meet with course staff on a bi-weekly basis to discuss their progress. Students will prepare a written report and a poster presentation at the end of the semester to describe what they have accomplished.
Prerequisite: 15-300 Min. grade C

15-405 Engineering Distributed Systems
Spring: 9 units
This is a course for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programing. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. If you do not have the 15-410 prerequisite you will need to get approval from the faculty.
Prerequisite: 15-410 Min. grade B

15-410 Operating System Design and Implementation
Fall and Spring: 15 units
Operating System Design and Implementation is a rigorous hands-on introduction to the principles and practice of operating systems. The core experience is writing a small Unix-inspired OS kernel, in C with some x86 assembly language, which runs on a PC hardware simulator (and on actual PC hardware if you wish). Work is done in two-person teams, and "team programming" skills (source control, modularity, documentation) are emphasized. The size and scope of the programming assignments typically result in students significantly developing their design, implementation, and debugging abilities. Core concepts include the process model, virtual memory, threads, synchronization, and deadlock; the course also surveys higher-level OS topics including file systems, interprocess communication, networking, and security. Students, especially graduate students, who have not satisfied the prerequisite at Carnegie Mellon are strongly cautioned - to enter the class you must be able to write a storage allocator in C, use a debugger, understand 2's-complement arithmetic, and translate between C and x86 assembly language. The instructor may require you to complete a skills assessment exercise before the first week of the semester in order to remain registered in the class. Auditing: this course is usually full, and we generally receive many more requests to audit than we can accept. If you wish to audit, please have your advisor contact us before the semester begins to discuss your educational goals.
Prerequisite: 15-213 Min. grade C

Course Website: https://www.csd.cs.cmu.edu/course-profiles/15-410_605-Operating-System-Design-and-Implementation

15-411 Compiler Design
Fall: 15 units
This course covers the design and implementation of compiler and run-time systems for high-level languages, and examines the interaction between language design, compiler design, and run-time organization. Topics covered include syntactic and lexical analysis, handling of user-defined types and type-checking, context analysis, code generation and optimization, and memory management and run-time organization.
Prerequisite: 15-213 Min. grade C

Course Website: https://csd.cs.cmu.edu/course-profiles/15-411_611-compiler-design

15-412 Operating System Practicum
Fall
The goal of this class is for students to acquire hands-on experience with operating-system code as it is developed and deployed in the real world. Groups of two to four students will select, build, install, and become familiar with an open-source operating system project; propose a significant extension or upgrade to that project; and develop a production-quality implementation meeting the coding standards of that project. Unless infeasible, the results will be submitted to the project for inclusion in the code base. Variations on this theme are possible at the discretion of the instructor. For example, it may be possible to work within the context of a non-operating-system software infrastructure project (window system, web server, or embedded network device kernel) or to extend a 15-410 student kernel. In some situations students may work alone. Group membership and unit count (9 units versus 12) will be decided by the third week of the semester. Contributing to a real-world project will involve engaging in some mixture of messy, potentially open-ended activities such as: learning a revision control system, writing a short design document, creating and updating a simple project plan, participating in an informal code review, synthesizing scattered information about hardware and software, classifying and/or reading large amounts of code written by various people over a long period of time, etc.
Prerequisite: 15-410

15-413 SEE 17-413 Software Engineering Practicum
Spring: 12 units
CHANGED TO 17-413 STARTING SPRING 2018. This course is a project-based course in which students conduct a semester-long project for a real client in small teams. The project defines real world needs for the client in their company. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Teams will give presentations and deliver documents on topics such as: risk management project planning requirements architecture detailed design quality assurance final product presentations reflections on the experience Evaluation will be based on the in-class presentations, process and project documentation, how well the teams follow software engineering (SE) practices, and the client's satisfaction with the product. Individual grades will be influenced by peer reviews, individual reflection documents, mentor impressions, and presentation performance. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. They will have teamwork, process, and product skills to support immediate competency in a software engineering organization, along with a deeper understanding that prepares them to evaluate the new processes and techniques they will encounter in the workplace.

15-414 Bug Catching: Automated Program Verification
Fall: 9 units
Many CS and ECE students will be developing software and hardware that must be ultra reliable at some point in their careers. Logical errors in such designs can be costly, even life threatening. There have already been a number of well publicized errors like the Intel Pentium floating point error and the Arian 5 crash. In this course we will study tools for finding and preventing logical errors. Three types of tools will be studied: automated theorem proving, state exploration techniques like model checking and tools based on static program analysis. Although students will learn the theoretical basis for such tools, the emphasis will be on actually using them on real examples. This course can be used to satisfy the Logic & Languages requirement for the Computer Science major.
Prerequisites: 15-122 Min. grade C and 15-251 Min. grade C

Course Website: http://www.cs.cmu.edu/~15414/

15-415 Database Applications
Fall: 12 units
This course covers the fundamental topics for Database Management Systems: Database System Architectural Principles (ACID properties; data abstraction; external, conceptual, and internal schemata; data independence; data definition and data manipulation languages), Data models (entity-relationship and relational data models; data structures, integrity constraints, and operations for each data model; relational query languages: SQL, algebra, calculus), Theory of database design (functional dependencies; normal forms; dependency preservation; information loss), Query Optimization (equivalence of expressions, algebraic manipulation; optimization of selections and joins), Storage Strategies (indices, B-trees, hashing), Query Processing (execution of sort, join, and aggregation operators), and Transaction Processing (recovery and concurrency control).
Prerequisites: 15-210 Min. grade C and 15-213 Min. grade C

Course Website: http://15415.courses.cs.cmu.edu/

15-417 HOT Compilation
Intermittent: 12 units
The course covers the implementation of compilers for higher-order, typed languages such as ML and Haskell, and gives an introduction to type-preserving compilation. Topics covered include type inference, elaboration, CPS conversion, closure conversion, garbage collection, phase splitting, and typed assembly language.
Prerequisites: 15-312 or 15-317

15-418 Parallel Computer Architecture and Programming
Spring: 12 units
The fundamental principles and engineering tradeoffs involved in designing modern parallel computers, as well as the programming techniques to effectively utilize these machines. Topics include naming shared data, synchronizing threads, and the latency and bandwidth associated with communication. Case studies on shared-memory, message-passing, data-parallel and dataflow machines will be used to illustrate these techniques and tradeoffs. Programming assignments will be performed on one or more commercial multiprocessors, and there will be a significant course project.
Prerequisite: 15-213 Min. grade C

Course Website: http://15418.courses.cs.cmu.edu

15-421 Information Security and Privacy
Fall: 12 units
As layers upon layers of technology mediate our activities, issues of information security and privacy are becoming increasingly pervasive and complex. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of robust computer and information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile computing, the Internet of Things, social networking and digital currencies. Topics Covered: Information Security and Privacy: the big picture; A gentle introduction to cryptography; Certificates, PKI, Decentralized Trust Management; Authentication; Internet Security protocols; Risk management; Trusted Computing; Systems security; Web attacks; Cybercrime; Understanding the cyber security legal landscape; Information Privacy: Fundamental concepts & legal landscape; Privacy and Big Data; Privacy Enhancing Technologies; Privacy Engineering; Usable Security and Privacy; Electronic payments and digital currencies; Emerging Security and Privacy challenges (e.g. Cloud Security and Privacy, Mobile and IoT Security and Privacy, Social Networking Security and Privacy)
Prerequisites: 76-101 and 15-112

Course Website: http://www.normsadeh.com/isp-content

15-423 Special Topic: Digital Signal Processing for Computer Science
Spring: 12 units
Digital signals comprise a large fraction of the data analyzed by computer scientists. Sound, e.g. speech and music, images, radar and many other signal types that were conventionally considered to be the domain of the Electrical engineer are now also in the domain of computer scientists, who must analyze them, make inferences, and develop machine learning techinques to analyze, classify and reconstruct such data. In this course we will cover the basics of Digital Signal Processing. We will concentrate on the basic mathematical formulations, rather than in-depth implementation details. We will cover the breadth of topics, beginning with the basics of signals and their representations, the theory of sampling, important transform representations, key processing techniques, and spectral estimation.
Prerequisites: (15-122 Min. grade C or 15-112 Min. grade C) and (36-625 or 36-225 or 36-217 or 21-325 or 15-359)

15-424 Logical Foundations of Cyber-Physical Systems
Intermittent: 12 units
Cyber-physical systems (CPSs) combine cyber effects (computation and/or communication) with physical effects (motion or other physical processes). Designing algorithms to control CPSs, such as those in cars, aircraft and robots, is challenging due to their tight coupling with physical behavior. At the same time, it is vital that these algorithms be correct, since we rely on CPSs for safety-critical tasks like keeping aircraft from colliding. Students in this course will understand the core principles behind CPSs, develop models and controls, identify safety specifications and critical properties of CPSs, understand abstraction and system architectures, learn how to design by invariant, reason rigorously about CPS models, verify CPS models of appropriate scale, understand the semantics of a CPS model and develop an intuition for operational effects. Students will write hybrid programs (HPs), which capture relevant dynamical aspects of CPSs in a simple programming language with a simple semantics, allowing the programmer to refer to real-valued variables representing real quantities and specify their dynamics as part of the HP.
Prerequisites: 15-122 Min. grade C and (21-241 Min. grade C or 18-202 Min. grade C or 15-251 Min. grade C) and 21-120 Min. grade C

Course Website: http://lfcps.org/course/lfcps19.html

15-437 Web Application Development
Fall and Spring: 12 units
This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technology introduced will be the Django framework for Python, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, XML, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must have programming and software design experience equivalent to about a typical Junior CS major—-a sequence of three college CS courses or more. Python-specific experience is not necessary. Students must provide their own computer hardware for this course. Please see the Related URL above for more information.
Prerequisite: 15-214

15-439 Special Topics: Blockchains and Cryptocurrencies
Intermittent: 12 units
Introduction to Blockchains and Cryptocurrencies. We focus on the cryptographic and mathematical foundations of Blockchains. The course will start from the basics and will cover the latest research in this area towards the end.

15-440 Distributed Systems
Fall and Spring: 12 units
The goals of this course are twofold: First, for students to gain an understanding of the principles and techniques behind the design of distributed systems, such as locking, concurrency, scheduling, and communication across the network. Second, for students to gain practical experience designing, implementing, and debugging real distributed systems. The major themes this course will teach include scarcity, scheduling, concurrency and concurrent programming, naming, abstraction and modularity, imperfect communication and other types of failure, protection from accidental and malicious harm, optimism, and the use of instrumentation and monitoring and debugging tools in problem solving. As the creation and management of software systems is a fundamental goal of any undergraduate systems course, students will design, implement, and debug large programming projects. As a consequence, competency in both the C and Java programming languages is required.
Prerequisite: 15-213 Min. grade C

Course Website: https://csd.cs.cmu.edu/course-profiles/15-440_640-distributed-systems

15-441 Computer Networks
Fall and Spring: 12 units
The emphasis in this course will be on the basic performance and engineering trade-offs in the design and implementation of computer networks. To make the issues more concrete, the class includes several multi-week projects requiring significant design and implementation. The goal is for students to learn not only what computer networks are and how they work today, but also why they are designed the way they are and how they are likely to evolve in the future. We will draw examples primarily from the Internet. Topics to be covered include: network architecture, routing, congestion/flow/error control, naming and addressing, peer-to-peer and the web, internetworking, and network security.
Prerequisite: 15-213 Min. grade C

15-445 Database Systems
Fall: 12 units
This course is on the design and implementation of database management systems. Topics include data models (relational, document, key/value), storage models (n-ary, decomposition), query languages (SQL, stored procedures), storage architectures (heaps, log-structured), indexing (order preserving trees, hash tables), transaction processing (ACID, concurrency control), recovery (logging, checkpoints), query processing (joins, sorting, aggregation, optimization), and parallel architectures (multi-core, distributed). Case studies on open-source and commercial database systems will be used to illustrate these techniques and trade-offs. The course is appropriate for students with strong systems programming skills.
Prerequisite: 15-213 Min. grade C

Course Website: http://15445.courses.cs.cmu.edu

15-449 Engineering Distributed Systems
Spring: 9 units
This is a course for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programing. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. If you do not have the 15-410 prerequisite you will need to get approval from the faculty.
Prerequisite: 15-410 Min. grade B

15-451 Algorithm Design and Analysis
Fall and Spring: 12 units
This course is about the design and analysis of algorithms. We study specific algorithms for a variety of problems, as well as general design and analysis techniques. Specific topics include searching, sorting, algorithms for graph problems, efficient data structures, lower bounds and NP-completeness. A variety of other topics may be covered at the discretion of the instructor. These include parallel algorithms, randomized algorithms, geometric algorithms, low level techniques for efficient programming, cryptography, and cryptographic protocols.
Prerequisites: 15-210 Min. grade C and 21-241 and (15-251 Min. grade C or 21-228)

Course Website: https://www.csd.cs.cmu.edu/course-profiles/15-451-Algorithm-Design-and-Analysis

15-453 Formal Languages, Automata, and Computability
Intermittent: 9 units
An introduction to the fundamental ideas and models underlying computing: finite automata, regular sets, pushdown automata, context-free grammars, Turing machines, undecidability, and complexity theory.
Prerequisites: 15-251 Min. grade C or 21-228 Min. grade C

15-455 Undergraduate Complexity Theory
Intermittent: 9 units
Complexity theory is the study of how much of a resource (such as time, space, parallelism, or randomness) is required to perform some of the computations that interest us the most. In a standard algorithms course, one concentrates on giving resource efficient methods to solve interesting problems. In this course, we concentrate on techniques that prove or suggest that there are no efficient methods to solve many important problems. We will develop the theory of various complexity classes, such as P, NP, co-NP, PH, #P, PSPACE, NC, AC, L, NL, UP, RP, BPP, IP, and PCP. We will study techniques to classify problems according to our available taxonomy. By developing a subtle pattern of reductions between classes we will suggest an (as yet unproven!) picture of how by using limited amounts of various resources, we limit our computational power.
Prerequisite: 15-251 Min. grade C

15-456 Computational Geometry
Intermittent: 9 units
How do you sort points in space? What does it even mean? This course takes the ideas of a traditional algorithms course, sorting, searching, selecting, graphs, and optimization, and extends them to problems on geometric inputs. We will cover many classical geometric constructions and novel algorithmic methods. Some of the topics to be covered are convex hulls, Delaunay triangulations, graph drawing, point location, geometric medians, polytopes, configuration spaces, linear programming, and others. This course is a natural extension to 15-451, for those who want to learn about algorithmic problems in higher dimensions.
Prerequisite: 15-451 Min. grade C

15-457 Special Topics in Theory: Advanced Algorithms
Intermittent: 12 units
Selected advanced topics in algorithms and computational theory. Topics vary from semester to semester.
Prerequisite: 15-451 Min. grade B

15-458 Discrete Differential Geometry
Fall: 12 units
Geometry plays a vital role in both engineering and scientific discovery, as well as in our everyday lives via emerging technologies like depth cameras and 3D printing. This course teaches students how to think about three-dimensional shape, both mathematically and computationally. Students will get a crash course in differential geometry, and will apply this knowledge to design and implement practical algorithms for 3D geometry processing. Basic geometric concepts (like curvature) are examined via complementary computational and mathematical points of view, with an emphasis on visual intution and real-world applications. In homework, students will derive and implement core geometry processing algorithms; they will also explore a topic of their choice in a final class project. MS and PhD students will complete additional written and coding exercises, and will perform a more comprehensive literature review for their final project. Topics include curves and surfaces, curvature, connections and parallel transport, exterior calculus, simplicial homology, conformal mapping, finite element methods, and numerical linear algebra; applications include approximation of curvature, curve and surface smoothing, surface parameterization, vector field design, and computation of geodesic distance.
Prerequisites: (15-112 Min. grade C or 15-122 Min. grade C) and 21-241 and 21-259

Course Website: http://geometry.cs.cmu.edu/ddg

15-462 Computer Graphics
Fall and Spring: 12 units
This course provides a comprehensive introduction to computer graphics modeling, animation, and rendering. Topics covered include basic image processing, geometric transformations, geometric modeling of curves and surfaces, animation, 3-D viewing, visibility algorithms, shading, and ray tracing.
Prerequisites: (21-259 and 21-240 and 15-213 Min. grade C) or (21-241 and 21-259 and 15-213 Min. grade C) or (18-213 Min. grade C and 18-202)

15-463 Computational Photography
Fall: 12 units
Computational photography is the convergence of computer graphics, computer vision and imaging. Its role is to overcome the limitations of the traditional camera, by combining imaging and computation to enable new and enhanced ways of capturing, representing, and interacting with the physical world. This advanced undergraduate course provides a comprehensive overview of the state of the art in computational photography. At the start of the course, we will study modern image processing pipelines, including those encountered on mobile phone and DSLR cameras, and advanced image and video editing algorithms. Then we will proceed to learn about the physical and computational aspects of tasks such as 3D scanning, coded photography, lightfield imaging, time-of-flight imaging, VR/AR displays, and computational light transport. Near the end of the course, we will discuss active research topics, such as creating cameras that capture video at the speed of light, cameras that look around walls, or cameras that can see through tissue. The course has a strong hands-on component, in the form of seven homework assignments and a final project. In the homework assignments, students will have the opportunity to implement many of the techniques covered in the class, by both acquiring their own images of indoor and outdoor scenes and developing the computational tools needed to extract information from them. For their final projects, students will have the choice to use modern sensors provided by the instructors (lightfield cameras, time-of-flight cameras, depth sensors, structured light systems, etc.). This course requires familarity with linear algebra, calculus, programming, and doing computations with images. The course does not require prior experience with photography or imaging.
Prerequisites: 15-213 Min. grade C and (18-202 or 21-241) and (15-462 Min. grade C or 16-385 Min. grade C or 18-793 Min. grade C or 16-720 Min. grade C)

Course Website: http://graphics.cs.cmu.edu/courses/15-463/

15-464 Technical Animation
Spring: 12 units
This course introduces techniques for computer animation such as keyframing, procedural methods, motion capture, and simulation. The course also includes a brief overview of story-boarding, scene composition, lighting and sound track generation. The second half of the course will explore current research topics in computer animation such as dynamic simulation of flexible and rigid objects,automatically generated control systems, and evolution of behaviors. The course should be appropriate for graduate students in all areas and for advanced undergraduates.
Prerequisite: 15-462 Min. grade C

15-465 Animation Art and Technology
Spring: 12 units
Animation Art and Technology is an interdisciplinary course cross-listed between Art and Computer Science. Faculty and teaching assistants from computer science and art teach the class as a team. It is a project-based course in which four to five interdisciplinary teams of students produce animations. Most of the animations have a substantive technical component and the students are challenged to consider innovation with content to be equal with the technical. The class includes basic tutorials for work in Maya leading toward more advanced applications and extensions of the software such as motion capture and algorithms for animating cloth, hair, particles, and grouping behaviors. The first class will meet in CFA room 303.
Prerequisites: 18-213 Min. grade C or 15-213 Min. grade C

15-466 Computer Game Programming
Spring: 12 units
The goal of this course is to acquaint students with the code required to turn ideas into games. This includes both runtime systems — e.g., AI, sound, physics, rendering, and networking — and the asset pipelines and creative tools that make it possible to author content that uses these systems. In the first part of the course, students will implement small games that focus on specific runtime systems, along with appropriate asset editors or exporters. In the second part, students will work in groups to build a larger, polished, open-ended game project. Students who have completed the course will have the skills required to extend — or build from scratch — a modern computer game. Students wishing to take this class should be familiar with the C++ language and have a basic understanding of the OpenGL API.
If you meet these requirements but have not taken 15-462 (the formal prerequisite), please contact the instructor.
Prerequisite: 15-462

15-469 Special Topic: Algorithmic Textiles Design
Intermittent: 12 units
Textile artifacts are — quite literally — all around us; from clothing to carpets to car seats. These items are often produced by sophisticated, computer-controlled fabrication machinery. In this course we will discuss everywhere code touches textiles fabrication, including design tools, simulators, and machine control languages. Students will work on a series of multi-week, open-ended projects, where they use code to create patterns for modern sewing/embroidery, weaving, and knitting machines; and then fabricate these patterns in the textiles lab. Students in the 800-level version of the course will additionally be required to create a final project that develops a new algorithm, device, or technique in textiles fabrication.

Course Website: http://graphics.cs.cmu.edu/courses/15-469K-s19/

15-482 Autonomous Agents
Fall: 12 units
Autonomous agents use perception, cognition, actuation, and learning to reliably achieve desired goals, where the agents can be smart homes, mobile robots, intelligent factories, self-driving cars, etc. The goal of this course is to provide students with the techniques needed for developing complete, integrated AI-based autonomous agents. Topics to be investigated include architectures for intelligent agents, task planning, reasoning under uncertainty, optimization, monitoring, execution, error detection and recovery, collaborative and adversarial multiagent interaction, machine learning, ethical behavior, and explanation. The course is project-oriented where, over the course of the semester, small teams of students will design, implement, and evaluate autonomous agents operating in a real-world environment.
Prerequisites: 15-381 or 10-601 or 10-301 or 10-315 or 15-281

15-483 Truth, Justice, and Algorithms
Intermittent: 9 units
Truth, Justice, and Algorithms is an interdisciplinary course that covers selected theoretical topics at the interface of computer science and economics, focusing on the algorithmic side of incentives and fairness. The course's topics include: computational social choice, e.g., voting rules as maximum likelihood estimators, the axiomatic approach to ranking systems and crowdsourcing, manipulation of elections and ways to circumvent it; cooperative games, focusing on solution concepts such as the core and the Shapley value, and their computation; fair division algorithms for allocating divisible and indivisible goods, and approximate notions of fairness; online matching algorithms (competitive analysis, not dating) and kidney exchange; noncooperative games, including Nash equilibrium and correlated equilibrium, their computation, connections to learning theory, Stackelberg security games, and the price of anarchy in congestion and routing games; and topics in social networks such as the diffusion of technologies and influence maximization. NOTE: This course is cross-listed with 15-896. Undergraduates may enroll into 15-896 but be aware of work load difference. The two courses are identical in terms of lectures, content, and homework assignments. The only difference is in the final project requirement. In 483, students will prepare a summary of several papers — this will require 10-20 hours of work. In 896, students will carry out a research project with the goal of obtaining novel results, and present their results in class — a good project will require 50-60 hours of work. Also note that 483 is 9 units, and 896 is 12 units.
Prerequisite: 15-451 Min. grade C

Course Website: http://www.cs.cmu.edu/~arielpro/15896s16/

15-487 Introduction to Computer Security
Fall: 12 units
This course will introduce students to the fundamentals of computer security and applied cryptography. Topics include software security, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.
Prerequisite: 15-213

15-491 Special Topic: CMRoboBits: AI and Robots for Daily-Life Problems
Fall: 12 units
This course will be a project-based course in which we will look at AI and robotics artifacts and techniques to automate solutions to real-world problems, in particular related to life in cities. The course will start by collecting and brainstorming about real problems biased to ones that involve the physical space in addition to the cyber information space, such as traffic rush hour, noise in cities, 3D building inspection, service and data gathering. We will then formalize the chosen problems and analyze existing real data. The course will proceed by possibly enabling the students to prototype their projects beyond simulation, and using the CORAL lab robots, e.g., the CoBot or NAO robots or drones. The course work will be a single large project, performed by groups of up to 3 students. The projects will be divided in three phases, due at the end of February, March, and the end of the course. Students are expected to have programming experience in C++ or python.
Prerequisite: 15-122 Min. grade C

15-492 Special Topic: Speech Processing
Fall: 12 units
Speech Processing offers a practical and theoretical understanding of how human speech can be processed by computers. It covers speech recognition, speech synthesis and spoken dialog systems. The course involves practicals where the student will build working speech recognition systems, build their own synthetic voice and build a complete telephone spoken dialog system. This work will be based on existing toolkits. Details of algorithms, techniques and limitations of state of the art speech systems will also be presented. This course is designed for students wishing understand how to process real data for real applications, applying statistical and machine learning techniques as well as working with limitations in the technology.
Prerequisite: 15-122 Min. grade C

Course Website: http://www.speech.cs.cmu.edu/15-492/

15-494 Cognitive Robotics: The Future of Robot Toys
Spring: 12 units
This course will explore the future of robot toys by analyzing and programming Anki Cozmo, a new robot with built-in artificial intelligence algorithms. Como is distinguished from earlier consumer robots by its reliance on vision as the primary sensing mode and its sophisticated use of A.I. Its capabilities include face and object recognition, map building, path planning, and object pushing and stacking. Although marketed as a pre-programmed children's toy, Cozmo's open source Python SDK allows anyone to develop new software for it, which means it can also be used for robotics education and research. The course will cover robot software architecture, human-robot interaction, perception, and planning algorithms for navigation and manipulation. Prior robotics experience is not required, just strong programming skills.
Prerequisite: 15-122 Min. grade C

15-503 This course is now 15-356 / 856 Introduction to Cryptography
Spring: 9 units
This course is aimed as an introduction to theoretical cryptography for graduate and advanced undergraduate students. We will cover formal definitions of security, as well as constructions of some of the most useful and popular primitives in cryptography: pseudorandom generators, encryption, signatures, zero-knowledge, multi-party computation, etc. In addition, we will cover the necessary number-theoretic background.
Prerequisites: 15-251 Min. grade C and 15-210 Min. grade C

Course Website: http://www.cs.cmu.edu/~goyal/15503.html

15-513 Introduction to Computer Systems
Fall and Spring: 12 units
This course provides a programmer's view of how computer systems execute programs, store information, and communicate. It enables students to become more effective programmers, especially in dealing with issues of performance, portability and robustness. It also serves as a foundation for courses on compilers, networks, operating systems, and computer architecture, where a deeper understanding of systems-level issues is required. Topics covered include: machine-level code and its generation by optimizing compilers, performance evaluation and optimization, computer arithmetic, memory organization and management, networking technology and protocols, and supporting concurrent computation.

15-591 Independent Study in Computer Science
Fall and Spring
The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-592 Independent Study in Computer Science
Fall
The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-593 Independent Study in Computer Science
Fall
The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-594 Independent Study in Computer Science
Fall
The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-599 SCS Honors Undergraduate Research Thesis
Fall and Spring
Available only to students registered in the CS Senior Research Thesis Program.

15-619 Cloud Computing
Fall and Spring: 12 units
This course gives students an overview of Cloud Computing, which is the delivery of computing as a service over a network, whereby distributed resources are rented, rather than owned, by an end user as a utility. Students will study its enabling technologies, building blocks, and gain hands-on experience through projects utilizing public cloud infrastructures. Cloud computing services are widely adopted by many organizations across domains. The course will introduce the cloud and cover the topics of data centers, software stack, virtualization, software defined networks and storage, cloud storage, and programming models. We will start by discussing the clouds motivating factors, benefits, challenges, service models, SLAs and security. We will describe several concepts behind data center design and management, which enable the economic and technological benefits of the cloud paradigm. Next, we will study how CPU, memory and I/O resources, network (SDN) and storage (SDS) are virtualized, and the key role of virtualization to enable the cloud. Subsequently, students will study cloud storage concepts like data distribution, durability, consistency and redundancy. We will discuss distributed file systems, NoSQL databases and object storage using HDFS, CephFS, HBASE, MongoDB, Cassandra, DynamoDB, S3, and Swift as case studies. Finally, students will study the MapReduce, Spark and GraphLab programming models. Students will work with Amazon Web Services and Microsoft Azure, to rent and provision compute resources and then program and deploy applications using these resources. Students will develop and evaluate scaling and load balancing solutions, work with cloud storage systems, and develop applications in several programming paradigms. 15619 students must complete an extra team project which entails designing and implementing a cost- and performance-sensitive web-service for querying big data.

Course Website: https://csd.cs.cmu.edu/course-profiles/15-319-619-Cloud-Computing

15-705 Engineering Distributed Systems
Spring: 12 units
This course is for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programing. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. Please refer to http://www.cs.cmu.edu/~csd-grad/courseschedules14.html this link for the most recent schedule updates.

15-719 Advanced Cloud Computing
Spring: 12 units
Computing in the cloud has emerged as a leading paradigm for cost-effective, scalable, well-managed computing. Users pay for services provided in a broadly shared, power efficient datacenter, enabling dynamic computing needs to be met without paying for more than is needed. Actual machines may be virtualized into machine-like services, or more abstract programming platforms, or application-specific services, with the cloud computing infrastructure managing sharing, scheduling, reliability, availability, elasticity, privacy, provisioning and geographic replication This course will survey the aspects of cloud computing by reading about 30 papers and articles, executing cloud computing tasks on a state of the art cloud computing service, and implementing a change or feature in a state of the art cloud computing framework. There will be no final exam, but there will be two in class exams. Grades will be about 50% project work and about 50% examination results. Please refer to https://www.cs.cmu.edu/~csd-grad/courseschedules19.html for the most recent schedule updates.
Prerequisites: 15-213 Min. grade B or 15-513 Min. grade B or 18-213 Min. grade B

Course Website: http://www.cs.cmu.edu/~15719/

15-749 Engineering Distributed Systems
Fall: 12 units
Computing has changed beyond recognition in half a century, from the room-filling mainframes of the 1960s to today's smartphones and wearable devices. Networks have also changed dramatically: from the 300-baud dialup modems of the early networking era to gigabit LANs, Wi-Fi and 4G today. Who knows what changes are in store for us over the next half century? Astonishingly, in spite of this tremendous change in hardware technology over time, a small core set of techniques for building distributed systems has emerged and remained surprisingly stable and applicable across many system layers. Many flavors of these techniques exist, and they continously evolve over time to reflect changing trade-offs in the design space. What are these core techniques, and how can we leverage them in creating distributed systems today and in the future? That is the central question addressed by this course. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered distributed systems that withstand the test of time, growth in scale, and stresses of live use. Strong design and implementation skills are expected of all students. The course assumes a high level of proficiency in all aspects of operating system design and implementation. A substantial project component is an integral part of the course. Please refer to http://www.cs.cmu.edu/~csd-grad/courseschedules14.html this link for the most recent schedule updates.

Course Website: http://www.cs.cmu.edu/~15-749/

15-769 Special Topics in Graphics:
Intermittent: 12 units
Please refer to http://www.cs.cmu.edu/~csd-grad/courseschedulef17.html for the most recent schedule updates. Class will not begin until the week of September 4th.

Course Website: http://graphics.cs.cmu.edu/courses/15869/fall2014/

15-883 Computational Models of Neural Systems
Intermittent: 12 units
This course is an in-depth study of information processing in real neural systems from a computer science perspective. We will examine several brain areas, such as the hippocampus and cerebellum, where processing is sufficiently well understood that it can be discussed in terms of specific representations and algorithms. We will focus primarily on computer models of these systems, after establishing the necessary anatomical, physiological, and psychophysical context. There will be some neuroscience tutorial lectures for those with no prior background in this area. Please refer to http://www.cs.cmu.edu/~csd-grad/courseschedulef19.html for the most recent schedule updates.

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/15883-f17/

SCS: Human-Computer Interaction Courses

05-291 Learning Media Design
Fall: 12 units
[IDeATe collaborative course] Learning is a complex human phenomenon with cognitive, social and personal dimensions that need to be accounted for in the design of technology enhanced learning experiences. In this studio course students will apply learning science concepts to critique existing forms of learning media, establish a set of design precedents to guide project work and produce a series of design concepts that support learning interactions in a real-world context. Collaborating in small interdisciplinary teams, students will partner with a local informal learning organization (e.g. museum, after school program provider, maker space) to conduct learning design research studies, synthesize findings, establish learning goals and iteratively prototype and assess design concepts. As final deliverables, students will present their design research findings, design concepts, and prototypes to stakeholders, and draft a media-rich proposal for their learning media concept to pitch to a local funder. Please note that there may be usage/materials fees associated with this course. Please note that there may be usage/materials fees associated with this course.

05-292 IDeATe: Learning in Museums
Spring: 12 units
Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences though a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts that improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions. This course will culminate in a media-rich presentation of design concepts and a prototype to a stakeholder audience, and include an evaluation plan describing how learning outcomes for the project would be assessed.

05-300 HCI Undergraduate Pro Seminar
All Semesters: 2 units
HCI is a broad field that brings together approaches from design, computer science, and psychology. This course provides an introduction to the field of HCI and to the HCI community at CMU. Guest speakers from around campus will provide a general introduction to these approaches and how they are pursued at CMU, and will describe research opportunities that are available to undergraduates. The course will also discuss career options in both industry and academia for students of HCI, and will include presentations from HCI alumni and sessions on preparing resumes, creating portfolios, and interviewing for jobs. The course is designed for current or potential HCI majors and minors but is open to anyone with an interest in applying for the HCI major/minor. Note that class will begin 5 minutes after the scheduled start to accommodate students arriving to Craig street from the main campus.

Course Website: https://hcii.cmu.edu/academics/courses

05-317 Design of Artificial Intelligence Products
Intermittent: 12 units
This course teaches students how to design new products and services that leverage the capabilities of AI and machine learning to improve the quality of people¿s lives. Students will learn to follow a matchmaking design, user-centered design, and service design process. Students will learn to ideate; reframing problematic situations by envisioning many possible products and services. Students will learn to iteratively refine and assess their ideas with real users/customers. Class projects will focus on the challenges of deploying systems that generate errors and the challenges of situating intelligent systems such that they harmonize the best qualities of human and machine intelligence.

Course Website: https://hcii.cmu.edu/academics/courses

05-318 Human AI Interaction
Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: http://www.hcii.cmu.edu/academics/courses

05-320 Social Web
Intermittent: 12 units
With the growth of online environments like MySpace, Second Life, World of Warcraft, Wikipedia, blogs, online support groups, and open source development communities, the web is no longer just about information. This course, jointly taught by a computer scientist and a behavioral scientist, will examine a sampling of the social, technical and business challenges social web sites must solve to be successful, teach students how to use high-level tools to analyze, design or build online communities, and help them understand the social impact of spending at least part of their lives online. This class is open to advanced undergraduates and graduate students with either technical or non-technical backgrounds. Course work will include lectures and class discussion, homework, class presentations, and a group research or design project.

05-333 Gadgets, Sensors and Activity Recognition in HCI
Fall: 12 units
Recent advances in HCI have been driven by new capabilities to deliver inexpensive devices to users, to display information in mobile and other contexts, to sense the user and their environment, and use these sensors to create models of a user's context and actions. This course will consider both concepts surrounding these new technological opportunities through discussion of current literature - and practical considerations the skills needed to actually build devices. About 1/3 of this class will review current advances in this area. The remainder will be devoted to development of individual skills so that students leaving the class will have an ability to actually build small devices for human interaction (in short: "HCI gadgets"). In particular, the course will concentrate on the basics of building simple microcontroller-based devices and will also provide very basic coverage of the machine learning techniques needed for simple sensor-driven statistical models. The course is designed to be accessible to students with a wide range of backgrounds including both technically-oriented and non-technical students (especially Designers) interested in HCI. The class will be project oriented with 4-5 electronic prototype building projects during the semester. At least two of these projects will be self-defined in nature and can be adapted to the existing skills and interests of each student. There are no formal prerequisites for this class. However, the class will involve programming and debugging of micro-controllers. Some coverage of the language used to do this will be provided, and if required by your background, the programming component of the projects can be made comparatively small (but, in that case some other aspect of the projects will need to be expanded). However, you should not take this course if you have no programming background. This course assumes no background in electronics.

Course Website: http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci

05-341 Organizational Communication
All Semesters: 9 units
Most of management is communication. You communicate to get information that will be the basis of decisions, coordinate activity, to provide a vision for the people who work for and with you, to and to sell yourself and your work. The goal of this course is to identify communication challenges within work groups and organizations and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. The intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly participate in when you move to a work environment, and strategies for improving communication within your groups. Because technology is changing communication patterns and outcomes both in organizations and more broadly in society, the course examines these technological changes. Readings come primarily from the empirical research literature.

Course Website: http://www.hcii.cmu.edu/courses/organizational-communication

05-391 Designing Human Centered Software
All Semesters: 12 units
Why are things so hard to use these days? Why doesn't this thing I just bought work? Why is this web site so hard to use? These are frustrations that we have all faced from systems not designed with people in mind. The question this course will focus on is: how can we design human-centered systems that people find useful and usable? This course is an introduction to designing, prototyping, and evaluating user interfaces. If you take only one course in Human-Computer Interaction, this is the course for you. This class is a core course for undergrads in the HCI Minor but open to all undergrads and grad students, with either technical or non-technical backgrounds.
We will cover theory as well as practical application of ideas from Human-Computer Interaction. Course work includes lectures, class discussion, homework, class presentations, and group project. Students will need a prerequisite of a fundamental computer programming course.
Prerequisites: 15-112 or 15-110 or 15-104 or 15-122

Course Website: http://www.hcii.cmu.edu/courses/designing-human-centered-software

05-392 Interaction Design Overview
Fall: 9 units
This studio course offers a broad overview of communication and interaction design. Students will learn design methodologies such as brainstorming, sketching, storyboarding, wire framing, and prototyping. Students learn to take a human-centered design approach to their work. Assignments include short in-class exercises as well as individual and team-based projects. Students take part in studio critiques, engaging in critical discussions about the strengths and weaknesses of their own work and the work of others. No coding is required.

05-395 Applications of Cognitive Science
Spring: 9 units
The goal of this course is to examine cases where basic research on cognitive science, including cognitive neuroscience, has made its way into application, in order to understand how science gets applied more generally. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se; for example, as a product, a change in practice, or a legal statute. Examples are virtual reality (in vision, hearing, and touch), cognitive tutors, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students. They should bring to the course an interest in application; extensive prior experience in cognitive science is not necessary. The course will include tutorials on basic topics in cognitive science such as perception, memory, and spatial cognition. These should provide sufficient grounding to discuss the applications.

Course Website: http://www.hcii.cmu.edu/courses/applications-cognitive-science

05-410 User-Centered Research and Evaluation
Fall: 12 units
This course provides and overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of task analysis, and analytic and empirical evaluation methods. This is a companion course to courses in visual design (51-422) and software implementation (05-430, 05-431). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school e.g. seniors, juniors, etc This course is NOT open to students outside the HCI major. When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school.

05-413 Human Factors
Fall: 9 units
This course uses theory and research from human factors, cognitive science, and social science to understand and design the interactions of humans with the built world, tools, and technology. The course emphasizes current work in applied domains such as automotive design, house construction, medical human factors, and design of information devices. The course also will emphasize not only individual human factors (e.g., visual response, anthropometry) but also the organizational arrangements that can amplify or correct human factors problems. Through reading, discussion, and projects, you will learn about human perceptual, cognitive, and physical processes that affect how people interact with, and use, technology and tools. You will learn why we have so many automobile accidents, voting irregularities, and injuries from prescription medication. You will learn some tried and true solutions for human factors problems, and some of the many problems in human factors that remain. You will also have gained experience in research in this field.

Course Website: http://www.hcii.cs.cmu.edu

05-417 Computer-mediated Communication
Spring: 6 units
This course examines fundamental aspects of interpersonal communication and considers how different types of computer-mediated communications (CMC) technologies affect communication processes. Among the topics we will consider are: conversational structure and CMC, tools to support nonverbal and paralinguistic aspects of communication such as gesture and eye gaze, and social and cultural dimensions of CMC. Students will be expected to post to weekly discussion lists, to write a paper on a specific aspect of CMC, and to present a talk on their final project to the class. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

05-418 Design Educational Games
Spring: 12 units
The potential of digital games to improve education is enormous. However, it is a significant challenge to create a game that is both fun and educational. In this course, students will learn to meet this challenge by combining processes and principles from game design and instructional design. Students will also learn to evaluate their games for fun, learning, and the integration of the two. They will be guided by the EDGE framework for the analysis and design educational games. The course will involve a significant hands-on portion, in which students learn a design process to create educational games digital or non-digital. They will also read about existing educational games and discuss game design, instructional design, learning and transfer, and the educational effectiveness of digital games. They will analyze an educational game and present their analysis to the class.

Course Website: http://www.hcii.cmu.edu/courses/design-educational-games

05-430 Programming Usable Interfaces
Spring: 15 units
This course is combines lecture, and an intensive programming lab and design studio. It is for those who want to express their interactive ideas in working prototypes. It will cover the importance of human-computer interaction/interface design, iterative design, input/output techniques, how to design and evaluate interfaces, and research topics that will impact user interfaces in the future. In lab, you will learn how to design and program effective graphical user interfaces, and how to perform user tests. We will cover a number of prototyping tools and require prototypes to be constructed in each, ranging from animated mock-ups to fully functional programs. Assignments will require implementing UIs, testing that interface with users, and then modifying the interface based on findings. Some class sessions will feature design reviews of student work. This course is for HCII Masters students and HCI dual majors with a minimal programming background. Students will often not be professional programmers, but will need to interact with programmers. RECITATION SELECTION: Students taking this course can sign up for either Prototyping Lab recitation. PREREQUISITES: Proficiency in a programming language, program structure, algorithm analysis, and data abstraction. Normally met through an introductory programming course using C, C++, Pascal or Java, such as 15100, 15112, 15127 or equivalent. Students entering this course should be able to independently write a 300-line program in 48 hours. This course is NOT open to students outside of the BHCI program.
Prerequisites: 15-110 or 15-104 or 15-112 or 15-127 or 15-100

05-431 Software Structures for User Interfaces
Fall: 15 units
SSUI (15-credit, combined lecture and lab) This course considers the basic and detailed concepts that go into building software to implement user interfaces. It considers factors of input, output, application interface, and related infrastructure as well as the typical patterns used to implement them. It will also consider how these components are organized and managed within a well-structured object oriented system. After considering these fundamental concepts in the first portion of the class, the later part will consider advanced topics related to emerging future concepts in user interface design. The course includes an intensive programming lab, either on the topic of mobile or web interfaces. This course is intended for HCII Master, BHCI dual majors and others who wish to understand the structures needed for professional development of interactive systems, and has a strong programming background. PREREQUISITES: Comfort in programming and related concepts equivalent to an undergraduate CS degree. Should be proficient in programming, and comfortable with abstract concepts relating to program structure, algorithm analysis, and data abstraction. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-432 Personalized Online Learning
Fall: 12 units
Online learning has become widespread (e.g., MOOCs, online and blended courses, and Khan Academy) and many claim it will revolutionize higher education and K-12. How can we make sure online learning is maximally effective? Learners differ along many dimensions and they change over time. Therefore, advanced learning technologies must adapt to learners to provide individualized learning experiences. This course covers a number of proven personalization techniques used in advanced learning technologies. One of the techniques is the use of cognitive modeling to personalize practice of complex cognitive skills in intelligent tutoring systems. This approach, developed at CMU, may well be the most significant application of cognitive science in education and is commercially successful. We will also survey newer techniques, such as personalizing based on student meta-cognition, affect, and motivation. Finally, we will look at personalization approaches that are widely believed to be effective but have not proven to be so. The course involves readings and discussion of different ways of personalizing instruction, with an emphasis on cognitive modeling approaches. Students will learn to use the Cognitive Tutor Authoring Tools (CTAT) to implement tutor prototypes that rely on computer-executable models of human problem solving to personalize instruction. The course is meant for graduate or advanced undergraduate students in Human-Computer Interaction, Psychology, Computer Science, Design, or related fields, who are interested in educational applications. Students should either have some programming skills or experience in the cognitive psychology of human problem solving, or experience with instructional design.

Course Website: http://www.hcii.cmu.edu/courses/personalized-online-learning

05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces
Fall: 6 units
Section A: Programming Usable Interfaces Section B: Software Structures for Usable Interfaces This is a lecture-only course (see 05-430/05-630 or 05-431/631 for the lecture + lab version of these courses) that is intended for those who want to learn how to design and evaluate user interfaces. We will cover the importance of human-computer interaction and interface design, the iterative design cycle used in HCI, an overview of input and output techniques, how to design and evaluate interaction techniques, and end with a discussion of hot topics in research that will impact user interfaces in the coming years. This course is only intended for HCII Masters students or HCI undergraduate majors who have already taken an associated User Interface lab, or non-MHCI/BHCI students interested in the design of user interfaces. PREREQUISITES: There are no prerequisites for this lecture-only course. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-434 Machine Learning in Practice
Fall and Spring: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization. 05-834 is the HCII graduate section. If you are an LTI student, please sign up for the LTI graduate course number (11-663) ONLY to count properly towards your degree requirements. 05-434 is the HCII undergraduate section. If you are an LTI student, please sign up for the LTI undergraduate course number (11-344) ONLY to count properly towards your degree requirements.

Course Website: http://www.hcii.cmu.edu/courses/applied-machine-learning

05-435 Advanced Fabrication Techniques for HCI
Fall: 12 units
This course will consider how new fabrication techniques such as 3D printing, laser cutting, CNC machining and related computer controlled technologies can be applied to problems in Human-Computer Interaction. Each offering will concentrate on a particular application domain for its projects. This year the course will consider assistive technology. This course will be very hands-on and skills-oriented, with the goal of teaching students the skills necessary to apply these technologies to HCI problems such as rapid prototyping of new device concepts. To this end? Every student in this course will build and take home a 3D printer. (There will be $400-$500 cost associated with this course to make that possible. Details on this are still to be determined.)

05-439 The Big Data Pipeline: Collecting and Using Big Data for Interactive Systems
Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: http://data.cmubi.org

05-440 Interaction Techniques
Intermittent: 12 units
This course will provide a comprehensive study of the many ways to interact with computers and computerized devices. An "interaction technique" starts when the user does something that causes an electronic device to respond, and includes the direct feedback from the device to the user. Examples include physical buttons and switches, on-screen menus and scroll bars operated by a mouse, touch screen widgets and gestures such as flick-to-scroll, text entry on computers or touch screens, consumer electronic controls such as remote controls, game controllers, and adaptations of all of these for people with disabilities. We will start with a history of the invention and development of these techniques, discuss the various options used today, and continue on to the future with the latest research on interaction techniques presented at conferences such as ACM CHI and UIST. Guest lectures from inventors of interaction techniques are planned. Students will have a choice for final projects that can focus on historical or novel interaction techniques. For example, one option will be to create a novel technique, perform a user study of it, and write a paper about the result, which may be suitable for conference submission. Another option will be to investigate and write a paper or make a video about the history and various previous designs for widely used interaction techniques, possibly including an interview with the inventor(s).

Course Website: http://www.cs.cmu.edu/~bam/uicourse/05440inter/

05-452 Service Design
Fall: 12 units
In this course, we will collectively define and study services and product service systems, and learn the basics of designing them. We will do this through lectures, studio projects, and verbal and written exposition. Classwork will be done individually and in teams.

05-499 Special Topics in HCI
Fall and Spring: 12 units
The Special Topics in HCI is an opportunity for students interested in HCI to gain a deeper understanding of a specific area in this field. Each class is designed to cover an emerging research area within HCI, from designing large-scale peer learning systems to creating video games around audience agency. All sections will help students: (1) build a more comprehensive understanding of an area of study within HCI, (2) work closely with faculty and peers to create mini-projects or team assignments that help students master the course material, (3) explore evidence-based research methods and techniques in HCI. Sections will vary in topic and often change from semester to semester. Because of this, students can take multiple sections, as they are individual classes. The Undergraduate section is 499 and the graduate section is 899. For descriptions of specific sections for this academic year, visit the "Courses" section on the Human-Computer Interaction Institute website: http://hcii.cmu.edu/academics/courses
Course Website: http://www.hcii.cmu.edu/academics/courses

05-540 Rapid Prototyping of Computer Systems
Spring: 12 units
This is a project-oriented course, which will deal with all four aspects of project development: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time. Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided development tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time.

Course Website: http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems

05-571 Undergraduate Project in HCI
Spring: 12 units
Experiential learning is a key component of the MHCI program. Through a substantial team project, students apply classroom knowledge in analysis and evaluation, implementation and design, and develop skills working in multidisciplinary teams. Student teams work with Carnegie Mellon University-based clients or external clients to iteratively design, build and test a software application which people directly use.
Prerequisites: 05-610 Min. grade B or 05-630 Min. grade B or 05-631 Min. grade B or 05-431 Min. grade B or 05-430 Min. grade B or 05-410 Min. grade B

Course Website: http://www.hcii.cmu.edu/courses/undergraduate-project-hci

05-589 Independent Study in HCI-UG
All Semesters
In collaboration with and with the permission of the professor, undergraduate students may engage in independent project work on any number of research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, complete a contract, and present a tangible deliverable. The Undergraduate Program Advisor's signature is required for HCI undergraduate-level Independent Study courses.

05-600 HCI Pro Seminar
Fall: 6 units
Students will attend weekly HCII Seminar Series of talks given by national leaders in the field of Human-Computer Interaction, attend communication workshops and conflict management workshops. This course is for MHCI students only.

Course Website: http://www.hcii.cs.cmu.edu

05-610 User-Centered Research and Evaluation
Fall: 12 units
This course provides and overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of task analysis, and analytic and empirical evaluation methods. This is a companion course to courses in visual design (05-650) and software implementation (05-630, 05-631). This course is NOT open to students outside of the MHCI program.

Course Website: http://www.hcii.cs.cmu.edu

05-618 Human AI Interaction
Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: https://www.hcii.cmu.edu/academics/courses

05-650 Interaction Design Studio II
Spring: 12 units
This course follows Interaction Design Fundamentals (05-651). Students are expected to apply what they have learned about design thinking and methodologies as a starting point for all assignments. Students will work in teams to perform guerrilla research, synthesize data, and consider the needs of multiple stakeholders in their design of mobile services and other intelligent systems. Design concepts go beyond user interfaces to include sensors, controls, and ubiquitous computing. Emphasis is placed on the quality of the students ideas and their ability to give form to their design concepts. By completing and presenting their work, students will gain skills related to professional UX design practice.
Prerequisites: 05-651 or 51-248 or 51-228 or 51-262 or 51-261 or 51-228 or 51-761 or 51-268

Course Website: http://www.hcii.cmu.edu/courses/interaction-design-studio

05-651 Interaction Design Studio 1
Fall: 12 units
This studio course introduces students to design thinking and the basic practices of interaction design. We follow a human-centered design process that includes research, concept generation, prototyping, and refinement. Students must work effectively as individuals and in small teams to design mobile information systems and other interactive experiences. Assignments approach design on three levels: specific user interactions, contexts of use, and larger systems. Students will become familiar with design methodologies such as sketching, storyboarding, wire framing, prototyping, etc. No coding is required. This course serves as a prerequisite for Interaction Design Studio (05-650). Students who are required to take this course have priority and will be enrolled first.

05-823 E-Learning Design Principles and Methods
Fall: 12 units
This course is about e-learning design principles, the evidence and theory behind them, and how to apply these principles to develop effective educational technologies. It is organized around the book "e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning" by Clark & Mayer with further readings drawn from cognitive science, educational psychology, and human-computer interaction. You will learn design principles 1) for combining words, audio, and graphics in multimedia instruction, 2) for combining examples, explanations, practice and feedback in online support for learning by doing, and 3) for balancing learner versus system control and supporting student metacognition. You will read about the experiments that support these design principles, see examples of how to design such experiments, and practice applying the principles in educational technology development.

Course Website: http://www.learnlab.org/research/wiki/index.php/E-learning_Design_Principles_2013#Course_Details

05-839 Interactive Data Science
Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: https://hcii.cmu.edu/academics/courses

05-840 Tools for Online Learning
Fall: 12 units
In this course, we will explore issues that pertain to interaction and interface design. The class will focus on elements of the larger interaction design process including basic design principles, information architecture and navigation, planning and brainstorming methods, and techniques for developing rapid sketches and prototypes. Course Requirements: This class will not focus on learning specific software tools. Students are expected to have prior experience using a variety of design and programming tools. Please speak with the instructor if you have questions regarding these prerequisites. This course was design for students in the METALS program.

SCS: Institute for Software Research Courses

17-200 Ethics and Policy Issues in Computing
Spring: 9 units
Note: Previously offered as 08-200. In this course, students will study the social impacts of computing technology and systems. The course will provide a brief introduction to ethics and to the new and difficult ethical questions modern computing technology presents us with. It will focus on a number of areas in which computers and information technology are having an impact on society including data privacy, social media, and autonomous technologies.

17-214 Principles of Software Construction: Objects, Design, and Concurrency
Fall and Spring: 12 units
Note: This course previously offered as 15-214. Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java.
Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C)

17-224 Influence, Persuasion, and Manipulation Online
Fall: 9 units
This course will introduce the fundamental behavioral science of influence, persuasion, and manipulation, and the application of these scientific principles to online campaigns to influence attitudes and behavior. In particular, we will discuss the psychology of persuasion, nudging, social influence, bias, persuasive design, and the ethics of persuasion. Against this background, we will analyze case studies drawn from recent, high profile events such as election campaigns, targeted advertising, sowing political division, memes and virality, impact of social media, and propagation of "fake news." Countermeasures to these tactics will be explored, including personal measures, technologies, and policy.

17-303 Cryptocurrencies, Blockchains and Applications
Spring
Note: Previously offered as 08-303. Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies. Prerequisites: 15-213 or equivalent strongly recommended

17-313 Foundations of Software Engineering
Fall: 12 units
Note: This course previously offered as 15313.Students gain exposure to the fundamental principles of software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software in real-world settings. Topics related to software artifacts include coding, software architecture, measurement, and quality assurance of various qualities (e.g., robustness, security, performance, maintainability) with static and dynamic analysis, testing, code review, and inspection. Topics related to software process include requirements engineering, process models and evaluation, personal and team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, a strong focus on developing team skills, and will include both written and programming assignments. Students will get experience with the latest software engineering tools and practices.

Course Website: https://www.cs.cmu.edu/~ckaestne/17313/

17-331 Information Security, Privacy, and Policy
Fall: 12 units
Note: This course previously offered as 15-421. As layers upon layers of technology mediate increasingly rich business processes and social interactions, issues of information security and privacy are growing more complex too. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile and pervasive computing as well as social networking. Format: Lectures, short student presentations on topics selected together with the instructor, and guest presentations. Target Audience: Primarily intended for motivated undergraduate and masters students with CS background. Also open to PhD students interested in a more practical, multi-disciplinary understanding of information security and privacy.

17-333 Privacy Policy, Law, and Technology
Fall and Spring: 9 units
Note: Previously offered as 08-533. This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-334 Usable Privacy and Security
Spring: 9 units
Note: Previously offered as 08-734. There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

17-340 Green Computing
Intermittent: 9 units
Note: Previously offered as 08-340. Energy is a key societal resource. However, our energy usage is rising at an alarming rate and therefore it has become critical to manage its consumption more efficiently for long term sustainability. This course introduces students to the exciting area of "Green Computing", and is organizationally divided into two tracks. The first track is "Energy-Efficient Computing", which considers the state of the art techniques for improving the energy efficiency of mobile devices, to laptop and desktop class computers and finally to data centers. We will cover energy efficiency across the hardware/software stack, starting from the individual components like processors and radio interfaces to system level architectures and optimizations. The second track is "Applying Computing towards Sustainability", covering topics that leverage computing to reduce the energy footprint of our society. In particular, we will focus on Smart Buildings and the Smart Grid, covering topics such as sensing, modeling and controlling the energy usage of buildings, new operating systems or software stacks for the smart infrastructure, as well as the privacy and security issues with the new "internet of things". The goal of this course is to help students acquire some of the knowledge and the skills needed to do research in this space of "Green Computing". Although the course is listed within SCS, it should be of interest to students in several departments, including ECE, MechE, CEE, EPP and Architecture.

17-350 Information Technology Policy: Evidence, Communication, & Advocacy
Spring: 9 units
In recent decades, developments in Information and Communication Technologies (ICTs) have rapidly moved from research environments to products and services used by billions of people. This rapid rate of change has often resulted in a public which does not understand the technologies shaping their lives and lawmakers who are poorly equipped to make sound policy. It is therefore incumbent upon specialists to communicate how ICTs work to the public and lawmakers so policy making is shaped by evidence and reflects public desires. This course will train students to be effective communicators and advocates in the ICT space. Students taking this course will learn about the broader scope of technology policymaking including formal lawmaking, agency rule-making, strategic litigation, and corporate social responsibility. Current ICT policy topics in privacy, free expression, net neutrality, and competition will be covered. Public communication strategies such as writing op-eds, interviewing with journalists, producing explanatory videos and interactive games will be explored. Finally, students will learn how to perform an expert role in areas such as writing policy briefs and providing testimony. The course is open to advanced undergraduate and graduate students. Graduate students whose research has public policy implications are encouraged to develop projects related to their research. There is no requirement for programming knowledge, but students with experience in developing interactive media and games will be encouraged to utilize such skills. The class will focus heavily on readings, critical evaluation of real ICT advocacy campaigns, and homework will provide hands-on experience with numerous strategies for public engagement. At the end of the semester students will have a portfolio of projects which they may release publicly.

17-355 Program Analysis
Spring: 12 units
This course covers both foundations and practical aspects of the automated analysis of programs, which is becoming increasingly critical to find software errors and assure program correctness. The theory of abstract interpretation captures the essence of a broad range of program analyses and supports reasoning about their correctness. Building on this foundation, the course will describe program representations, data flow analysis, alias analysis, inter-procedural analysis, dynamic analysis, Hoare Logic, and symbolic execution. Through assignments and projects, students will design and implement practical analysis tools that find bugs and verify properties of software. This course satisfies the Logic and Languages constrained elective category of the Computer Science major, and the Technical Software Engineering requirement for the Software Engineering minor.
Prerequisites: 15-251 Min. grade C and (15-214 Min. grade C or 15-150 Min. grade C)

Course Website: http://www.cs.cmu.edu/~aldrich/courses/17-355-18sp/

17-356 Software Engineering for Startups
Spring: 12 units
Startup engineering is critical to innovation. The skills required to effectively prototype, launch, and scale products are vital to engineers everywhere, from fledgling companies founded in dorm rooms to local mid-size companies to internal startups from multi-national tech giants. However, developing software in a startup environment poses unique engineering challenges. These challenges include making and justifying foundational architectural and technical decisions despite extreme uncertainty; rapidly prototyping and evaluating new ideas and features, while building minimum viable products; prioritizing engineering effort in severely constrained environments; and communicating effectively both within a small engineering team and with internal and external non-technical stakeholders. This course teaches the skills necessary to engineer successfully in a startup environment, through lectures, group projects, case study discussions, and guest speakers drawn from experienced, practicing startup engineers. This is an engineering-focused course; no entrepreneurship background is required or expected. Students do not need to have a startup idea to participate fully. Prerequisites: 15-214 OR 15-213
Prerequisites: 15-213 or 15-214

17-401 Software Engineering for AI-Enabled Systems
Fall: 12 units
New Course Need Description

Course Website: https://ckaestne.github.io/seai/

17-413 Software Engineering Practicum
Spring: 12 units
Note: This course previously offered as 15413. This course is a project-based course in which students conduct a semester-long project for a real client in small teams. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. After the course, students will have the teamwork, process, and product skills to be immediately competent in a software engineering organization, and will be able to evaluate the new processes and techniques they will encounter in the workplace.

17-415 Software Engineering Reflection
Fall: 6 units
Note: This course previously offered as 17-413. This course is an opportunity to reflect on a software engineering experience you have had in industry. It is structured as a writers workshop, in which you will work with the instructor and other students to identify and flesh out a software engineering theme that is illustrated by your industry experience. You will prepare a 10-page report on this theme, comparable to a practitioner's report at a conference like ICSE or OOPSLA, and a 30-minute presentation to match. This course fulfills a requirement of the Software Engineering Minor program, but students in other programs may take the course if they meet the prerequisite industry experience and if space is available.

17-422 Building User-Focused Sensing Systems
Fall and Spring: 12 units
Note: Previously offered as 08-421. These days we are surrounded by sensing and computation. Smart devices, such as smartphones, smartwatches, are packed with sensors. While they are already very useful devices, we have only started to scratch the surface here. The aim of this class will be to introduce the students to building and understanding smart sensing devices. The course will include discussion into contribution of various fields, including human-computer interaction, embedded computing, computer vision, distributed systems, machine learning, signal processing, security, and privacy. We will discuss how these various disciplines are coming together to form an end-to-end system that generates useful and user-actionable data. We will take a hands-on approach towards building and evaluating these systems. The students will gain practical experience in developing sensing systems in different application domains, such as activity recognition, health sensing, gestural interaction, etc. You will learn about embedded systems and understand the advantages and limitations of different platforms. You will learn about sensors and how to interface them with the real world to be able to get useful and actionable data. You will learn how to build a network of sensors that can communicate with each other. You will also learn about storing the sensor data for visualization, analysis and presentation both locally and to the cloud. The course will be a combination of lectures, tutorials, class discussions, and demonstrations. Students will be evaluated based on 5 mini-projects/assignments, class participation, weekly reading summaries, and a final project. All hardware resources will be provided to the students and they will be given an option to take their final prototypes with them for the cost of the hardware components. Students should have reasonable programming experience and an interest in tinkering.

17-428 Machine Learning and Sensing
Fall: 12 units
Machine learning and sensors are at the core of most modern computing devices and technology. From Amazon Echo to Apple Watch to Google Photos to self-driving cars, making sense of the data coming from powerful but noisy sensors is the key challenge. The aim of the course will be to explore this intersection of sensors and machine learning, understand the inner workings on modern computing technologies, and design the future ones. We will cover data collection, signal processing, data processing, data visualization, feature engineering, machine learning tools, and some prototyping technologies. The course will focus on class discussions, hands-on demonstrations, and tutorials. Students will be evaluated on their class participation, multiple mini projects, and a final team project.

17-437 Web Application Development
Fall and Spring: 12 units
Note: This course previously offered as 15-437. This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technologies introduced will be the Django framework for Python and Java Servlets, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, XML, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must be comfortable programming in Java and/or Python to register for this course. Students must provide their own computer hardware for this course. Please see the Related URL above for more information.
Prerequisites: 15-214 or 17-514 or 17-214 or 14-513 or 15-513 or 15-213 or 18-213

17-445 Software Engineering for AI-Enabled Systems
Fall: 12 units
The course takes a software engineering perspective on building software systems with a significant machine learning or AI component. It discusses how to take an idea and a model developed by a data scientist (e.g., scripts and Jupyter notebook) and deploy it as part of scalable and maintainable system (e.g., mobile apps, web applications, IoT devices). Rather than focusing on modeling and learning itself, this course assumes a working relationship with a data scientist and focuses on issues of design, implementation, operation, and assurance and how those interact with the data scientist's modeling. This course is aimed at software engineers who want to understand the specific challenges of working with AI components and at data scientists who want to understand the challenges of getting a prototype model into production; it facilitates communication and collaboration between both roles.

Course Website: https://ckaestne.github.io/seai/

17-480 API Design and Implementation
Fall: 12 units
This class focuses on the design of programming interfaces, the APIs, within larger real-world software and ecosystems. We discuss the history and importance of APIs, and the principles behind designing good APIs. This includes study of specific examples of APIs, both good and bad, for inspiration and precaution. Students gain experience with the major steps of API design: gathering requirements, documenting, testing, implementing, refining, evolving, and reimplementing APIs. The principles taught are largely language-independent, though most examples are in Java or C. Students may be able to do assignments in other languages, within reason.
Prerequisites: 15-214 or 15-213 or 17-214

17-514 Principles of Software Construction: Objects, Design, and Concurrency
Fall and Spring: 12 units
Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java.
Prerequisites: (15-121 Min. grade C or 15-122 Min. grade C) and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C)

17-536 Pervasive and Ubiquitous Computing
Intermittent: 12 units
Note: Previously offered as 08530. The aim of the class will be to explore the area of Ubiquitous Computing (ubicomp) and allow students to work on a variety of small technology projects. Students will be exposed to the basics of building ubicomp systems, emerging new research topics, and advanced prototyping techniques. This course will focus more on class discussions and hands on demonstrations, while formal lectures will be conducted only as needed. Students will be evaluated on their class participation, reading summaries, and mini projects.

17-537 Artificial Intelligence Methods for Social Good
Spring: 9 units
Note: Previously offered as 08-537. Optimization: mathematical programming, robust optimization, influence maximization Game Theory and Mechanism Design: security games, human behavior modeling, auction and market equilibrium, citizen science Machine Learning: classification, clustering, probabilistic graphical models, deep learning Sequential Decision Making: Markov Decision Processes (MDPs), partially observable MDPs, online planning, reinforcement learning In addition to providing a deep understanding of these methods, the course will introduce which societal challenges they can tackle and how, in the areas of (i) healthcare, (ii) social welfare, (iii) security and privacy, (iv) environmental sustainability. The course will also cover special topics such as AI and Ethics and AI and Humans. The course content is designed to not have too much overlap with other AI courses offered at CMU. Although the course is listed within SCS, it should be of interest to students in several other departments, including ECE, EPP and SDS. The students in this 9-unit course are expected to have taken at least three mathematics courses covering linear algebra, calculus, and probability. The students will work in groups on a systematic literature review or a project exploring the possibility of applying existing AI tools to a societal problem, with a survey paper or technical report and presentation delivered at the end of the semester.

17-562 Law of Computer Technology
Fall: 9 units
NOTE: Previously offered as 08-532. A survey of how legislatures and courts cope with rapidly advancing computer technologies and how scientific information is presented to, and evaluated by, civil authorities. The course is also an introduction to the legal process generally and the interaction between the legal system and technology organizations. Topics include: patents, copyrights in a networked world, law of the Internet, free speech, data security, technology regulation, international law, and trans-border crime. Open to juniors, seniors and graduate students in any school. Open to sophomores by permission of the instructor. Prerequisites: none.

17-615 Software Process Definition
Intermittent: 9 units
A software process definition is the cornerstone of implementing and improving a software process. The objective of this course is to prepare students to understand how processes work within the context of an operational, day-to-day engineering company, and most importantly how they can, as an individual within an engineering environment, change a process for the betterment of all. Although the focus is on software process, this course will be useful to all students who will be executing, improving, or defining most any type of process. An incremental methodology and modular approach to software process definition is used and covers: * guidelines for early success and building a sound foundation * organizing the process definition as it develops * approaches to avoid unnecessarily elaborate or formal notations * developing the process using organizational goals and constraints * using the environmental context that the process resides within and builds upon Although the focus is on software process, this course will be useful to all students who will be executing, improving, or defining most any type of process. Requirement: This course is intended for individuals who have operational software engineering experience or a comprehensive undergraduate coursework in software engineering.

17-619 Introduction to Real-Time Software and Systems
Intermittent: 12 units
Introduction to Real-Time Software and Systems presents an overview of time as it relates engineering complex systems. Any system that responds at the pace of relevant events has real-time constraints whether the timescale is short, like the flight controls for an aircraft, or longer, like the flight reservation system for an airline. Fundamental concepts, terminology, and issues of real-time systems are introduced in this course. The focus is on software solutions to real-time problems-solutions that must be both correct and timely. Software development is examined with emphasis on real-time issues during each phase of the software lifecycle. Real-time requirements analysis, architecting real-time systems, designing and modeling system timing, and implementation and testing strategies are studied. Modeling techniques using UML 2.0 are applied. Particular emphasis is placed on real-time scheduling to achieve desired timing, reliability, and robustness. Languages and operating systems for real-time computing, and real-time problems in concurrent and distributed systems are explored. This course provides a comprehensive view of real-time systems with theory, techniques and methods for the practitioner. After successfully completing this course, the student will be able to identify constraints and understand real-time issues in system development, and propose approaches to typical real-time problems. The aim of this course is to motivate and prepare students to pursue more in-depth study of specific problems in real-time computing and systems development. REQUIREMENT: Proficiency with a high-level programming language such as C or Ada and basic concepts of computing systems. Familiarity with software engineering concepts and system development lifecycle.

17-621 Computational Modeling of Complex Socio-Technical Systems
Intermittent: 12 units
NOTE: Previously offered as 08-621. Social and cultural systems are complex. Whether considering world transforming events such as the Arab Spring or the impact of health care reforms, the interactions among people, technology, and organizations can generate unanticipated outcomes. Computer simulation is a critical methodology for explaining and predicting these events. In this course, the basics of simulation modeling, design, testing and validation are covered. Different simulation approaches are contrasted such as agent-based modeling and system dynamics.

17-635 Software Measurement
Fall: 9 units
Sections D and PP are NOT available for on-campus students. The purpose of this course is to introduce students to software measurement — from need identification through analysis and feedback and into the process. Much of the course material demonstrates concepts of software measurement that are used by managers and practitioners in industry today. The course is taught within the framework of the software engineering process. Required text: Selected Readings handed out in class Requirement: This course is intended for individuals who have industrial software engineering experience with a large project, or a comprehensive undergraduate course in software engineering.

17-640 IoT, Big Data, and ML: A Hands-on Approach
Intermittent: 12 units
This course is designed to teach IoT concepts, big data, and machine learning techniques using a hands-on approach. An IoT system simulating an order fulfillment process is central to the hands-on learning of the concepts and techniques. Students will work in 4-5 person teams to enable the system and implement the requirements. In doing so, they will incorporate sound design principles of software engineering acquired in lectures. Students will capture the data generated during the execution of the system as it fulfills orders that are received from a front-end system developed by the students. Students will be expected to prepare, process, and model the data for statistical analysis applying techniques taught in class. They will then visualize, analyze and interpret the results, and implement improvements to obtain a 360-degree experience of a business application using the automated system. This course will provide insight into the ways in which business enterprises think about leveraging technology and software in the management of their production operations. The course prepares students for professional opportunities requiring such skills allowing them to identify use cases that facilitate innovation and promote competitiveness.

17-643 Hardware for Software Engineers
Intermittent
The goal of this course is to provide an understanding of electronics beyond the average computer organization course. Its purpose is to enable software engineers to be more effective in domains where software and hardware are closely coupled. Examples of such domains include robotics, avionics, automotive, process control, and many others. Students successfully completing this course will be better prepared to communicate with hardware-oriented engineers, understand the hardware environment, and the subtle regions where software and hardware meet. Requirement: Students need not have a hardware background, but they should have a solid computer science background including languages, data structures, discrete math, operating systems, and computer organization. It is highly desirable that students have project experience, preferably real-world experience, although project course work and/or internships will suffice. Undergraduates need instructor approval (lattanze@cs.cmu.edu).

17-648 Engineering Data Intensive Scalable Systems
Intermittent: 12 units
Internet services companies such as Google, Yahoo!, Amazon, and Facebook have pioneered systems that have achieved unprecedented scale while still providing high level availability and a high cost-performance. These systems differ from mainstream high performance systems in fundamental ways. They are data intensive rather than compute intensive as we see with mainstream super computers spending the bulk of their time performing data I/O and manipulation rather than computation. They need to inherently support scalability, typically having high reliability and availability demands as well. Given that they often operate in the commercial space the cost-performance of these systems needs to be such that the organizations dependent on such systems can turn a profit. Designing and building these systems require a specialized set of skills. This course will cover the set of topics needed in order to design and build data intensive scalable systems. In this domain engineers not only need to know how to architect systems that are inherently scalable, but to do so in a way that also supports high availability, reliability, and performance. Given the large distributed nature of these systems basic distributed systems concepts such as consistency and time and synchronization are also important. These systems largely operate around the clock, placing an emphasis on operational concerns. This course will introduce students to these concerns with the intent that they understand the extent to which things like deploying, monitoring, and upgrading impact the design. The course will be a hands-on project oriented course. The basic concepts will be given during the lectures and applied in the project. The students will gain exposure to the core concepts needed to design and build such systems as well as current technologies in this space. Class size will be limited.

17-649 Artificial Intelligence for Software Engineering
All Semesters: 12 units
Advances in artificial intelligence (AI) and machine learning (ML) offer new opportunities in software engineering to explore the design space and improve software quality. This includes discovering interactions among natural language requirements, prioritizing feature requests, and finding and fixing bugs. Consequently, software engineers must take on the role of data scientist, which entails curating datasets, understanding the trade-offs in statistical models, and learning to evaluate their models. This course aims to introduce students to advances in natural language processing (NLP), including symbolic and statistical NLP techniques, and in deep learning to analyze software artifacts. The course will emphasize algorithm setup and configuration, data preparation, analytic workflow, and evaluation. Datasets will be drawn from industrial requirements, mobile app reviews, bug reports and source code with documented vulnerabilities. At course end, students will understand terminology and have hands on experience to help guide their decisions in applying AI to contemporary engineering problems.

Course Website: http://relab.cs.cmu.edu/ai4se/

17-651 Models of Software Systems
Fall: 12 units
Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not MSE/MSIT-SE/MITS, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken an undergraduate discrete math course, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

17-652 Methods: Deciding What to Design
Fall: 12 units
Sections D and PP are NOT available for on-campus students. Practical development of software requires an understanding of successful methods for bridging the gap between a problem to be solved and a working software system. In this course you will study a variety of ways of understanding the problem to be solved by the system you're developing and of framing an appropriate solution to that problem. After completing this course, you will be able to: identify different classes of problems and their structures; analyze technical, organizational, usability, business, and marketing constraints on solutions; apply engineering approaches to frame solutions; understand how your understanding of the problem should be reflected in the software design. PREREQUISITE: minimum of 3 months hands-on software development experience in industry. Students not accepted into the MSE program must present a current resume showing relevant industrial experience to department coordinator. This course is offered to only MSE/MITS and MSIT-SE students for fall semester. This course is for graduate students only. This course is for letter grade only (no pass/fail grades). To register for Methods course, you will need a requirement of a minimum of 3 mos hands-on software development experience in industry. Please submit a statement that gives the company, the dates, and a sentence or two about what you were actually doing during that time (i.e. programming, testing, other things actually involved in software development)to jdh@cs.cmu.edu. This is a graduate course. Only undergrad SE minors may take this course.

Course Website: http://spoke.compose.cs.cmu.edu/methods-fall-05/res/bib.htm

17-653 Managing Software Development
Fall: 12 units
Sections D, F, PP and G are NOT available for on-campus students. Large scale software development requires the ability to manage resources - both human and computational - through control of the development process. This course provides the knowledge and skills necessary to lead a project team, understand the relationship of software development to overall product engineering, estimate time and costs, and understand the software process. After completing this course, students will: 1. be able to write a software project management plan, addressing issues of risk analysis, schedule, costs, team organization, resources, and technical approach 2. be able to define the key process areas of the Capability Maturity Model and the technology and practices associated with each and a variety of software development life cycle models and explain the strengths, weaknesses, and applicability of each 3. understand the relationship between software products and overall products (if embedded), or the role of the product in the organizational product line 4. understand the legal issues involved in liability, warranty, patentability, and copyright 5. understand the purpose and limitations of software development standards and be able to apply sensible tailoring where needed 6. be able to use software development standards for documentation and implementation 7. be able to apply leadership principles 8. be able to perform requirements elicitation REQUIREMENT: Students must have had industrial software engineering experience with a large project, or a comprehensive undergraduate course in software engineering. This course is for letter grade only. Contact the instructor (mirandae@andrew.cmu.edu) for permission to join the class. This is a course for graduate students. Only undergrad SE minors may take this course.

Course Website: http://mse.isri.cmu.edu/software-engineering/documents/syllabi/17-653_F15_MSD_Syllabus.pdf

17-654 Analysis of Software Artifacts
Spring: 12 units
Analysis is the systematic examination of an artifact to determine its properties. This course will focus on analysis of software artifacts—primarily code, but also including analysis of designs, architectures, and test suites. We will focus on functional properties, but also cover non-functional properties like performance and security. In order to illustrate core analysis concepts in some depth, the course will center on static program analysis; however, the course will also include a breadth of techniques such as testing, model checking, theorem proving, dynamic analysis, and type systems. The course will balance theoretical discussions with lab exercises in which students will apply the ideas they are learning to real artifacts. After completing this course, students will: * know what kinds of analyses are available and how to use them * understand their scope and power,when they can be applied and what conclusions can be drawn from their results * have a grasp of fundamental notions sufficient to evaluate new kinds of analysis when they are developed * have some experience selecting and writing analyses for a real piece of software, applying them and interpreting the results Ph.D. students taking the 17-754 version of the course will gain a broad overview of the analysis research literature and in-depth knowledge of a particular sub-area through a course project. Requirement: A recent discrete math course and programming experience. Strongly Recommended: Models of SW Development course (17-651) before taking this course. This course is for letter grade only (no pass/fail grades). This is a graduate course. Only undergrad SE minors may take this course with the instructor's permission.

Course Website: http://www-2.cs.cmu.edu/~aldrich/courses/654/

17-655 Architectures for Software Systems
Spring: 12 units
Successful design of complex software systems requires the ability to describe, evaluate, and create systems at an architectural level of abstraction. This course introduces architectural design of complex software systems. The course considers commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures. It teaches the skills and background students need to evaluate the architectures of existing systems and to design new systems in principled ways using well-founded architectural paradigms. After completing this course, students will be able to: 1. describe an architecture accurately 2. recognize major architectural styles in existing software systems 3. generate architectural alternatives for a problem and choose among them 4. construct a medium-sized software system that satisfies an architectural specification 5. use existing definitions and development tools to expedite such tasks 6. understand the formal definition of a number of architectures and be able to reason about the properties of those architectures 7. use domain knowledge to specialize an architecture for a particular family of applications. REQUIREMENT: Experience with at least one large software system, either through industrial software development experience or an undergraduate course in software engineering, compilers, operating sys., or the like. This course is for letter grade only. Instructor wants each student who wants to take his Architectures class to have worked on a significant software system in your courses or in industry. Write to (garlan@cs.cmu.edu) for admission into the course stating the experience you have had. This is a graduate course. Only undergrad SE minors may take this course

17-685 Dynamic Network Analysis
Spring: 12 units
Who knows who? Who knows what? Who communicates with whom? Who is influential? How do ideas, diseases, and technologies propagate through groups? How do social media, social, knowledge, and technology networks differ? How do these networks evolve? How do network constrain and enable behavior? How can a network be compromised or made resilient? Such questions can be addressed using Network Science. Network Science, a.k.a. social network analysis and link analysis, is a fast-growing interdisciplinary field aimed at understanding simple & high dimensional networks, from both a static and a dynamic perspective. Across an unlimited application space, graph theoretic, statistical, & simulation methodologies are used. An interdisciplinary perspective on network science is provided, with an emphasis on high-dimensional dynamic data. The fundamentals of network science, methods, theories, metrics & confidence estimation, constraints on data collection & bias, and key research findings & challenges are examined. Illustrative networks discussed include social media based (e.g., twitter), disaster response, organizational, semantic, political elite, crises, terror, & P2P networks. Critical procedures covered include: basic centralities and metrics, group and community detection, link inference, network change detection, comparative analytics, and big data techniques. Applications from business, science, art, medicine, forensics, social media & numerous other areas are explored. Key issues addressed: Conceptualization, measurement, comparison & evaluation of networks. Identification of influential nodes and hidden groups. Network emergence, evolution, change & destabilization. Graduate course taught every other year. Prerequisite: Undergraduate-level statistics course or instructor permission. Linear algebra is recommended. Students are encouraged to bring & use their own data, or to use provided data.

17-702 Current Topics in Privacy Seminar
Fall and Spring: 3 units
Note: Previously offered as 08-602. In this seminar course students will discuss recent papers and current public policy issues related to privacy. Privacy professionals from industry, government, and non-profits will deliver several guest lectures each semester.

17-731 Foundations of Privacy
Fall: 12 units
Note: Previously offered as 08-604. Privacy is a significant concern in modern society. Individuals share personal information with many different organizations - healthcare, financial and educational institutions, the census bureau, Web services providers and online social networks - often in electronic form. Privacy violations occur when such personal information is inappropriately collected, shared or used. We will study privacy in a few settings where rigorous definitions and enforcement mechanisms are being developed - statistical disclosure limitation (as may be used by the census bureau in releasing statistics), semantics and logical specification of privacy policies that constrain information flow and use (e.g., by privacy regulations such as the HIPAA Privacy Rule and the Gramm-Leach-Bliley Act), principled audit and accountability mechanisms for enforcing privacy policies, anonymous communication protocols - and other settings in which privacy concerns have prompted much research, such as in social networks, location privacy and Web privacy (in particular, online tracking & targeted advertising).

17-749 Artificial Intelligence for Software Engineering
All Semesters: 12 units
Advances in artificial intelligence (AI) and machine learning (ML) offer new opportunities in software engineering to explore the design space and improve software quality. This includes discovering interactions among natural language requirements, prioritizing feature requests, and finding and fixing bugs. Consequently, software engineers must take on the role of data scientist, which entails curating datasets, understanding the trade-offs in statistical models, and learning to evaluate their models. This course aims to introduce students to advances in natural language processing (NLP), including symbolic and statistical NLP techniques, and in deep learning to analyze software artifacts. The course will emphasize algorithm setup and configuration, data preparation, analytic workflow, and evaluation. Datasets will be drawn from industrial requirements, mobile app reviews, bug reports and source code with documented vulnerabilities. At course end, students will understand terminology and have hands on experience to help guide their decisions in applying AI to contemporary engineering problems.

Course Website: http://www.cs.cmu.edu/~sadeh/17%20749.html

17-781 Mobile and IoT Computing Services
Spring: 12 units
With over 6 billion mobile phone users worldwide, including well over a 2 billion smart phone users, new wireless and pervasive computing applications and services are changing the way enterprises interact with customers and employees. The explosion in smart phone ownership along with the deployment of 4G and soon 5G networks is leading to a slew of new mobile apps and services. They range from mobile commerce and enterprise apps, social networking apps, all the way to more Internet of Things technologies (e.g. smart homes, smart cars, smart glasses, health/fitness sensors). These apps and services are emerging as part of an increasingly rich ecosystem where context awareness and intelligent predictive technologies are used to offer increasingly personalized experiences to users. This same ecosystem has emerged as the engine behind increasingly targeted marketing and advertising scenarios that also raise challenging privacy issues. The course objective is to introduce participants to the technologies, services and business models associated with Mobile and Pervasive Commerce. It also provides an overview of future trends and ongoing research. You will learn to evaluate critical design tradeoffs associated with different mobile technologies, architectures, interfaces and business models and how they impact the usability, security, privacy and commercial viability of mobile and pervasive computing services and apps. Topics include Mobile Communications, Mobile OS, Mobile Web technologies including app development, Mobile Security, Mobile Payments, Mobile Web Apps and Services (e.g. Mobile Entertainment, Mobile Banking, Mobile, Mobile Social Networking, Mobile Health, etc.), Location-Based Services, RFID, Mobile Enterprise Apps, Pervasive Computing Applications, Context awareness, intelligent assistant technologies, and privacy.

Course Website: http://www.normsadeh.com/ms-course-overview

17-801 Dynamic Network Analysis
Spring: 12 units
Note: Previously offered as 08-801. Who knows who? Who knows what? Who communicates with whom? Who is influential? How do ideas, diseases, and technologies propagate through groups? How do social media, social, knowledge, and technology networks differ? How do networks evolve? How do networks constrain and enable behavior? How can a network be destroyed or made resilient? Such questions can be addressed using network science. Network Science, also referred to as social network analysis and link analysis, is an interdisciplinary field aimed at understanding complex behavior using networks. Graph theoretic, statistical and simulation techniques are used. Applications areas are limited only be your imagination. This course covers the basics of network science from an interdisciplinary perspective. Key methods, theories, constraints on data collection, research findings and challenges are examined. Application areas discussed include: social media (e.g. twitter), disaster response, organizational networks, citation networks, semantic networks, political elite networks and crises, terror networks, disease and health networks, nation-state networks, and cyber networks. Methods covered include: basic centralities, group and community detection, link inference, network change detection, comparative analytics and big data techniques. Questions addressed include:How do we conceptualize, measure, compare and evaluate various types of networks? How do we evaluate the impact of policies and technology on networks? What nodes, relations, groups, or motifs stand out or are influential in a network? How do networks emerge, evolve, and change? Prerequisite: Undergraduate-level statistics course or permission of instructor. Linear algebra is recommended but not required. Students are encouraged to bring and use their own data, or to use publicly available network dataset for assignments.

Course Website: http://lorrie.cranor.org/courses/sp04/

17-821 Computational Modeling of Complex Socio-Technical Systems
Spring: 12 units
NOTE: Previously offered as 08-810. Social and cultural systems are complex. Whether considering world transforming events such as the Arab Spring or the impact of health care reforms, the interactions among people, technology, and organizations can generate unanticipated outcomes. Computer simulation is a critical methodology for explaining and predicting these events. In this course, the basics of simulation modeling, design, testing and validation are covered. Different simulation approaches are contrasted such as agent-based modeling and system dynamics.

SCS: Language Technologies Institute Courses

11-291 Applied Computational Intelligence Lab
Intermittent: 9 units
What would an "intelligent" picture on the wall do? What if it could see and hear you? What should it say if it could talk? What if your pantry, wardrobe or medicine cabinet could sense, think and act? What should they do and say? What should your cell phone be saying to you? These are not whimsical or theoretical questions...they inevitably arise as ordinary everyday objects around us acquire the ability to sense changes in their environment, think about their implications, and act in pursuit of their goals. These objects are connected to the web and become conduits for services, erasing the distinction between products and services. The ability to invent and build smart products/services is becoming a key skill in the new technology-driven services economy. The focus of the course will be on building "ordinary" objects that can sense, think and act in the real world and on exploring the implications of these capabilities. Students will select their own project and by the end of the semester will create a working prototype that will be exhibited in a public place. Prizes will be offered for the most creative projects. In the course of their projects, students will learn how to use state-of-the-art tools for: Object detection using video cameras, microphones and other sensors Movement and gesture detection Speech recognition and generation Reasoning and planning: While the course organizers have many ideas for specific projects, students will be encouraged to design their own projects. Students are expected to work in small groups on their own time and receive faculty advice as needed. There will be weekly meetings of the whole class.
Prerequisites: 21-127 Min. grade C and 15-122 Min. grade C

11-324 Human Language for Artificial Intelligence
Fall: 12 units
An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-344 Machine Learning in Practice
Fall: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization.

11-364 An Introduction to Knowledge-Based Deep Learning and Socratic Coaches
Spring: 12 units
The subject of this course will be deep learning, one of the most dynamic and exciting emerging areas of computer science. Deep learning deals with and is conquering the problems resulting from the enormous quantity of data that now surrounds us. Furthermore, the course will explore knowledge-based deep learning, a new methodology invented by the instructor that offers many potential advantages over conventional deep learning. This is a learn-by-doing, team-project based course, which will be divided into four phases. In phase one, each student will read and present a number of papers describing state-of-the-art deep learning systems and successful applications. In phase two, each team will implement the system described in one of the papers. In phase three, each team will scale that implementation to one of the large benchmark datasets. In phase four, each team will do a special research project implementing a knowledge-based deep learning system based on pending patent applications of Professor Baker. As a potential follow-on for successful projects, students may participate in a summer course on entrepreneurial applications of deep learning or work as interns in a bootstrap startup based on the knowledge-based deep learning projects. Prerequisite: Strong quantitative aptitude, programming skill, ability to quickly absorb new ideas, teamwork skills.

11-411 Natural Language Processing
Intermittent: 12 units
This course will introduce students to the highly interdisciplinary area of Artificial Intelligence known alternately as Natural Language Processing (NLP) and Computational Linguistics. The course aims to cover the techniques used today in software that does useful things with text in human languages like English and Chinese. Applications of NLP include automatic translation between languages, extraction and summarization of information in documents, question answering and dialog systems, and conversational agents. This course will focus on core representations and algorithms, with some time spent on real-world applications. Because modern NLP relies so heavily on Machine Learning, we'll cover the basics of discrete classification and probabilistic modeling as we go. Good computational linguists also know about Linguistics, so topics in linguistics (phonology, morphology, and syntax) will be covered when fitting. From a software engineering perspective, there will be an emphasis on rapid prototyping, a useful skill in many other areas of Computer Science. In particular, we will introduce some high-level languages (e.g., regular expressions and Dyna) and some scripting languages (e.g., Python and Perl) that can greatly simplify prototype implementation.
Prerequisite: 15-122

11-423 ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.
Spring: 12 units
Students will work individually or in small groups to create artificial human(oid) languages for fictional human cultures or SciFi worlds. Students will implement language technologies for their languages. In the course of creating the languages, students will learn about the building blocks of human language such as phones, phonemes, morphemes, and morpho-syntactic constructions including their semantics and pragmatics. Class instruction will focus specifically on variation among human languages so that the students can make conlangs that are not just naively English-like. We will also touch on philosophical issues in philosophy of language and on real-world socio-political issues related to language policy. Students will be required to use at least one of the following technologies: language documentation tools that are used for field linguistics and corpus annotation, automatic speech recognition, speech synthesis, morphological analysis, parsing, or machine translation. Learning Objectives: 1. The building blocks (phonemes, morphemes, etc.) of language, how languages are built from them, and how they interact 2. Metalinguistic awareness and knowledge about variation in human language 3. Language, thought, and culture: how does language reflect thought and culture, and vice versa. Why wouldn't Elvish be a good language for Klingons? 4. Language policy in the real world: For students who want to manipulate real languages. 5. Historical linguistics and language change: for students who want to manipulate real languages or make families of related conlangs for fictional worlds. 6. Practical experience with a language technology. http://tts.speech.cs.cmu.edu/11-823/
Course Website: http://tts.speech.cs.cmu.edu/11-823

11-441 Machine Learning for Text Mining
Fall and Spring: 9 units
This course provides a comprehensive introduction to the theory and implementation of algorithms for organizing and searching large text collections. The first half of the course studies text search engines for enterprise and Web environments; the open-source Indri search engine is used as a working example. The second half studies text mining techniques such as clustering, categorization, and information extraction. Programming assignments give hands-on experience with document ranking algorithms, categorizing documents into browsing hierarchies, and related topics.

11-442 Search Engines
Fall: 9 units
This course studies the theory, design, and implementation of text-based search engines. The core components include statistical characteristics of text, representation of information needs and documents, several important retrieval models, and experimental evaluation. The course also covers common elements of commercial search engines, for example, integration of diverse search engines into a single search service ("federated search", "vertical search"), personalized search results, diverse search results, and sponsored search. The software architecture components include design and implementation of large-scale, distributed search engines.

Course Website: http://boston.lti.cs.cmu.edu/classes/11-642/

11-485 Introduction to Deep Learning
Intermittent: 9 units
Neural networks have increasingly taken over various AI tasks, and currently produce the state of the art in many AI tasks ranging from computer vision and planning for self-driving cars to playing computer games. Basic knowledge of NNs, known currently in the popular literature as "deep learning", familiarity with various formalisms, and knowledge of tools, is now an essential requirement for any researcher or developer in most AI and NLP fields. This course is a broad introduction to the field of neural networks and their "deep" learning formalisms. The course traces some of the development of neural network theory and design through time, leading quickly to a discussion of various network formalisms, including simple feedforward, convolutional, recurrent, and probabilistic formalisms, the rationale behind their development, and challenges behind learning such networks and various proposed solutions. We subsequently cover various extensions and models that enable their application to various tasks such as computer vision, speech recognition, machine translation and playing games. Instruction Unlike prior editions of 11-785, the instruction will primarily be through instructor lectures, and the occasional guest lecture. Evaluation Students will be evaluated based on weekly continuous-evaluation tests, and their performance in assignments and a final course project. There will be six hands-on assignments, requiring both low-level coding and toolkit-based implementation of neural networks, covering basic MLP, convolutional and recurrent formalisms, as well as one or more advanced tasks, in addition to the final project.
Prerequisites: 15-112 and 21-120 and 21-241

11-492 Speech Processing
Fall: 12 units
Speech Processing offers a practical and theoretical understanding of how human speech can be processed by computers. It covers speech recognition, speech synthesis and spoken dialog systems. The course involves practicals where the student will build working speech recognition systems, build their own synthetic voice and build a complete telephone spoken dialog system. This work will be based on existing toolkits. Details of algorithms, techniques and limitations of state of the art speech systems will also be presented. This course is designed for students wishing understand how to process real data for real applications, applying statistical and machine learning techniques as well as working with limitations in the technology.
Prerequisite: 15-211 Min. grade B

11-546 Applied Legal Analytics & Artificial Intelligence
Spring: 12 units
Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon University¿s Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industry¿s need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: https://luimagroup.github.io/appliedlegalanalytics/

11-630 MCDS Practicum Internship
Fall
The MCDS Practicum course is used for recording CDS students summer internships for the MCDS Program. Section A is used for 7-month internship opportunities Section B is used for Returning Fall Analytic students who DO NOT attain a 7-mo Internships. Section R is used to record MCDS students Internship Requirements

11-646 Applied Legal Analytics & Artificial Intelligence
Spring: 12 units
Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon University¿s Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industry¿s need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: https://luimagroup.github.io/appliedlegalanalytics/

11-661 Language and Statistics
Fall: 12 units
Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob&stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI & SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: http://www.cs.cmu.edu/~roni/11661/

11-696 MIIS Capstone Planning Seminar
Spring: 6 units
The MIIS Capstone Planning Seminar prepares students to complete the MIIS Capstone Project in the following semester. Students are organized into teams that will work together to complete the capstone project. They define project goals, requirements, success metrics, and deliverables; and they identify and acquires data, software, and other resources required for successful completion of the project. The planning seminar must be completed in the semester prior to taking the capstone project.

11-711 Algorithms for NLP
All Semesters: 12 units
Algorithms for NLP is an introductory graduate-level course on the computational properties of natural languages and the fundamental algorithms for processing natural languages. The course will provide an in-depth presentation of the major algorithms used in NLP, including Lexical, Morphological, Syntactic and Semantic analysis, with the primary focus on parsing algorithms and their analysis.

11-716 Graduate Seminar on Dialog Processing
All Semesters: 6 units
Dialog systems and processes are becoming an increasingly vital area of interest both in research and in practical applications. The purpose of this course will be to examine, in a structured way, the literature in this area as well as learn about ongoing work. The course will cover traditional approaches to the problem, as exemplified by the work of Grosz and Sidner, as well as more recent work in dialog, discourse and evaluation, including statistical approaches to problems in the field. We will select several papers on a particular topic to read each week. While everyone will do all readings, a presenter will be assigned to overview the paper and lead the discussion. On occasion, a researcher may be invited to present their own work in detail and discuss it with the group. A student or researcher taking part in the seminar will come away with a solid knowledge of classic work on dialog, as well as familiarity with ongoing trends.

11-721 Grammars and Lexicons
All Semesters: 12 units
Grammars and Lexicons is an introductory graduate course on linguistic data analysis and theory, focusing on methodologies that are suitable for computational implementations. The course covers major syntactic and morphological phenomena in a variety of languages. The emphasis will be on examining both the diversity of linguistic structures and the constraints on variation across languages. Students will be expected to develop and defend analyses of data, capturing linguistic generalizations and making correct predictions within and across languages. The goal is for students to become familiar with the range of phenomena that occur in human languages so that they can generalize the insights into the design of computational systems. The theoretical framework for syntactic and lexical analysis will be Lexical Functional Grammar. Grades will be based on problem sets and take-home exams.

11-722 Grammar Formalisms
Intermittent: 12 units
The goal of this course is to familiarize students with grammar formalisms that are commonly used for research in computational lingusitics, language technologies, and lingusitics. We hope to have students from a variety disciplines (linguistics, computer science, psychology, modern languages, philosophy) in order to cover a broad perspective in class discussions. Comparison of formalisms will lead to a deeper understanding of human language and natural language processing algorithms. The formalisms will include: Head Driven Phrase Structure Grammar, Lexical Functional Grammar, Tree Adjoining Grammar and Categorial Grammar. If time permits, we will cover Penn Treebank, dependency grammar, and Construction Grammar. We will cover the treatment of basic syntactic and semantic phenomena in each formalism, and will also discuss algorithms for parsing and generating sentences for each formalism. If time permits, we may discuss formal language theory and generative capacity. The course is taught jointly by the following faculty of the Language Technologies Institute: Alan Black Alon Lavie Lori Levin (main coordinator)

11-731 Machine Translation and Sequence-to-Sequence Models
Spring: 12 units
Instructors: Graham Neubig. Prerequisites: This course has no official pre-requisites, although 11-711 "Algorithms for NLP" or 10-701 "Machine Learning" would be helpful. Course Description: Machine Translation and Sequence-to-Sequence Models is an introductory graduate-level course surveying the primary approaches and methods for developing systems to translate between human languages, or other sequential data. The main objective of the course is to obtain basic understanding and implementation skills for modern methods for MT and sequence transduction, including how to design models, how to learn the model parameters, how to search for the best output, and how to create training data. The course will focus on machine translation, but also briefly cover tasks such as dialog response generation, image caption generation, and others.

11-741 Machine Learning for Text Mining
Fall and Spring: 12 units
This course studies the theory, design, and implementation of text-based information systems. The Information Retrieval core components of the course include statistical characteristics of text, representation of information needs and documents, several important retrieval models (Boolean, vector space, probabilistic, inference net, language modeling), clustering algorithms, automatic text categorization, and experimental evaluation. The software architecture components include design and implementation of high-capacity text retrieval and text filtering systems. A variety of current research topics are also covered, including cross-lingual retrieval, document summarization, machine learning, topic detection and tracking, and multi-media retrieval. Prerequisites: Programming and data-structures at the level of 15-212 or higher. Algorithms comparable to the undergraduate CS algorithms course (15-451) or higher. Basic linear algebra (21-241 or 21-341). Basic statistics (36-202) or higher.

11-751 Speech Recognition and Understanding
All Semesters: 12 units
The technology to allow humans to communicate by speech with machines or by which machines can understand when humans communicate with each other is rapidly maturing. This course provides an introduction to the theoretical tools as well as the experimental practice that has made the field what it is today. We will cover theoretical foundations, essential algorithms, major approaches, experimental strategies and current state-of-the-art systems and will introduce the participants to ongoing work in representation, algorithms and interface design. This course is suitable for graduate students with some background in computer science and electrical engineering, as well as for advanced undergraduates. Prerequisites: Sound mathematical background, knowledge of basic statistics, good computing skills. No prior experience with speech recognition is necessary. This course is primarily for graduate students in LTI, CS, Robotics, ECE, Psychology, or Computational Linguistics. Others by prior permission of instructor.

11-752 Speech II: Phonetics, Prosody, Perception and Synthesis
Spring: 12 units
The goal of the course is to give the student basic knowledge from several fields that is necessary in order to pursue research in automatic speech processing. The course will begin with a study of the acoustic content of the speech signal. The students will use the spectrographic display to examine the signal and discover its variable properties. Phones in increasingly larger contexts will be studied with the goal of understanding coarticulation. Phonological rules will be studied as a contextual aid in understanding the spectrographic display. The spectrogram will then serve as a first introduction to the basic elements of prosody. Other displays will then be used to study the three parts of prosody: amplitude, duration, and pitch. Building on these three elements, the student will then examine how the three interact in careful and spontaneous speech. Next, the students will explore perception. Topics covered will be: physical aspects of perception, psychological aspects of perception, testing perception processes, practical applications of knowledge about perception. The second part of this course will cover all aspects of speech synthesis. Students need only have a basic knoweldge of speech and language processing. Some degree of programming and statistical modelling will be beneficial, but not required. Taught every other year

11-755 Machine Learning for Signal Processing
Fall: 12 units
Signal Processing is the science that deals with extraction of information from signals of various kinds. This has two distinct aspects — characterization and categorization. Traditionally, signal characterization has been performed with mathematically-driven transforms, while categorization and classification are achieved using statistical tools. Machine learning aims to design algorithms that learn about the state of the world directly from data. A increasingly popular trend has been to develop and apply machine learning techniques to both aspects of signal processing, often blurring the distinction between the two. This course discusses the use of machine learning techniques to process signals. We cover a variety of topics, from data driven approaches for characterization of signals such as audio including speech, images and video, and machine learning methods for a variety of speech and image processing problems.

11-761 Language and Statistics
Fall: 12 units
Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob&stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI & SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: http://www.cs.cmu.edu/~roni/11761/

11-762 Language and Statistics II
Fall: 12 units
This course will cover modern empirical methods in natural language processing. It is designed for language technologies students who want to understand statistical methodology in the language domain, and for machine learning students who want to know about current problems and solutions in text processing. Students will, upon completion, understand how statistical modeling and learning can be applied to text, be able to develop and apply new statistical models for problems in their own research, and be able to critically read papers from the major related conferences (EMNLP and ACL). A recurring theme will be the tradeoffs between computational cost, mathematical elegance, and applicability to real problems. The course will be organized around methods, with concrete tasks introduced throughout. The course is designed for SCS graduate students. Prerequisite: Language and Statistics (11-761) or permission of the instructor. Recommended: Algorithms for Natural Language Processing (11-711), Machine Learning (15-681, 15-781, or 11-746).
Prerequisite: 11-761

11-763 Structured Prediction for Language and other Discrete Data
Fall: 12 units
This course seeks to cover statistical modeling techniques for discrete, structured data such as text. It brings together content previously covered in Language and Statistics 2 (11-762) and Information Extraction (10-707 and 11-748), and aims to define a canonical set of models and techniques applicable to problems in natural language processing, information extraction, and other application areas. Upon completion, students will have a broad understanding of machine learning techniques for structured outputs, will be able to develop appropriate algorithms for use in new research, and will be able to critically read related literature. The course is organized around methods, with example tasks introduced throughout.

Course Website: http://www.cs.cmu.edu/~nasmith/SPFLODD/

11-777 Multimodal Machine Learning
Fall: 12 units
Multimodal machine learning (MMML) is a vibrant multi-disciplinary research field which addresses some of the original goals of artificial intelligence by integrating and modeling multiple communicative modalities, including linguistic, acoustic and visual messages. With the initial research on audio-visual speech recognition and more recently with language vision projects such as image and video captioning, this research field brings some unique challenges for multimodal researchers given the heterogeneity of the data and the contingency often found between modalities. The course will present the fundamental mathematical concepts in machine learning and deep learning relevant to the five main challenges in multimodal machine learning: (1) multimodal representation learning, (2) translation & mapping, (3) modality alignment, (4) multimodal fusion and (5) co-learning. These include, but not limited to, multimodal auto-encoder, deep canonical correlation analysis, multi-kernel learning, attention models and multimodal recurrent neural networks. We will also review recent papers describing state-of-the-art probabilistic models and computational algorithms for MMML and discuss the current and upcoming challenges. The course will discuss many of the recent applications of MMML including multimodal affect recognition, image and video captioning and cross-modal multimedia retrieval. This is a graduate course designed primarily for PhD and research master students at LTI, MLD, CSD, HCII and RI; others, for example (undergraduate) students of CS or from professional master programs, are advised to seek prior permission of the instructor. It is required for students to have taken an introduction machine learning course such as 10-401, 10-601, 10-701, 11-663, 11-441, 11-641 or 11-741. Prior knowledge of deep learning is recommended."

Course Website: https://piazza.com/cmu/fall2018/11777/home

11-792 Intelligent Information Systems Project
Spring: 12 units
The Software Engineering for IS sequence combines classroom material and assignments in the fundamentals of software engineering (11-791) with a self-paced, faculty-supervised directed project (11-792). The two courses cover all elements of project design, implementation, evaluation, and documentation. Students may elect to take only 11-791; however, if both parts are taken, they should be taken in proper sequence. Prerequisite: 11-791. The course is required for VLIS students.
Prerequisites: 11-791 or 15-393

11-927 MIIS Capstone Project
Fall: 36 units
The capstone project course is a group-oriented demonstration of student skill in one or more areas covered by the degree. Typically the result of the capstone project is a major software application. The capstone project course consists of two components. The classroom component guides students in project planning, team management, development of requirements and design specifications, and software tools for managing group-oriented projects. The lab component provides project-specific technical guidance and expertise, for example in the development of a question answering system, dialog, or sentiment analysis application. Thus, each project receives two types of supervision, often from two separate members of the faculty.

SCS: Machine Learning Courses

10-301 Introduction to Machine Learning
Fall and Spring: 12 units
Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10301 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation & the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets & Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam. 10301 is recommended for undergraduates who are not SCS majors. (SCS majors should instead take 10315.) Prerequisites (strictly enforced): strong quantitative aptitude, college probability & statistics course, and programming proficiency. For learning to apply ML practically & effectively, without the above prerequisites, consider 11344/05834 instead. You can evaluate your ability to take the course via a self-assessment exam (http://bit.ly/2fkddDN). Also, be sure to read the ML course comparison (http://bit.ly/2eV3UaD).
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (36-218 Min. grade C or 15-359 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 36-217 Min. grade C)

10-315 Introduction to Machine Learning (Undergrad)
Spring: 12 units
Machine learning is subfield of computer science with the goal of exploring, studying, and developing learning systems, methods, and algorithms that can improve their performance with learning from data. This course is designed to give undergraduate students a one-semester-long introduction to the main principles, algorithms, and applications of machine learning and is specifically designed for the SCS undergrad majors. The topics of this course will be in part parallel with those covered in the graduate machine learning courses (10-715, 10-701, 10-601), but with a greater emphasis on applications and case studies in machine learning. After completing the course, students will be able to: *select and apply an appropriate supervised learning algorithm for classification problems (e.g., naive Bayes, perceptron, support vector machine, logistic regression). *select and apply an appropriate supervised learning algorithm for regression problems (e.g., linear regression, ridge regression). *recognize different types of unsupervised learning problems, and select and apply appropriate algorithms (e.g., clustering, linear and nonlinear dimensionality reduction). *work with probabilities (Bayes rule, conditioning, expectations, independence), linear algebra (vector and matrix operations, eigenvectors, SVD), and calculus (gradients, Jacobians) to derive machine learning methods such as linear regression, naive Bayes, and principal components analysis. *understand machine learning principles such as model selection, overfitting, and underfitting, and techniques such as cross-validation and regularization. *implement machine learning algorithms such as logistic regression via stochastic gradient descent, linear regression (using a linear algebra toolbox), perceptron, or k-means clustering. *run appropriate supervised and unsupervised learning algorithms on real and synthetic data sets and interpret the results.
Prerequisites: 15-122 Min. grade C and (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C) and (15-359 Min. grade C or 36-218 Min. grade C or 36-217 Min. grade C or 21-325 Min. grade C or 36-225 Min. grade C)

10-335 Art and Machine Learning
Spring: 12 units
Ars, the Latin origin of the word art, means Art and Science. These two fields, which have been separated for a long time, are joining back together in many areas. One of those junctions is where Art and Machine Learning meet. Art in recent years has been moving forward along with the rise of new technologies and scientific discoveries. Machine Learning (ML) is one of the most cutting edge advancements in Computer Science. The popularity and accessibility of frameworks such as Google's Deep Dream system, Pikazo the neural style transfer, Kulitta AI Music Generation Framework, Deep Mind's WaveNet, Sony's Flow Machines, and recurrent neural network based language models brought great attention to the marriage of Art and ML methods. The number of ML applications that mimic famous artworks, e.g. The Next Rembrandt project, or even create original artworks such as the robot artist TAIDA's paintings, is rapidly growing. Increasing number of artists are also attempting to use ML methods in their artworks. This course is project-based and aims to introduce the crossroad of Art and Machine Learning to the broad range of students including both Art and Computer Science majors. We will offer the knowledge of examples, technologies, and issues that connect Art and Machine Learning to the students. Students will study example codes and produce creative applications/artworks using ML methods. Students do not need to have pre-existing knowledge of Machine Learning or experience of Art practice. Students are required to have basic understanding of Python and be open-minded, for example, open to learn the necessary mathematical background and open to discussions on conceptual development and artistic value of their projects.

10-401 Introduction to Machine Learning (Undergrad)
Fall and Spring: 12 units
Machine learning is subfield of computer science with the goal of exploring, studying, and developing learning systems, methods, and algorithms that can improve their performance with learning from data. This course is designed to give undergraduate students a one-semester-long introduction to the main principles, algorithms, and applications of machine learning. Topics. The topics of this course will be in part parallel with those covered in the graduate machine learning courses (10-715, 10-701, 10-601), but with a greater emphasis on applications and case studies in machine learning. After completing the course, students will be able to: *select and apply an appropriate supervised learning algorithm for classification problems (e.g., naive Bayes, perceptron, support vector machine, logistic regression). *select and apply an appropriate supervised learning algorithm for regression problems (e.g., linear regression, ridge regression). *recognize different types of unsupervised learning problems, and select and apply appropriate algorithms (e.g., clustering, linear and nonlinear dimensionality reduction). *work with probabilities (Bayes rule, conditioning, expectations, independence), linear algebra (vector and matrix operations, eigenvectors, SVD), and calculus (gradients, Jacobians) to derive machine learning methods such as linear regression, naive Bayes, and principal components analysis. *understand machine learning principles such as model selection, overfitting, and underfitting, and techniques such as cross-validation and regularization. *implement machine learning algorithms such as logistic regression via stochastic gradient descent, linear regression (using a linear algebra toolbox), perceptron, or k-means clustering. *run appropriate supervised and unsupervised learning algorithms on real and synthetic data sets and interpret the results.
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (36-218 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 15-359 Min. grade C)

10-403 Deep Reinforcement Learning & Control
Spring: 12 units
TBD
Prerequisites: 10-401 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

10-405 Machine Learning with Large Datasets (Undergraduate)
Intermittent: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-401, 10-601, or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and the introductory machine learning course concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Java and good programming skills.
Prerequisites: 15-210 or 15-214 or 15-211 or 17-214

10-417 Intermediate Deep Learning
Intermittent: 12 units
Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.
Prerequisites: 10-715 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

10-418 Machine Learning for Structured Data
Intermittent: 12 units
A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) — as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-401 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C

10-500 Senior Research Project
All Semesters
Register for this course if you are minoring in Machine Learning. This course is intended for research with a faculty member that would count towards the minor.

10-520 Independent Study
All Semesters
Independent Study intended to work on research with a Machine Learning faculty member.

10-600 Mathematical background for Machine Learning
Fall and Spring: 12 units
This course provides a place for students to practice the necessary mathematical background for further study in machine learning — particularly for taking 10-601 and 10-701. Topics covered include probability, linear algebra (inner product spaces, linear operators), multivariate differential calculus, optimization, and likelihood functions. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course supersedes the two mini-courses 10-606 and 10-607.

10-601 Introduction to Machine Learning (Master's)
Fall and Spring: 12 units
Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10601 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation & the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets & Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam. 10601 is recommended for CS Seniors & Juniors, quantitative Masters students, & non-MLD PhD students. Prerequisites (strictly enforced): strong quantitative aptitude, college probability & statistics course, and programming proficiency. For learning to apply ML practically & effectively, without the above prerequisites, consider 11344/05834 instead. You can evaluate your ability to take the course via a self-assessment exam (http://bit.ly/2fkddDN). Also, be sure to read the ML course comparison (http://bit.ly/2eV3UaD).
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (36-217 Min. grade C or 21-325 Min. grade C or 36-225 Min. grade C or 15-359 Min. grade C or 36-218 Min. grade C)

10-605 Machine Learning with Large Datasets
Spring: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and 10-601 concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Java and good programming skills.
Prerequisites: 15-210 or 15-214 or 17-214

Course Website: http://goo.gl/W2kPqO

10-606 Mathematical Foundations for Machine Learning
Fall and Spring: 6 units
This course provides a place for students to practice the necessary mathematical background for further study in machine learning. Topics covered include probability (random variables, modeling with continuous and discrete distributions), linear algebra (inner product spaces, linear operators), and multivariate differential calculus (partial derivatives, matrix differentials). The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning — particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-607 Computational Foundations for Machine Learning
Fall and Spring: 6 units
This course provides a place for students to practice the necessary computational background for further study in machine learning. Topics covered include computational complexity, analysis of algorithms, proof techniques, optimization, dynamic programming, recursion, and data structures. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above computational concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning — particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-608 Conversational Machine Learning
Intermittent: 12 units
Machine Learning today is largely about finding patterns in large amounts of data. But as personal devices that interact with us in natural language become ubiquitous (e.g., Siri, Google Now), they open an amazing possibility of letting users teach machines in natural language, similar to how we teach each other. Conversation, as an interface to machine learning systems, opens a new paradigm that both unifies several existing machine learning paradigms (e.g., active learning, supervised learning), but also brings a unique set of advantages and challenges that lie at the intersection of machine learning and natural language processing. This course will be structured as a well-defined mini-challenge (project) course. We will present you with several well-defined open problems and provide you with recently collected datasets that can get you started immediately! But you will be free to define your own problem using that data as well, or come up with your own problem entirely. There are no other constraints, and since this is a new area of research, you can (and should) be creative and as crazy in coming up with methods to tackle them. At the same time, we will provide guidance via readings and class-based hacking sessions. This course is a great way to get introduced to open problems in a collaborative and structured environment. Challenges Building a classifier with zero examples. Telling sequence to sequence models about their mistakes Letting machine learning models ask questions
Prerequisites: 10-401 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-715 Min. grade C

10-617 Intermediate Deep Learning
Intermittent: 12 units
Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.
Prerequisites: 10-601 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

10-618 Machine Learning for Structured Data
Intermittent: 12 units
A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) — as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-301 Min. grade C or 10-315 Min. grade C or 10-401 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C

10-701 Introduction to Machine Learning (PhD)
Fall and Spring: 12 units
Machine learning studies the question "How can we build computer programs that automatically improve their performance through experience?" This includes learning to perform many types of tasks based on many types of experience. For example, it includes robots learning to better navigate based on experience gained by roaming their environments, medical decision aids that learn to predict which therapies work best for which diseases based on data mining of historical health records, and speech recognition systems that learn to better understand your speech based on experience listening to you. This course is designed to give PhD students a thorough grounding in the methods, mathematics and algorithms needed to do research and applications in machine learning. Students entering the class with a pre-existing working knowledge of probability, statistics and algorithms will be at an advantage, but the class has been designed so that anyone with a strong numerate background can catch up and fully participate. You can evaluate your ability to take the course via a self-assessment exam that will be made available to you after you register. If you are interested in this topic, but are not a PhD student, or are a PhD student not specializing in machine learning, you might consider the master's level course on Machine Learning, 10-601." This class may be appropriate for MS and undergrad students who are interested in the theory and algorithms behind ML. You can evaluate your ability to take the course via a self-assessment exam at: https://qna-app.appspot.com/view.html?aglzfnFuYS1hcHByGQsSDFF1ZXN0aW9uTGlzdBiAgICgpO-KCgw ML course comparison: https://docs.google.com/document/d/1Y0Jx_tcINWQrWJx31WGEQSsUs059OUMmPIVSeyxNdeM/edit
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (36-225 Min. grade C or 15-259 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C or 15-359 Min. grade C or 36-217 Min. grade C)

10-702 Statistical Machine Learning
Spring: 12 units
Statistical Machine Learning is a second graduate level course in advanced machine learning, assuming that students have taken Machine Learning (10-701) or Advanced Machine Learning (10-715), and Intermediate Statistics (36-705). The term ?statistical? in the title reflects the emphasis on statistical theory and methodology. This course is mostly focused on methodology and theoretical foundations. It treats both the ?art? of designing good learning algorithms and the ?science? of analyzing an algorithm?s statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. Though computation is certainly a critical component of what makes a method successful, it will not receive the same central focus as methodology and theory. We will cover topics in statistical theory that are important for researchers in machine learning, including consistency, minimax estimation, and concentration of measure. We will also cover statistical topics that may not be covered in as much depth in other machine learning courses, such as nonparametric density estimation, nonparametric regression, and Bayesian estimation.
Prerequisites: (36-705 or 10-705) and (10-701 or 10-715)

Course Website: http://www.stat.cmu.edu/~larry/=sml/

10-703 Deep Reinforcement Learning & Control
Spring: 12 units
This course will cover latest advances in Reinforcement Learning and Imitation learning. This is a fast developing research field and an official textbook is available only for about one forth of the course material. The rest will be taught from recent research papers. This course brings together many disciplines of Artificial Intelligence to show how to develop intelligent agent that can learn to sense the world and learn to act imitating others or maximizing sparse rewards Particular focus will be given in incorporating visual sensory input and learning suitable visual state representations.
Prerequisites: 10-601 Min. grade B or 10-701 Min. grade B or 10-715 Min. grade B or 10-401 Min. grade B or 10-315 Min. grade B or 10-301 Min. grade B

10-707 Topics in Deep Learning
Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from high-dimensional data lies at the core of solving many AI related tasks. In the past few years, researchers across many different communities, from applied statistics to engineering, computer science and neuroscience, have developed deep (hierarchical) models — models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. This is an advanced graduate course, designed for Master's and Ph.D. level students, and will assume a reasonable degree of mathematical maturity. The goal of this course is to introduce students to the recent and exciting developments of various deep learning methods. Some topics to be covered include: restricted Boltzmann machines (RBMs) and their multi-layer extensions Deep Belief Networks and Deep Boltzmann machines; sparse coding, autoencoders, variational autoencoders, convolutional neural networks, recurrent neural networks, generative adversarial networks, and attention-based models with applications in vision, NLP, and multimodal learning. We will also address mathematical issues, focusing on efficient large-scale optimization methods for inference and learning, as well as training density models with intractable partition functions. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.
Prerequisites: 10-401 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C

10-708 Probabilistic Graphical Models
Spring: 12 units
Many of the problems in artificial intelligence, statistics, computer systems, computer vision, natural language processing, and computational biology, among many other fields, can be viewed as the search for a coherent global conclusion from local information. The probabilistic graphical models framework provides an unified view for this wide range of problems, enabling efficient inference, decision-making and learning in problems with a very large number of attributes and huge datasets. This graduate-level course will provide you with a strong foundation for both applying graphical models to complex problems and for addressing core research topics in graphical models. The class will cover three aspects: The core representation, including Bayesian and Markov networks, and dynamic Bayesian networks; probabilistic inference algorithms, both exact and approximate; and, learning methods for both the parameters and the structure of graphical models. Students entering the class should have a pre-existing working knowledge of probability, statistics, and algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. It is expected that after taking this class, the students should have obtain sufficient working knowledge of multi-variate probabilistic modeling and inference for practical applications, should be able to formulate and solve a wide range of problems in their own domain using GM, and can advance into more specialized technical literature by themselves. Students are required to have successfully completed 10701 or 10715, or an equivalent class.
Prerequisites: 10-715 or 10-701

Course Website: https://sailinglab.github.io/pgm-spring-2019/lectures/

10-715 Advanced Introduction to Machine Learning
Fall: 12 units
The rapid improvement of sensory techniques and processor speed, and the availability of inexpensive massive digital storage, have led to a growing demand for systems that can automatically comprehend and mine massive and complex data from diverse sources. Machine Learning is becoming the primary mechanism by which information is extracted from Big Data, and a primary pillar that Artificial Intelligence is built upon. This course is designed for Ph.D. students whose primary field of study is machine learning, and who intend to make machine learning methodological research a main focus of their thesis. It will give students a thorough grounding in the algorithms, mathematics, theories, and insights needed to do in-depth research and applications in machine learning. The topics of this course will in part parallel those covered in the general PhD-level machine learning course (10-701), but with a greater emphasis on depth in theory and algorithms. The course will also include additional advanced topics such as fairness in machine learning. Students entering the class are expected to have a pre-existing strong working knowledge of algorithms, linear algebra, probability, and statistics. If you are interested in this topic, but do not have the required background or are not planning to work on a PhD thesis with machine learning as the main focus, you might consider the general PhD-level Machine Learning course (10-701) or the Masters-level Machine Learning course (10-601). ML course comparison: https://goo.gl/mmR2eL
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (21-325 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 15-359 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C)

Course Website: http://www.cs.cmu.edu/~nihars/teaching/10715-Fa19/index.html

10-716 Advanced Machine Learning: Theory and Methods
Spring: 12 units
Advanced Machine Learning: Theory and Methods is a graduate level course introducing the theoretical foundations of modern machine learning, as well as advanced methods and frameworks used in modern machine learning. The course assumes that students have taken graduate level introductory courses in machine learning (Introduction to Machine Learning, 10-701 or 10-715), as well as Statistics (Intermediate Statistics, 36-700 or 36-705). The course treats both the art of designing good learning algorithms, as well as the science of analyzing an algorithm's computational and statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. We will cover theoretical foundation topics such as computational and statistical convergence rates, minimax estimation, and concentration of measure. We will also cover advanced machine learning methods such as nonparametric density estimation, nonparametric regression, and Bayesian estimation, as well as advanced frameworks such as privacy, causality, and stochastic learning algorithms.
Prerequisites: (10-715 or 10-701) and (36-705 or 36-700)

10-725 Convex Optimization
Intermittent: 12 units
Nearly every problem in machine learning can be formulated as the optimization of some function, possibly under some set of constraints. This universal reduction may seem to suggest that such optimization tasks are intractable. Fortunately, many real world problems have special structure, such as convexity, smoothness, separability, etc., which allow us to formulate optimization problems that can often be solved efficiently. This course is designed to give a graduate-level student a thorough grounding in the formulation of optimization problems that exploit such structure, and in efficient solution methods for these problems. The main focus is on the formulation and solution of convex optimization problems, though we will discuss some recent advances in nonconvex optimization. These general concepts will also be illustrated through applications in machine learning and statistics. Students entering the class should have a pre-existing working knowledge of algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. Though not required, having taken 10-701 or an equivalent machine learning or statistical modeling class is strongly encouraged, as we will use applications in machine learning and statistics to demonstrate the concepts we cover in class. Students will work on an extensive optimization-based project throughout the semester.

Course Website: http://www.stat.cmu.edu/~ryantibs/convexopt/

10-737 Creative AI
Intermittent: 12 units
Artificial intelligence (AI) systems now generate authentic paintings, compose music pieces, and find out-of-box solutions to real-life problems in our world. Creativity, which was considered to be a moon shot for AI, does not seem to be too far any more. Is that true? Are we close to see creative AI? The answer is yes and no. We are moving closer with meaningful developments in Machine Learning, however there are several questions to be explored further to achieve the creative AI. What kind of creativity we want to represent? How do we translate creativity into what machines can understand? How do we design ML algorithms to be more creative? This course is where we explore these questions through seminars and projects. Our goal is to design computational models that present the very possibility of the creative AI. The instructors who are specialized in Machine Learning Art and Robotics lead this course together. We introduce related examples and possible methods including multi-modal data-driven learning, learning from demonstration, and combined learning from data and human demonstrations. Students are welcome to bring in their expertise and passion from diverse backgrounds to explore this topic together.

Course Website: http://kangeunsu.com/creativeai19f/

10-745 Scalability in Machine Learning
Fall: 12 units
The goal of this course is to provide a survey into some of the recent advances in the theory and practice of dealing with scalability issues in machine learning. We will investigate scalability issues along the following dimensions: Challenges with i) large datasets, ii) high-dimensions, and iii) complex data structure. The course is intended to prepare students to write research papers about scalability issues in machine learning. This is an advanced-level, fast-paced course that requires students to already have a solid understanding of machine learning (e.g. by taking an intro to ML class), good programming skills in Python, and being comfortable with dealing with abstract mathematical concepts and reading research papers. The course will have significant overlap with 10-405/605/805, but 10-745 will be faster-paced and go deeper into the theoretical investigations of the methods. Some of the classes will be flipped that will require students to watch a video lecture or read a research paper before the class, and the content will be discussed during the class time. The class will include a course project, HW assignments, and two-in class exams.
Prerequisites: 10-701 Min. grade B or 10-601 Min. grade B or 10-401 Min. grade B or 10-315 Min. grade B or 10-715 Min. grade B or 10-301 Min. grade B

10-805 Machine Learning with Large Datasets
Spring: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. The class will include programming assignments, presentation of relevant research papers to the class, and a research project chosen by the student, to be presented to the class, and written up in a conference-paper format. 10-805 will share lectures with 10-605, but 10-805 students need to make class presentations and complete a research project, and will do fewer programming assignments, so 10-805 students are expected to be capable of surveying recent literature and conducting research. Four lecture sessions for 10-605 will also be reserved for 10-805 students' presentations. If there is sufficient interest we will introduce a mechanism for 10-605 students to collaborate of 10-805 students on projects.
Prerequisites: 15-214 or 15-210 or 17-214

Course Website: http://goo.gl/W2kPqO

10-806 Foundations of Machine Learning and Data Science
Fall: 12 units
This course will cover fundamental topics in Machine Learning and Data Science, including powerful algorithms with provable guarantees for making sense of and generalizing from large amounts of data. The course will start by providing a basic arsenal of useful statistical and computational tools, including generalization guarantees, core algorithmic methods, and fundamental analysis models. We will examine questions such as: Under what conditions can we hope to meaningfully generalize from limited data? How can we best combine different kinds of information such as labeled and unlabeled data, leverage multiple related learning tasks, or leverage multiple types of features? What can we prove about methods for summarizing and making sense of massive datasets, especially under limited memory? We will also examine other important constraints and resources in data science including privacy, communication, and taking advantage of limited interaction. In addressing these and related questions we will make connections to statistics, algorithms, linear algebra, complexity theory, information theory, optimization, game theory, and empirical machine learning research. Topics to be covered will include: - Fundamental measures of complexity for generalization, including VC-dimension and Rademacher complexity. - Core algorithmic tools including boosting, regularization, and online optimization with connections to game theory. - Spectral methods, streaming algorithms and other approaches for handling massive data. - Foundations and algorithms for addressing important constraints or externalities such as privacy, limited memory, and communication constraints. - Foundations for modern learning paradigms including semi-supervised learning, never-ending learning, interactive learning, and deep learning.

Course Website: http://www.cs.cmu.edu/~ninamf/courses/806/10-806-index.html

10-807 Topics in Deep Learning
Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from high-dimensional data lies at the core of solving many AI related tasks. In the past few years, researchers across many different communities, from applied statistics to engineering, computer science and neuroscience, have developed deep (hierarchical) models — models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. This is an advanced graduate course, designed for Master's and Ph.D. level students, and will assume a reasonable degree of mathematical maturity. The goal of this course is to introduce students to the recent and exciting developments of various deep learning methods. Some topics to be covered include: restricted Boltzmann machines (RBMs) and their multi-layer extensions Deep Belief Networks and Deep Boltzmann machines; sparse coding, autoencoders, variational autoencoders, convolutional neural networks, recurrent neural networks, generative adversarial networks, and attention-based models with applications in vision, NLP, and multimodal learning. We will also address mathematical issues, focusing on efficient large-scale optimization methods for inference and learning, as well as training density models with intractable partition functions. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.
Prerequisites: 10-701 Min. grade C or 10-715 Min. grade C

10-822 Presentation Skills
Fall and Spring: 6 units
This course provides a forum for students to learn and refine public speaking and technical reading skills. The course will include brief workshops embedded throughout the semester to cover such things as effective structure of presentations and papers, how to give a short talk (think NIPS spotlights), "elevator" talks, structure of a research paper, conference presentations, proposal writing (think thesis and beyond), slide crafting, posters, critical evaluation, and public communications for research. Students will be expected to prepare and present a number of practice talks throughout the semester.

10-830 Machine Learning in Policy
Spring: 12 units
Machine learning, a field derived primarily from computer science and statistics, has matured and gained wide adoption over past decades. Alongside exponential increases in data measurement and availability, the ability to develop appropriate and tailored analyses is in demand. As practitioners in the social sciences consider machine learning methods, however, we are identifying limitations and externalities of the applications of machine learning techniques, such as overconfidence in settings with concept drift, lack of generalizability due to selection bias, and magnification of inequities. Machine Learning and Policy seeks to (1) demonstrate motivations and successes of machine learning, to (2) contrast them with more classical methods, and to (3) investigate the promise and cautions of machine learning for public policy. The course will cover variety of topics, including: Basics of machine learning; probability/Bayes/likelihood/conjugacy, terminology, code/algorithm design, evaluation, mathematical formulations Popular and well-performing methods; random forests/trees/ensembles, neural networks/backpropagation/embeddings/generalized adversarial networks, generalized linear models/shrinkage/convexity/basis functions, support vector machines/kernels/optimization/Lagrangian Leveraging other data sources; natural language processing/topic modeling/relational (non-i.i.d.)/relational (Markov logic networks)/temporal data Additional topics: causality/confounding/propensity scoring/inverse weighting/causal directed acyclic graphs, fairness/ethics, interpretation/explanation/visualization, anomaly detection, semi-supervised and active learning, reinforcement learning.

Course Website: https://www.andrew.cmu.edu/user/jweiss2/mlp/

10-831 Special Topics in Machine Learning and Policy
Spring: 6 units
Special Topics in Machine Learning and Policy (90-921/10-831) is intended for Ph.D. students in Heinz College, MLD, and other university departments who wish to engage in detailed exploration of a specific topic at the intersection of machine learning and public policy. Qualified master's students may also enroll with permission of the instructor; all students are expected to have some prior background in machine learning and data mining (10-601, 10-701, 90-866, 90-904/10-830, or a similar course). We will explore state-of-the-art methods for detection of emerging events and other relevant patterns in massive, high-dimensional datasets, and discuss how such methods can be applied usefully for the public good in medicine, public health, law enforcement, security, and other domains. The course will consist of lectures, discussions on current research articles and future directions, and course projects. Specific topics to be covered may include: anomaly detection, change-point detection, time series monitoring, spatial and space-time scan statistics, pattern detection in graph data, submodularity and LTSS properties for efficient pattern detection, combining multiple data sources, scaling up pattern detection to massive datasets, applications to public health, law enforcement, homeland security, and health care. A sample syllabus is available at: http://www.cs.cmu.edu/~neill/courses/90921-S10.html
Course Website: http://www.cs.cmu.edu/~neill/courses/90921-S10.html

SCS: Robotics Courses

16-161 ROB Freshman Seminar: Artificial Intelligence and Humanity
Fall and Spring: 9 units
In 1965 British mathematician I.J. Good wrote, An ultraintelligent machine could design even better machines; there would then unquestionably be an intelligence explosion, and the intelligence of man would be left far behind. As we enter an age where companies like Uber are testing driverless cars in Pittsburgh and innovative interfaces like IBMs Watson can play jeopardy and learn techniques for medical diagnoses, how are we to negotiate an intelligence explosion that for many individuals might threaten the very notions of what it means to be human? The future of human-to-machine relationships will likely define our historical epoch and yet, many young technologists and humanists underestimate the downstream impact of technological innovations on human society. Presently, we have little choice but to attend to this rapidly anxiety-ridden question. This seminar will attend to the challenge of present existential questions on what it means to be human (read not machine) in the context of a rapidly advancing technological age. We will consider human narratives throughout history that exam how governments and individual citizens defined humanity in the context of slavery and colonialism as a framework for exploring and projecting what it means to be human in the age of rapidly advancing intelligent machines. We will trace the technological advancements of the recent five decades and identify historical precedents and speculative narratives that help us to consider issues like labor, economic disparity, negotiations of power, human dignity and ethical responsibility within the context of human relations with advancing technological tools that are now coined, artificial intelligence.

16-223 IDeATe Portal: Creative Kinetic Systems
Fall: 10 units
The art and science of machines which evoke human delight through physical movement is founded on a balance of form and computation. This introductory physical computing course addresses the practical design and fabrication of robots, interactive gadgets, and kinetic sculptures. The emphasis is on creating experiences for human audiences through the physical behavior of devices which embody computation with mechanism, sensing, and actuation. Specific topics include basic electronics, elementary mechanical design, embedded programming, and parametric CAD. A key objective is gaining an intuitive understanding of how information and energy move between the physical, electronic, and computational domains to create a compelling behavior. The final projects are tested in the field on children and adults. This interdisciplinary course is an IDeATe Portal Course open to students from all colleges. For students choosing to follow an IDeATe program it is an entry into either Physical Computing or Intelligent Environments. The structure of the class revolves around collaborative exercises and projects which introduce core physical computing and system engineering techniques in a human-centric context. Students apply system and design thinking across multiple domains, work together to make and test several devices, and participate in wide-ranging critique which considers both technical and artistic success.

Course Website: https://courses.ideate.cmu.edu/16-223

16-264 Humanoids
Spring: 12 units
This course surveys perception, cognition, and movement in humans, humanoid robots, and humanoid graphical characters. Application areas include more human-like robots, video game characters, and interactive movie characters.

Course Website: http://www.cs.cmu.edu/~cga/humanoids-ugrad/

16-299 Introduction to Feedback Control Systems
Spring: 12 units
This course is designed as a first course in feedback control systems for computer science majors. Course topics include classical linear control theory (differential equations, Laplace transforms, feedback control), linear state-space methods (controllability/observability, pole placement, LQR), nonlinear systems theory, and an introduction to control using computer learning techniques. Priorities will be given to computer science majors with robotics minor.
Prerequisites: 21-122 and 15-122

Course Website: https://piazza.com/class/j8unqbhmwa3t

16-311 Introduction to Robotics
Spring: 12 units
This course presents an overview of robotics in practice and research with topics including vision, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensors. In course projects, students construct robots which are driven by a microcontroller, with each project reinforcing the basic principles developed in lectures. Students nominally work in teams of three: an electrical engineer, a mechanical engineer, and a computer scientist. This course will also expose students to some of the contemporary happenings in robotics, which includes current robot lab research, applications, robot contests and robots in the news.
Prerequisites: 21-240 Min. grade C or 24-311 Min. grade C or 21-260 Min. grade C or 21-241 Min. grade C or 18-202 Min. grade C

Course Website: http://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/16311/www/current/

16-350 Planning Techniques for Robotics
Spring: 12 units
Planning is one of the core components that enable robots to be autonomous. Robot planning is responsible for deciding in real-time what should the robot do next, how to do it, where should the robot move next and how to move there. This class does an in-depth study of popular planning techniques in robotics and examines their use in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students learn the theory of these methods and also implement them in a series of programming-based projects. To take the class students should have taken an Intro to Robotics class and have a good knowledge of programming and data structures.

Course Website: http://www.cs.cmu.edu/~maxim/classes/robotplanning/

16-362 Mobile Robot Algorithms Laboratory
Fall: 12 units
This course is a comprehensive hands-on introduction to the concepts and basic algorithms needed to make a mobile robot function reliably and effectively. We will work in small groups with small robots that are controlled over wireless from your laptop computers. The robots are custom-designed mini forktrucks that can move pallets from place to place just like commercial automated guided vehicles do today. The robots are programmed in the modern MATLAB programming environment. It is a pretty easy language to learn, and a very powerful one for prototyping robotics algorithms. You will get a lot of experience in this course in addition to some theory. Lectures are focused on the content of the next lab. There is a lab every week and they build on each other so that a complete robot software system results. The course will culminate with a class-wide robot competition that tests the performance of all of your code implemented in the semester. In order to succeed in the course, students must have a 1) 2nd year science/engineering level background in mathematics (matrices, vectors, coordinate systems) and 2) have already mastered at least one procedural programming language like C or Java, and 3) have enough experience to be reasonably prepared to write a 5000 line software system in 13 weeks with the help of one or two others. When the course is over, you will have written a single software system that has been incrementally extended in functionality and regularly debugged throughout the semester.

Course Website: http://www.frc.ri.cmu.edu/~alonzo/teaching/16x62/16x62.html

16-371 Personalized Responsive Environments
Spring: 9 units
[IDeATe collaborative course]. Environmental factors have a significant impact on mood and productivity. Creating responsive environments necessitates the design of surroundings that are able to metamorphose in order to optimize user strengths and available resources and evolve in stride with user needs. This course will investigate the development of spaces that adapt to user preferences, moods, and task specific demands. Both the design and engineering of such personalized environments will be explored. Central course concepts will include, understanding the user, integrating various modalities (e.g., light, heat, sound) to support the changing needs of task and user, and the creation of adaptive environments that learn user preferences over time. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 18-090 Min. grade C or 15-104 Min. grade C or 62-150 Min. grade C or 60-223 Min. grade C

16-374 IDeATe: Art of Robotic Special Effects
Spring: 12 units
Inspired by the early "trick" films of George Melies, this project-oriented course brings together robotics and film production technique to infuse cinema with the wonder of live magic. Students will learn the basics of film production using animatronics, camera motion control, and compositing. The projects apply these techniques to create innovative physical effects for short films, all the way from concept to post-production. The course emphasizes real-time practical effects to explore the immediacy and interactivity of improvisation and rehearsal. The robotics topics include animatronic rapid prototyping and programming human-robot collaborative performance. The course includes a brief overview of the history of special effects and robotics to set the work in context.

Course Website: https://courses.ideate.cmu.edu/16-374

16-375 IDeATe: Robotics for Creative Practice
Fall: 10 units
Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include closed-loop motion control, expressive physical and computational behavior, machine choreography, and performance conceptualization. Discussion topics include both contemporary kinetic sculpture and robotics research. This interdisciplinary course is part of IDeATe Physical Computing but is open to any student.
Prerequisites: 62-150 or 60-223 or 15-104 or 16-223

Course Website: https://courses.ideate.cmu.edu/16-375

16-376 IDeATe: Kinetic Fabrics
Spring: 10 units
Kinetic Fabrics brings together the fields of robotics and textiles to explore their unified creative and expressive potential. It is a wide-open frontier for kinetic art, wearable art, and architectural installation. In this course students will build a variety of performative systems combining fabrics and robotic technologies. Students will apply modular actuation and sensing to textile artworks, using software designed to facilitate fluid explorations, rapid iterations, and playful experimentation. Students will learn basic textile skills, such as hand and machine sewing, as well as gain facility and familiarity with the characteristics of multiple type of fabrics. Historical precedents as well as contemporary examples of works will support students creative growth and knowledge of the field. Students' course work will include short-term and long-term projects, sampling and prototyping, critique, and documentation. Additionally, students will organize an end-of-semester event where they will perform a developed kinetic fabric work for a public audience.

Course Website: https://courses.ideate.cmu.edu/16-376

16-384 Robot Kinematics and Dynamics
Fall: 12 units
Foundations and principles of robotic kinematics. Topics include transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and basic equations of motion. Course also include programming on robot arms.
Prerequisites: 21-241 or 24-311 or 18-202 or 16-311 or 15-122 Min. grade C

16-385 Computer Vision
Fall and Spring: 12 units
This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision, sensing and perception, and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems. This course is for undergraduate students only.
Prerequisites: (18-202 Min. grade C and 15-122 Min. grade C) or (21-259 Min. grade C and 21-241 Min. grade C and 15-122 Min. grade C)

Course Website: http://www.cs.cmu.edu/~16385/

16-397 Art, Conflict and Technology in Northern Ireland
Spring: 12 units
Art, Conflict and Technology in Northern Ireland is a 12-unit course cross-listed between the School of Art, the Department of English, and the Robotics Institute. Throughout the term students will be introduced to a history of social strife in the North of Ireland from the 1960s to the present, and efforts to reconcile such differences in the contemporary period. We will consider the influence of advancing technology on how narratives are shared within a community and worldwide. We will reflect upon and analyze a variety of literary and visual art sources from the chosen time period, while also learning how to create mixed-media projects using Gigapan and Hear Me systems from Carnegie Mellon?s CREATE Lab in the Robotics Institute. If you have ever considered how artists explore societal strife through their writing or visual arts practice, if you are interested in the social and political influences of evolving technology, or if you are a practicing artist who uses advancing technology as a tool for individual expression, this integrative course is for you. Throughout the semester we will examine the practice of a range of visual artists that include Rita Duffy, John Kindness and Willie Doherty and writers and dramatists like Dermot Healy, Patrick McCabe, and Christina Reid. Students will learn how to use CREATE Lab?s Gigapan and Hear Me systems as platforms for exploring the content presented in the class for the development of final projects. We will travel to Belfast for spring break 2015, to meet a variety of writers and artists whose work we will study, and stakeholders in the reconciliation efforts throughout the region. In addition to weekly lectures on Thursdays throughout the term, students will have a six-week lab on Tuesdays. Lab sessions begin in the second week of classes (January 20).

16-421 Vision Sensors
Spring: 12 units
This course covers the fundamentals of vision cameras and other sensors - how they function, how they are built, and how to use them effectively. The course presents a journey through the fascinating five hundered year history of "camera-making" from the early 1500's "camera obscura" through the advent of film and lenses, to today's mirror-based and solid state devices (CCD, CMOS). The course includes a significant hands-on component where students learn how to use the sensors and understand, model and deal with the uncertainty (noise) in their measurements. While the first half of the course deals with conventional "single viewpoint" or "perspective" cameras, the second half of the course covers much more recent "multi-viewpoint" or "multi-perspective" cameras that includes a host of lenses and mirrors.
Prerequisites: 21-241 and 21-111

Course Website: http://www.cs.cmu.edu/~ILIM/courses/vision-sensors/

16-423 Designing Computer Vision Apps
Fall: 12 units
Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for students who are not familiar with computer vision, but want to come up to speed rapidly with the latest in environments, software tools and best practices for developing computer vision apps. No prior knowledge of computer vision or machine learning is required although a strong programming background is a must (at a minimum good knowledge of C/C++). Topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE), and development on iOS devices using mobile vision libraries such as GPUImage and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focussed on a single operating system, the knowledge gained from this class is intended to generalize to other mobile platforms such as Android etc.
Prerequisites: (15-213 and 21-240) or (21-241 and 15-213) or (18-213 and 18-202)

Course Website: http://16423.courses.cs.cmu.edu

16-425 Medical Image Analysis
Spring: 12 units
Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

16-441 Advanced CP/SIS: Urban Intervention
Fall and Spring: 12 units
This course introduces students to theories, practices, and communities for critical investigation of urban spaces and play within them. The course unfolds along two parallel trajectories: research (literature review, lectures, readings, demonstrations) and design (three iterated individualized projects and a fourth larger scale final project). The first half of the course will introduce students to a wide range of theories and techniques within urban intervention that draw from fluxus, the situationist international, activism and hacktivism, as well as public policy, philosophy, psychology and economics. Students will study theoretical and practical frameworks for artistic intervention into public urban spaces, while concurrently researching actual sites and communities within Pittsburgh for experimentation. Students are required to conceptualized projects on larger (urban) scales, and find ways to implement their projects safely and legally by pursuing the necessary administrative, social, technical, financial steps required to create meaningful interventions in public spaces. This class will specifically explore three media for urban intervention: Sound Outdoor video projection Robotics, Autonomy and Mobility in the way of remote control vehicles (e.g. cars, quad-copters, etc.). For each theme, students are required to produce one project that is iterated twice or more. The undergraduate (60441) and graduate (60741) sections of the course meet concurrently and follow the same syllabus and assignments. In addition to the coursework documented in the syllabus, Graduate level students are expected to write a research paper suitable for submission to a notable relevant academic conference. This process includes a rough draft, revisions and a completed and formatted paper ready for submission

16-450 Robotics Systems Engineering
Fall: 12 units
Systems engineering examines methods of specifying, designing, analyzing and testing complex systems. In this course, principles and processes of systems engineering are introduced and applied to the development of robotic devices. The focus is on robotic system engineered to perform complex behavior. Such systems embed computing elements, integrate sensors and actuators, operate in a reliable and robust fashion, and demand rigorous engineering from conception through production. The course is organized as a progression through the systems engineering process of conceptualization, specification, design, and prototyping with consideration of verification and validation. Students completing this course will engineer a robotic system through its compete design and initial prototype. The project concept and teams can continue into the Spring-semester (16-474 Robotics Capstone) for system refinement, testing and demonstration.
Prerequisites: 16-311 Min. grade B and (18-370 Min. grade B or 16-299 Min. grade B or 24-451 Min. grade B)

16-455 IDeATe: Human-Machine Virtuosity
Spring: 12 units
[IDeATe course] Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

Course Website: https://courses.ideate.cmu.edu/16-455

16-456 Reality Computing Studio
Fall: 12 units
[IDeATe collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). Taught in collaboration with the school of architecture, this studio asks students to apply these technologies to real world problems such as residential design, sustainability, and infrastructure monitoring.

Course Website: http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/

16-457 Reality Computing II
Spring: 12 units
[IDeATe collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). This iteration of the reality computing course will focus on "design realization": the translation from digital design to fully realized tangible artifact. Collaborating with the UDBS design studio, and within the context of a full-scale residential prototype, students will investigate how reality computing technologies can be used to accelerate and advance the process of design realization by using reality computing to understand existing homes, map design data into the real world, and highlight conflicts between design and reality. Topics of special focus within the course are residential design (John Folan) and augmented reality and robotics (Pyry Matikainen).

Course Website: http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/

16-461 Experimental Capture
Fall: 9 units
Performance capture is used in applications as varied as special effects in movies, animation, sports training, physical rehabilitation, and human-robot/human-computer interaction. This course will survey state-of-the-art techniques and emerging ideas, in the industry and in academia, to capture, model, and render human performances. The course will be a mix between lectures and discussion of recent progress in human motion capture and analysis. The course evaluation will be project-based, in which students will capture their own body and face motion, and build projects around the data they collect individually and as a group. We will cover: 1. Capture Techniques: We will describe and use various systems including motion capture, video-based capture, depth sensors, scanners, and eye-gaze trackers; 2. Modeling and Representation: We will cover classic and contemporary representations of face and body pose and motion, including statistical and physics-based techniques; 3. Rendering Applications: As new rendering paradigms emerge, new applications continue to develop. We will study recent progress in animation, synthesis, classification, and rehabilitation on new forms of displays. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 60-422 or 15-365

16-465 Game Engine Programming
Spring: 10 units
This course is designed to help students understand, modify, and develop game engines. Game engines consist of reusable runtime and asset pipeline code. They provide game-relevant abstractions of low-level system services and libraries, making it easier to write bug-free games that work across multiple platforms. Game engines also handle artistic content, providing or integrating with authoring tools to ease the process of creating high-fidelity games. In this course, we will discuss the problems game engines attempt to solve, examine how current state-of-the-art engines address these problems, and create our own engines based on what we learn. We will cover both the content authoring and runtime aspects of engines. Coursework will consist of frequent, tightly-scoped programming and system design assignments; expeditions through game engine source code; and two group projects — one in an engine created from scratch, and one that requires modification of an existing engine. Prerequisites: Students will be expected to be fluent in at least one programming language. We will be working with C++, Javascript, and a smattering of Python. We will be using git for version control and code sharing. The assignments in the course will be designed to be completed on an OSX or Linux workstation (e.g. the IDeATe "virtual cluster"). Working with Windows will be possible, but might require extra effort. We will be building a 3D model pipeline around Blender, but no prior knowledge of the tool will be assumed.
Prerequisites: 62-150 Min. grade C or 15-213 Min. grade C or 15-104 Min. grade C or 15-112 Min. grade C

16-467 Human Robot Interaction
Spring: 12 units
The field of human-robot interaction (HRI) is fast becoming a significant area of research in robotics. The basic objective is to create natural and effective interactions between people and robots. HRI is highly interdisciplinary, bringing together methodologies and techniques from robotics, artificial intelligence, human-computer interaction, psychology, education, and other fields. This course is primarily lecture-based, with in-class participatory mini-projects, homework assignments, a group term project that will enable students to put theory to practice, and a final. The topics covered will include technologies that enable human-robot interactions, the psychology of interaction between people and robots, how to design and conduct HRI studies, and real-world applications such as assistive robots. This course has no prerequisites, but some basic familiarity with robots is recommended (programming knowledge is not necessary, but is useful for the term project).

Course Website: http://harp.ri.cmu.edu/courses

16-474 Robotics Capstone
Spring: 12 units
In this course students refine the design, build, integrate, test, and demonstrate the performance of the robot they designed in the pre-requisite Systems Engineering Course (16-450). The students are expected to continue to apply the process and methods of Systems Engineering to track requirements, evaluate alternatives, refine the cyberphysical architectures, plan and devise tests, verify the design, and validate system performance. In addition, the students learn and apply Project Management techniques to manage the technical scope, schedule, budget, and risks of their project. The course consists of lectures, class meetings, reviews, and a final demonstration. Lectures cover core topics in Project Management and special topics in Systems Engineering. During class meetings the students and instructor review progress on the project and discuss technical and project-execution challenges. There are three major reviews approximately at the end of each of the first three months of the semester. For each review, the students give a presentation and submit an updated version of the System Design and Development Document. The course culminates in a System Performance Validation Demonstration at the end of the semester. In addition to that the students hold a special demonstration of their robotic system for the broader Robotics community.
Prerequisite: 16-450 Min. grade C

16-595 Undergraduate Independent Study
All Semesters
For students to pursue an independent study with a Robotics Institute faculty member.

16-597 Undergraduate Reading and Research
Fall and Spring
Missing Course Description - please contact the teaching department.

16-621 MSCV Project I
Fall and Spring: 12 units
The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

16-622 MSCV Capstone
Fall: 12 units
The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

16-623 Advanced Computer Vision Apps.
Fall: 12 units
Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for graduate students who are familiar with computer vision, and are keen to learn more about the applying state of the art vision methods on smart devices and embedded systems. A strong programming background is a must (at a minimum good knowledge of C/C++), topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE, Torch 7), and development on iOS devices using mobile vision libraries such as GPUImage, Metal and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focused on a single operating system, the knowledge gained from this class will easily generalize to other mobile platforms such as Android etc.
Prerequisites: 16-385 or 16-720

Course Website: http://16623.courses.cs.cmu.edu

16-627 MSCV Seminar
Fall
(Only open to MSCV students.) MSCV students will be required to participate in this one-semester seminar course which will prepare them for the MSCV project starting in the Spring semester. The first part of this course will cover talks by computer vision and related faculty about the ongoing research, development programs related to Computer Vision at CMU. The second part of this course will include student/faculty tutorial on topics such as OpenCV, Dataset Creation, Mechanical Turk etc. The goal of this series is to get students acquainted with practical knowledge for a successful project. In the last month of the course, each lecture will cover upto four possible MSCV projects pitched by faculty or industrial sponsors. At the end of the course students will turn in their choices, and a faculty committee will assign them the final projects.

16-665 Robot Mobility on Air, Land, & Sea
Fall: 12 units
Many robots are designed to move through their environments. Three prevalent environments on earth are land, air, and water. This course will explore the modeling, control, and navigation of ground-based (wheeled and legged), air-based (rotorcraft such as quadcopters), and water-based robots.

16-720 Computer Vision
Fall and Spring: 12 units
This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include image formation and representation, camera geometry, and calibration, computational imaging, multi-view geometry, stereo, 3D reconstruction from images, motion analysis, physics-based vision, image segmentation and object recognition. The material is based on graduate-level texts augmented with research papers, as appropriate. Evaluation is based on homeworks and a final project. The homeworks involve considerable Matlab programming exercises. Texts recommended but not required: Title: "Computer Vision Algorithms and Applications" Author: Richard Szeliski Series: Texts in Computer Science Publisher: Springer ISBN: 978-1-84882-934-3 Title: "Computer Vision: A Modern Approach" Authors: David Forsyth and Jean Ponce Publisher: Prentice Hall ISBN: 0-13-085198-1

Course Website: http://www.andrew.cmu.edu/course/16-720/

16-725 (Bio)Medical Image Analysis
Spring: 12 units
Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

16-730 Robotics Business
Spring: 12 units
This course introduces and develops business concepts that will be useful to new and existing companies, while focusing on robotic technology exemplars. The concepts begin with how to identify a new idea to for a business that can be effectively started. Initial ideas often start as a grandiose plan to change the world and these plans are legitimately the fuel that drive new businesses forward. However, when a company starts (e.g., builds a prototype or writes a first line of code), what is the least product a company can produce that customers still want and need? This kernel — extracted from the "big plan"— is a Minimal Viable Product (MVP). Once an MVP business kernel is formulated, we will learn and study how to understand customer needs, how to market a new idea and how raise and manage money for a new business entity. These steps abridge information that can be found in an MBA curriculum, but engineers and scientists focused on the technical side will need this information to participate in the process of building companies. In parallel, we will investigate the marketplace through the stock market. The stock market is a powerful window into the world of business. In other words, when a new business is built it has to live inside the competitive environment of every other business. To understand this eco-system, we will follow several companies in-situ as they go through their own ups-and-downs within the business world. The course is project based. Each student will either build their own business concept, or they will build an improvement plan that would be targeted to improve an existing business. Professor Bourne is a founding member of the Robotics Institute(1979) and has taught business concepts within the Tepper Business School and the Robotics Institute since 1988. In addition, he is the President of his own company Design One Software.

16-735 Robotic Motion Planning
Intermittent: 12 units
The robot motion field and its applications have become incredibly broad and theoretically deep at the same time. The goal of the course is to provide an up-to-date foundation in the motion planning field, make the fundamentals of motion planning accessible to the novice and relate low-level implementation to high-level algorithmic concepts. We cover basic path planning algorithms using potential functions, roadmaps and cellular decompositions. We also look at the recent advances in sensor-based implementation and probabalistic techniques, including sample-based roadmaps, rapidly exploring random trees, Kalman filtering, and Bayesian estimation.

16-740 Learning for Manipulation
Spring: 12 units
Manipulation is the process of changing the state of objects through direct physical interactions. To perform manipulation tasks in unstructured environments, autonomous robots will need to learn about the objects in their surroundings as well as the skills required to manipulate and change the state of these objects. In this course, we explore the use of machine learning and data-driven algorithms for robot manipulation. The course introduces students to the wide variety of challenges posed by manipulation tasks, and how these challenges can be formulated as learning problems. Students are taught how these problems can be solved using machine learning techniques. The types of machine learning methods covered in this course include supervised, unsupervised, active, and reinforcement learning methods. The course includes both lectures and guided paper discussions.

16-741 Mechanics of Manipulation
Fall: 12 units
Kinematics, statics, and dynamics of robotic manipulator's interaction with a task, focusing on intelligent use of kinematic constraint, gravity, and frictional forces. Automatic planning based on mechanics. Application examples drawn from manufacturing and other domains.

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/index.html

16-742 Geometry of Locomotion
Fall: 12 units
This course introduces geometric methods for the analysis of locomoting systems. Focusing on the kinematics of locomoting systems, the course covers topics from differential geometry, geometric mechanics, and motion planning . Specific topics include configuration spaces, manifolds, groups, Lie groups, representations of velocity, holonomic and nonholonomic constraints, constraint curvature, response to cyclic inputs and distance metrics. The primary goal of this class is to develop an intuitive understanding of these concepts and how they are used in locomoting systems, rather than working through a set of formal proofs and derivations. We do, however, incorporate enough mathematical formalism for this class to serve as a starting point for further investigation into this topic area. We also call upon biological data, when available, and relate to the mathematical formalisms in the class.

16-745 Optimal Control and Reinforcement Learning
Spring: 12 units
This course surveys the use of optimization (especially optimal control) to design behavior. We will explore ways to represent policies including hand-designed parametric functions, basis functions, tables, and trajectory libraries. We will also explore algorithms to create policies including parameter optimization and trajectory optimization (first and second order gradient methods, sequential quadratic programming, random search methods, evolutionary algorithms, etc.). We will discuss how to handle the discrepancy between models used to create policies and the actual system being controlled (evaluation and robustness issues). The course will combine lectures, student-presented material, and projects. The goal of this course will be to help participants find the most effective methods for their problems.

Course Website: http://www.cs.cmu.edu/~cga/dynopt/

16-748 Underactuated Robots
Fall: 12 units
People and animals move through and interact with the world in a fundamentally dynamic way. In the vast majority of cases the same cannot be said for robots. In fact, many conventional approaches to motion planning and robot control attempt to explicitly cancel out the dynamics associated with different tasks. This class will consider underactuated robots, systems that do not have full control over their state and therefore cannot be planned for or controlled via conventional methods. Our goal will be to make novel locomoting robots act more "naturally." This class will highlight the relationship between conventional ideas from deterministic motion planning and control design (e.g., dynamic programming and linear-quadratic regulators) and their contemporary counterparts, many of which help form the analytical basis for the probabilisitic reasoning that underlies contemporary AI systems (e.g., POMDPs). Note that this course is inspired by and, for the most part, will follow the format of "Underactuated Robotics: Learning, Planning, and Control for Efficient and Agile Machines" created by Prof. Russ Tedrake at MIT. We will take several tangents, but the course materials provided by Prof. Tedrake through MIT Open Courseware are an incredible resource for this course (and really just in general).

16-761 Mobile Robots
Spring: 12 units
The course is targeted to senior undergraduates and graduate level students. The lectures will develop the fundamentals of this emerging sub-field of robotics by calling on the experience of practitioners, the common themes of the literature, and relevant material from more basic fields such as computer vision, mathematics, and physics.

Course Website: http://www.frc.ri.cmu.edu/~alonzo/teaching/16-761/16-761.html

16-778 Mechatronic Design
Spring: 12 units
Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. This course is a semester-long multidisciplinary capstone hardware project design experience in which small (typically four-person) teams of electrical and computer engineering, mechanical engineering and robotics students deliver an end-of-course demonstration of a final integrated system capable of performing a mechatronic task. Throughout the semester, the students design, configure, implement, test and evaluate in the laboratory devices and subsystems culminating in the final integrated mechatronic system. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, microcontroller, electronic, sensor, and control components.

Course Website: http://www.ece.cmu.edu/courses/items/18578.html

16-782 Planning and Decision-making in Robotics
Fall: 12 units
Planning and Decision-making are critical components of autonomy in robotic systems. These components are responsible for making decisions that range from path planning and motion planning to coverage and task planning to taking actions that help robots understand the world around them better. This course studies underlying algorithmic techniques used for planning and decision-making in robotics and examines case studies in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students will learn the algorithms and implement them in a series of programming-based projects.

16-785 Integrated intelligence in robotics: vision, language, and planning
Spring: 12 units
This course covers the topics on building cognitive intelligence for robotic systems. Cognitive capabilities constitute high-level, humanlike intelligence that exhibits reasoning or problem solving skills. Such capabilities as semantic perception, language understanding, and task planning can be built on top of low-level robot autonomy that enables autonomous control of physical platforms. The topics generally bridge across multiple technical areas, for example, vision-language intersection and language-action/plan grounding. This course is composed of 50% lectures and 50% seminar classes. There are no explicit prerequisites for this class, but a general background knowledge in AI and machine learning is assumed.

Course Website: http://www.cs.cmu.edu/~jeanoh/16-785/

16-791 Applied Data Science
Spring: 12 units
This course explores the rapidly developing field of data science in the context of its pragmatic applications. Applied Data Science strives to achieve three main goals. The first is to optimize the efficacy of decision making by human managers. The second is to maximize the utilization of available data, so that no important clue is ever missed. The third is to improve understanding of data and the underlying processes that produce it. This course aims at building skills required to systematically achieve those goals in practice. The students will gain and solidify awareness of the most prevalent contemporary methods of Data Science, and develop intuition needed for assessing practical utility of the studied topics in application scenarios. They will be able to learn how to formulate analytic tasks in support of project objectives, how to define successful analytic projects, and how to evaluate utility of existing and potential applications of the discussed technologies in practice.

16-823 Physics-based Methods in Vision (Appearance Modeling)
Intermittent: 12 units
Everyday, we observe an extraordinary array of light and color phenomena around us, ranging from the dazzling effects of the atmosphere, the complex appearances of surfaces and materials, and underwater scenarios. For a long time, artists, scientists, and photographers have been fascinated by these effects, and have focused their attention on capturing and understanding these phenomena. In this course, we take a computational approach to modeling and analyzing these phenomena, which we collectively call "visual appearance". The first half of the course focuses on the physical fundamentals of visual appearance, while the second half of the course focuses on algorithms and applications in a variety of fields such as computer vision, graphics and remote sensing and technologies such as underwater and aerial imaging.
Prerequisites: 15-385 or 16-720 or 15-462

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/16823-f06/

16-824 Visual Learning and Recognition
Spring: 12 units
A graduate seminar course in Computer Vision with emphasis on representation and reasoning for large amounts of data (images, videos and associated tags, text, gps-locations etc) toward the ultimate goal of Image Understanding. We will be reading an eclectic mix of classic and recent papers on topics including: Theories of Perception, Mid-level Vision (Grouping, Segmentation, Poselets), Object and Scene Recognition, 3D Scene Understanding, Action Recognition, Contextual Reasoning, Image Parsing, Joint Language and Vision Models, etc. We will be covering a wide range of supervised, semi-supervised and unsupervised approaches for each of the topics above.
Prerequisites: 16-720 Min. grade B or 15-781 Min. grade B or 10-701 Min. grade B or 16-722 Min. grade B

Course Website: http://graphics.cs.cmu.edu/courses/16-824/2017_spring/

16-831 Statistical Techniques in Robotics
Fall: 12 units
Data-driven learning techniques are now an essential part of building robotic systems designed to operate in the real world. These systems must learn to adapt to changes in the environment, learn from experience, and learn from demonstration. In particular we will cover three important sub-fields of Machine Learning applied to robotic systems: (1) We will cover Online Learning, which can be used to give robotic systems the ability to adapt to changing environmental conditions. (2) We will cover Reinforcement Learning, which takes into account the tradeoffs between exploration and exploitation to learn how to interact with the environment. We will also cover Deep Reinforcement Learning techniques in the context of real-world robotic systems. (3) We will cover Apprenticeship Learning (Imitation Learning and Inverse Reinforcement Learning) which is critical for teaching robotic systems to learn from expert behavior. Prerequisites: Linear Algebra, Multivariate Calculus, Probability theory.

16-833 Robot Localization and Mapping
Fall and Spring: 12 units
Robot localization and mapping are fundamental capabilities for mobile robots operating in the real world. Even more challenging than these individual problems is their combination: simultaneous localization and mapping (SLAM). Robust and scalable solutions are needed that can handle the uncertainty inherent in sensor measurements, while providing localization and map estimates in real-time. We will explore suitable efficient probabilistic inference algorithms at the intersection of linear algebra and probabilistic graphical models. We will also explore state-of-the-art systems.

Course Website: http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018

16-845 Insects and Robots
Fall: 12 units
This course will cover all facets of modeling, design, fabrication, and analysis of robots operating on the insect scale, with a microrobotics perspective. Insects can perform different tasks, such as manipulation or locomotion, with their small scale bodies varying from 200¿m to 16cm length. Similarly, we can define a micro-robotic system as an autonomous or semi-autonomous device with features on the micron scale or that make use of micron-scale physics for mobility or manipulation of objects. Due to their small size scales, microrobots will encounter difficulties unlike their macro-scale counterparts, in terms of fabrication and autonomy. In this project-based course, our aim will be on learning the physics of scaling, fabrication paradigms, actuation and sensing strategies, with numerous case studies, and to build an insect-inspired robotic system. We will also discuss multiple applications such as surgical robotics, mobile microrobots, multi-agent systems, and micro/nano manipulation.

16-848 Hands: Design and Control for Dexterous Manipulation
Spring: 12 units
Research related to hands has increased dramatically over the past decade. Hands are in focus in computer graphics and virtual reality, new robot hands have been popping up in great variety, and manipulation has been featured in widely publicized programs such as the DARPA Robotics Challenge. With all of this attention on hands, are we close to a breakthrough in dexterity, or are we still missing some things needed for truly competent manipulation? In this course, we will survey robotic hands and learn about the human hand with the goal of pushing the frontiers on hand design and control for dexterous manipulation. We will consider the necessary kinematics and dynamics for dexterity, what sensors are required to carry out dexterous interactions, the importance of reflexes and compliance, and the challenge of uncertainty. We will examine the human hand: its structure, sensing capabilities, human grasp choice and control strategies for inspiration and benchmarking. Students will be asked to present one or two research papers, participate in discussions and short research or design exercises, and carry out a final project.

Course Website: http://graphics.cs.cmu.edu/nsp/course/16899-s18/

16-881 Special Topics: Deep Reinforcement Learning for Robotics
Spring: 12 units
The format of the class will be: each class, 2 students will present (1 paper each); one paper will be an interesting new paper on deep RL; the other will be a paper on robotics, which will have an impressive robotics result, possibly using RL but not deep RL. The class will compare and contrast these papers and try to understand: - How did the robotics paper achieve its result without deep RL? - What are the strengths and limitations of the approach described in the robotics paper? - What insights can we take away from this paper? - What are the strengths and limitations of the method described in the deep RL paper? - How can the method described in each paper be improved? Students will also work on a class project related to deep RL, of their choosing. Grading will be based on the presentations and the class project. Prerequisites: Students are expected to have already have a basic understanding of reinforcement learning, such as from 10-703, 16-748, 16-831, or a similar course, prior to taking this course.

Course Website: https://sites.google.com/view/16-881-cmu/home?authuser=0

16-882 Special Topics: Systems Engineering and Project Management for Robotics
Spring: 12 units
This course covers in-depth topics in systems engineering and project management, addressing the application of such topics in robotic system development. Even though the course stands on its own content-wise, it assumes that students have some basic knowledge of systems engineering and project management from other related courses (such as 16450 or 16650) or work experience. The course is partitioned into three segments: in the first, the course covers methods for systematic implementation of systems engineering, a formal discipline that guides the development of a system throughout its life cycle. The course will focus on methods that apply especially in the engineering development phase of systems engineering, exposing students to detailed system architecting, requirements decomposition, engineering design in systems engineering, and operational feasibility (reliability, affordability, MANPRINT, etc.) In the second segment, the course covers techniques and strategies for managing projects in robotics specifically. To achieve a successful system within scope-of-work, budget, and time, engineers must pay attention to project management alongside systems engineering. The course will introduce students to models for project management, project structures with cost and schedule control, estimation, and constraint-based prioritization. In the third segment of the course, students will apply the concepts they have learned on a robotic system they are developing as part of a sponsored research project, another course, or as a personal or business endeavor.

16-883 Special Topics: Provably Safe Robotics
Intermittent: 12 units
Safe autonomy has become increasingly critical in many application domains. It is important to ensure not only the safety of the ego robot, but also the safety of other agents (humans or robots) that directly interact with the autonomy. For example, robots should be safe to human workers in human-robot collaborative assembly; autonomous vehicles should be safe to other road participants. For complex autonomous systems with many degrees of freedom, safe operation depends on the correct functioning of all system components, i.e., accurate perception, optimal decision making, and safe control. This course deals with both the design and the verification of safe robotic systems. From the design perspective, we will talk about how to assure safety through planning, prediction, learning, and control. From the verification perspective, we will talk about verification of deep neural networks, safety or reachability analysis for closed loop systems, and analysis of multi-agent systems.

Course Website: http://www.cs.cmu.edu/~cliu6/provably-safe-robotics.html

16-884 Special Topic: Engineering a Robotics Startup
Intermittent: 6 units
In this mini course, we'll cover all the major areas of new venture creation, with an emphasis on issues related to starting robotics companies. There are unprecedented opportunities for entrepreneurship in robotics, and substantial funding, talent, and resources are available to founders who combine solid technical innovation with a viable business model. Our focus will primarily be on examining and evaluating business models for robotics companies using a Business Model Canvas approach, along with issues related to evaluating market size, dealing with venture capital, and developing financial forecasts. We'll make use of case studies to examine successful and failed robotics companies. As follow-on to this class, Marketing For Entrepreneurship, taught in the Tepper School of Business, is suggested, especially for RI students who desire 6 additional units of credit. Students who take 16-884 may register for 45-908 in the second half of the semester where the focus there will be on marketing and sales strategies for new companies.

16-899 Special Topics
Fall and Spring: 12 units
Section D: Nuclear Robots

Course Website: https://sites.google.com/site/cmuunderactuatedrobotics/

Tepper School of Business

Robert M. Dammon, Dean

Sevin Yeltekin, Senior Associate Dean, Education

Location: Tepper Quad 2400

Online Appointment Scheduler for Advisors and Executive Directors:
www.tepper.cmu.edu/undergradappt
www.cmu.edu/tepper/programs

The mission of the Tepper School of Business is to improve the leadership and problem-solving capabilities of individuals so as to enhance their value to organizations and society at large. The Tepper School of Business strives for excellence in the creation and dissemination of knowledge that is grounded in scientific principles and interdisciplinary collaboration, and is directed toward improving the practice and profession of management.

History

Since its founding in 1949 by William Larimer Mellon, the Tepper School of Business at Carnegie Mellon has been a pioneer in the field of analytical decision-making and management science. Its three main activities are undergraduate education, graduate education, and research.

Today, the business school is most recognized for research and teaching in the areas of economics, finance, marketing, operations management, organizational behavior, and operations research. The School's notable contributions to the intellectual community include nine Nobel laureates. It is also ranked among the schools with the highest rate of academic citations in the fields of finance, operations/production, operations research, and organizational behavior. The academic offerings of the Tepper School of Business include undergraduate studies in business and economics, masters studies in business administration and financial engineering, and doctoral studies.

Undergraduate and graduate students gain a valuable academic foundation in the fundamental disciplines of economics, the behavioral sciences and the management sciences. In addition to emphasizing an analytical approach to problem-solving and decision-making, students integrate communication, strategic thinking and leadership into their student experience.

Educational Objectives

The Tepper School of Business is committed to excellence at all levels of education – undergraduate, graduate, executive, and life-long learning. We recognize that educational excellence does not occur in a vacuum: It is the result of an intentionally created environment that values and takes advantage of diversity of community, thought, and experience. The result is the "Tepper School Experience" where open exchange of ideas exists and where discovery, innovation, creativity and entrepreneurship germinate and flourish.

Our goal of undergraduate educational excellence is grounded on four pillars:

- creating and providing innovative and dynamic curricula;
- challenging students with opportunities and experiences that encourage them to reflect on the intersections of ethics, responsibility, and professionalism – enabling them to develop the skills needed to be successful future leaders of teams and organizations;
- transforming the classroom experience to make use of technology-enhanced learning so that students have multiple and differentiated learning models; and
- collaborating with programs and colleges across the CMU campus to create unique synergistic curricular and meta-curricular opportunities that take advantage of the breadth of CMU's excellence.

Academic Programs

Undergraduate Degrees Offered

The Tepper School offers degrees and programs that allow students to explore particular fields within their major. These are outlined below — see the departmental sections of the catalog for further details.

Business Administration

The Undergraduate Business Administration Program is among the world's elite programs for undergraduate business study and is consistently rated in the top ten undergraduate programs by *US News & World Report* and in the top twenty-five by *Businessweek*. Its reputation is based upon a rigorous academic curriculum, rich in the technical aspects of management, along with the breadth of liberal arts courses that characterizes what the best of undergraduate study means for the development of the person.

The Tepper School offers the degree of Bachelor of Science in Business Administration with the following concentration areas for specialized study:

- Accounting
- Business Analytics
- Business Technology
- Entrepreneurship
- Finance
- Graphic Media Management
- International Business
- Leadership & Organizational Effectiveness
- Marketing
- Operations Management

Economics

The Undergraduate Economics Program has a unique position at Carnegie Mellon University. It is the sole undergraduate program that is a joint program of the Tepper School of Business and the Marianna Brown Dietrich College of Humanities and Social Sciences. The combination of research strength (The Tepper School has been home to nine Nobel laureates in Economics) and commitment to liberal arts and interdisciplinary studies (Dietrich College has "the most creative general education program of any American university" – New York Times) provides our undergraduates with a world-class economics program.

Economics majors are considered members of both colleges and enjoy the full support and services of both. Undergraduate economics students should consult the program's website for details about applicable Tepper School and Marianna Brown Dietrich academic policies and procedures.

The Undergraduate Economics Program offers five primary degrees (listed below). The Undergraduate Economics Program offers six concentration areas which allow students to specialize in: Market Design and the Digital Economy, Global Change and Disruption, Strategy and Markets, Global Markets and Finance, Policy and Social Impact, and Advanced Quantitative Economics Methods. Concentrations consist of groups of mutually reinforcing economics electives that build off the economics core curriculum. These focused sets of electives allow a student to explore a group of allied topics, and/or develop a specialized and advanced skill set appropriate for a desired career. To fulfill a concentration, students must take four courses from the designated set of electives; courses in the concentrations may count towards your elective requirements. Students are not required to complete a concentration in order to earn a degree. See the program website (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum) for more details.

- B.A. in Economics
- B.S. in Economics
- B.S. in Economics and Mathematical Sciences
- B.S. in Economics and Politics
- B.S. in Economics and Statistics

Minors, Additional Majors and Dual Degrees

In addition to offering major degrees, both undergraduate programs offer additional majors, dual degrees and minors to all members of the Carnegie Mellon undergraduate community. These degrees are:

- Additional Major in Business Administration
- Additional Major in Economics
- Additional Major in Economics and Politics
- Additional Major in Economics and Statistics
- Minor in Business Administration
- Minor in Operations and Supply Chain Management
- Minor in Economics
- Minor in Innovation and Entrepreneurship

Students interested in these degrees should consult with the appropriate Tepper School academic advisor.

First Year Experience and General Education Program

Although the undergraduate business students and the undergraduate economics students follow different first year curricula, both programs provide a broad foundation upon which students build their eventual majors. Details about the first-year experience and general education requirements for the undergraduate business students and the undergraduate economics students can be found, respectively, on the Undergraduate Business Program website (https://www.cmu.edu/tepper/programs/undergraduate-business) and the Dietrich College of Humanities and Social Sciences General Education website (http://www.hss.cmu.edu/gened).

Study Abroad

The Undergraduate Programs encourage students to consider enriching their educational experience by studying abroad during their undergraduate tenure. Interested students should meet with their academic advisors and with the Office of International Educational advisors.

Honors Degree Programs

Both the Undergraduate Economics Program and the Undergraduate Business Administration Program encourage and offer qualified students the opportunity to participate in an honors degree program. See each program's section of the catalog for more details.

Accelerated Masters Programs

Accelerated Master's Degree programs enable exceptional Tepper undergraduate students to earn both an undergraduate degree and a masters degree by remaining one additional year at Carnegie Mellon.

All Carnegie Mellon undergraduates with outstanding academic performance are eligible to apply to the Tepper School's accelerated MBA program (https://www.cmu.edu/tepper/programs/mba/curriculum/dual-and-joint-degrees/3-2-mba.html). Students who are accepted bypass their senior year as undergraduates and earn both their bachelors degree and their MBA degree in five years. Applicants to this 3-2 program are evaluated not only on their academic achievement but also on their maturity, commitment, sense of direction, and interpersonal and communications skills. Their experiences in summer internships and their extracurricular activities are also evaluated. Admission to the MBA program is highly competitive, and 3-2 applicants compete with the entire applicant pool for spaces in the program. Students interested in the 3-2 program should read the MBA catalog available from the Masters Admissions Office. They should also talk with their individual academic advisors concerning completion of their undergraduate requirements.

The Heinz College of Information Systems and Public Policy offers seven professional accelerated masters degree options for CMU undergraduates with outstanding academic records: a Master of Science in Arts Management (https://www.heinz.cmu.edu/programs/arts-management-master), Master of Entertainment Industry Management (https://www.heinz.cmu.edu/programs/entertainment-industry-management-master), Master of Science in Health Care Analytics and IT (https://www.heinz.cmu.edu/programs/health-care-analytics-master), Master of Information Systems Management (https://www.heinz.cmu.edu/programs/information-systems-management-master), and Master of Science in Health Care Policy and Management (https://www.heinz.cmu.edu/programs/health-care-policy-management-master), Master of Science in Information Security Policy and Management (https://www.heinz.cmu.edu/programs/information-security-policy-management-master), and Master of Science in Public Policy and Management (https://www.heinz.cmu.edu/programs/public-policy-management-master).

Research Centers

www.cmu.edu/tepper/faculty-and-research/centers

True to its heritage, the Tepper School commits significant resources to continuing research that advances business practice and theory. Students have the opportunity to learn from professors who spearhead internationally recognized research centers, including:

- Accelerate Leadership Center (https://www.cmu.edu/tepper/faculty-and-research/centers/accelerate-leadership-center)
- Blockchain Initiative (https://www.cmu.edu/tepper/faculty-and-research/centers/blockchain-initiative)
- Healthcare Initiative (https://www.cmu.edu/tepper/faculty-and-research/centers/health-care-initiative)
- Inclusive Growth and Prosperity Initiative (https://www.cmu.edu/tepper/faculty-and-research/centers/inclusive-growth-prosperity-initiative)
- Sustainability Initiative (https://www.cmu.edu/tepper/faculty-and-research/centers/sustainability-initiative)
- Carnegie Mellon Electricity Industry Center (https://ceic.tepper.cmu.edu)
- Center for Behavioral and Decision Research (http://cbdr.cmu.edu)
- Center for Organizational Learning, Innovation and Knowledge (https://www.cmu.edu/tepper/faculty-and-research/centers/center-for-organizational-learning-innovation-and-knowledge)
- Green Design Institute (http://www.cmu.edu/gdi)
- PNC Center for Financial Services Innovation (https://www.cmu.edu/tepper/pnc-center-for-financial-services-innovation)
- Swartz Center for Entrepreneurship (https://www.cmu.edu/swartz-center-for-entrepreneurship)

Policies & Procedures

Academic Standards

A detailed list and explanation of university-wide academic standards and practices governing undergraduate students may be found in the Undergraduate Academic Regulations (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateacademicregulations) section of the catalog. Undergraduate Business Administration students are governed by the program's academic policies described in the program's section of this catalog (http://coursecatalog.web.cmu.edu/tepper/undergraduatebusinessadministrationprogram/#policiesprocedurestext); Undergraduate Economics students are governed by the Dietrich College academic actions policies (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/#academicstandardsregulationsandprotocols).

Graduation Requirements

Students in both the Business Administration Program and the Economics Programs qualify to graduate by meeting the following conditions:

1. Complete all degree, College, and University course requirements as shown in the Undergraduate Business Administration's and Undergraduate Economics Program's sections of this catalog.
2. Be recommended for their degree by the faculty of the Tepper School.
3. Meet the University's residency requirement, detailed in the Undergraduate Academic Regulations (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateacademicregulations) section of the catalog.
4. Meet all financial obligations to the university before being awarded a degree.

Modification of Graduation Requirements: A student may seek permission to modify graduation requirements by petition to the Program head and the Senior Associate Dean, Education.

In addition to meeting university and college graduation requirements, the Undergraduate Economics Program has the additional requirement that economics courses counting towards any economics degree must be completed with a grade of "C" or better.

Undergraduate Business Administration Program

Burton Hollifield, Faculty Head

Jennifer Wegner, Executive Director

Location: Tepper Quad 2400
Email: uba@andrew.cmu.edu
www.cmu.edu/tepper/programs/undergraduate-business

The Business Administration Program in the Tepper School of Business is for students interested in a broad undergraduate education based on quantitative reasoning, leadership development, and communications skills. The curriculum is rigorous and flexible to accommodate the interests of students with diverse goals, ranging from beginning a professional career to graduate study.

Tepper bases the curriculum around a central core of courses in the functional areas of business, economics, mathematics, communications, and breadth courses in liberal arts and sciences. Students complete an in-depth study in one functional business concentration along with additional business electives. Students also complete a minor from outside the Tepper School of Business to obtain breadth and compliment their business education. The minor promotes students' intellectual confidence and leads to the broad knowledge that can last a lifetime. The curriculum structure helps Tepper graduates become leaders in complex global business, technical, and political environments.

Beyond the major in Business Administration, we offer the opportunity for a minor and additional major to students in other programs of the university.

B.S. Degree in Business Administration

To receive the B.S. degree in Business Administration, students must complete at least 364 units, consisting of the requirements for the Business Foundation, Business Core, Concentration Area, Breadth, and a Minor.

Business Foundations

Mathematics		Units
21-120	Differential and Integral Calculus	10
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
70-257	Optimization for Business	9
or 21-257	Models and Methods for Optimization	
or 21-292	Operations Research I	

Economics		
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	

Statistics		
70-207	Probability and Statistics for Business Applications	9
or 36-200	Reasoning with Data	
70-208	Regression Analysis	9
or 36-202	Statistics & Data Science Methods	

Computing		
70-110	Business Computing	9

Business Core

		Units
70-106	Business Science	9
70-122	Introduction to Accounting	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-340	Business Communications	9
70-345	Business Presentations	9
70-371	Operations Management	9
70-381	Marketing I	9
70-391	Finance	9
70-104	Business Leadership Endeavor I	3
70-204	Business Leadership Endeavor II	3
70-304	Business Leadership Endeavor III	3
70-401	Management Game	12

Concentration

Concentrations provide a focus of additional courses (both required and elective) that the student must complete in order to obtain in-depth knowledge of a particular function area. Students should review the required and elective courses for each concentration found on the program's website (https://www.cmu.edu/tepper/programs/undergraduate-business/curriculum/business-concentration-areas.html) at the time of declaration to ensure appropriate understanding of course options which may change as curriculum adjustments are made.

Students must complete at least one of the following concentrations. For students electing to complete an additional major, the concentration requirement is waived.

- Accounting
- Business Analytics
- Business Technology
- Economics, Markets, and Strategy
- Entrepreneurship
- Finance
- Global Economics and Business
- International Business
- Leadership & Organizational Effectiveness
- Marketing
- Operations Management

Business Electives

Students must complete 27 units of Business electives that do not double-count with any other degree requirement. This can include 21-270 Introduction to Mathematical Finance and upper-level Economics courses (73-3xx and above) that do not double-count with any other degree requirement. This cannot include 70-350 Acting for Business.

Breadth

Students must take one course from each of the five distribution categories (Science & Technology; Cognition, Choice, & Behavior; Political & Social Institutions; Creative Production & Reflection; Cultural Analysis) to meet these requirements. The website (https://www.cmu.edu/tepper/programs/undergraduate-business/curriculum/breadth-requirements.html) has the current list of course offerings in each category. Further, students must complete the First-year Writing Requirement and Global Histories to fulfill the requirements for the BA degree. 70-350 Acting for Business can be used to satisfy the Creative Production & Reflection category.

The minimum number of units required to complete the breadth requirements is 63 units.

First-Year WRITING

76-101	Interpretation and Argument	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106 & 76-107	Writing about Literature, Art and Culture and Writing about Data	
or 76-106 & 76-108	Writing about Literature, Art and Culture and Writing about Public Problems	
or 76-107 & 76-108	Writing about Data and Writing about Public Problems	

GLOBAL HISTORIES

79-104	Global Histories	9

Distributional CATEGORIES

Current course offerings can be on the program website (https://www.cmu.edu/tepper/programs/undergraduate-business/curriculum/breadth-requirements.html). Choose one from each category:

- COGNITION, CHOICE, AND BEHAVIOR - This requirement explores the process of thinking, decision making, and behavior in the context of the individual.
- CREATIVE PRODUCTION & REFLECTION - These courses foster creativity and provide exposure to artistic and intellectual products such as drama, literature, design, music, expository writing, and foreign languages. It also seeks to stimulate critical reflection on the process of creating, and inquiry into why one chooses certain kinds of creative productions.
- CULTURAL ANALYSIS - This requirement fosters deeper understanding of the role cultures play in shaping individual and social behaviors.
- POLITICAL AND SOCIAL INSTITUTIONS - This requirement presents courses that analyze, through model-based reasoning, the processes by which institutions organize individual preferences and actions into collective outcomes. Choices draw upon such disciplines as political science, history, and policy analysis.
- SCIENCE & TECHNOLOGY - This requirement seeks to engage students in both exposure to substance, and the experience of, methods in science and technology through courses drawn from the natural and physical sciences, computer science, and engineering.

Minor

In order to obtain the degree, students must complete a minor from another academic department. For students electing to complete an additional major, the minor requirement is waived.

Computing @ Carnegie Mellon

99-101 Computing @ Carnegie Mellon

This course is required of all students for them to learn about the campus computing environment (usually taken prior to one's first semester of first year).

Additional Major/Dual Degree

Additional Major in Business Administration

Students interested in pursuing the additional major in Business Administration must consult with the Undergraduate Business Administration program and meet the requirements outlined on the

declaration form.

The following courses are required for the Additional Major:

Business Foundations

Mathematics		Units
21-120	Differential and Integral Calculus	10
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
70-257	Optimization for Business	9
or 21-257	Models and Methods for Optimization	
or 21-292	Operations Research I	

Economics		
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	

Statistics		
70-207	Probability and Statistics for Business Applications	9
or 36-200	Reasoning with Data	
70-208	Regression Analysis	9
or 36-202	Statistics & Data Science Methods	

Computing		
70-110	Business Computing	9

Business Core

70-122	Introduction to Accounting	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-340	Business Communications	9
70-345	Business Presentations	9
70-371	Operations Management	9
70-381	Marketing I	9
70-391	Finance	9
70-401	Management Game	12

Business Electives

Students must also complete a minimum of 18 units with a maximum of 21 units in Business courses (70-xxx). Business Leadership Endeavor courses (70-104 Business Leadership Endeavor I, 70-105 Business Leadership Endeavor: Intern, 70-204 Business Leadership Endeavor II, 70-205 Business Leadership Endeavor: Analyst, 70-304 Business Leadership Endeavor III, 70-305 Business Leadership Endeavor III) and 70-350 Acting for Business cannot count for this requirement.

Double-Counting Restriction

No more than two business core/business elective courses may double-count toward any other major or minor requirements. There are no double counting restrictions between the additional major and a student's home college general education requirements.

Dual Degree in Business Administration

Students intending to pursue a Dual Degree in Business Administration are required to apply for the degree in the same way students apply for the additional major. In addition to the student's primary degree requirements, a student accepted for Dual Degree in Business Administration is required to complete at least 454 units in total and meet all requirements for the Business Administration major including the major's breadth requirements, concentration area, and business elective requirements. The student's primary major will substitute for the minor requirement. The student's primary major must be completed prior to or at the same time as the dual degree in Business Administration to satisfy the minor requirement.

Double-Counting Restriction

No more than two business core/business elective courses may double-count toward any other degree requirements.

Minors

Minor in Business Administration

Students interested in pursuing the minor in Business Administration must consult with the Undergraduate Business Administration program and meet the requirements outlined on the declaration form.

Required:

70-100	Global Business [1]	9
70-122	Introduction to Accounting	9
73-102	Principles of Microeconomics	9

[1] 70-100 Global Business is intended for first-year and sophomore students only. Juniors and seniors interested in pursuing the business minor must replace the course with a constrained elective.

Constrained Elective - Choose one:

70-311	Organizational Behavior	9
70-371	Operations Management	9
70-381	Marketing I	9
70-391	Finance	9

Business Electives: Choose 18 units of 70-xxx courses.

- The electives cannot include: the Business Leadership Endeavor courses (70-104 Business Leadership Endeavor I, 70-105 Business Leadership Endeavor: Intern 70-204 Business Leadership Endeavor II, 70-205 Business Leadership Endeavor: Analyst 70-304 Business Leadership Endeavor III, 70-305 Business Leadership Endeavor III), 70-207 Probability and Statistics for Business Applications, 70-208

  Regression Analysis, 70-340 Business Communications, 70-345 Business Presentations, 70-350 Acting for Business, and Independent Study/Internship courses.
- Some courses have prerequisites that might include specific mathematics or other Business courses. These may be found in the course descriptions and should be discussed with a Business academic advisor.

Double-Counting Restriction

Students pursuing the minor in Business Administration may double-count one minor course with any other major or minor requirements. There are no double counting restrictions between the minor and the student's home college general education requirements.

Minor in Innovation & Entrepreneurship (IDeATe)

The minor in Innovation & Entrepreneurship is offered by the Tepper School of Business as part of the Integrative Design, Arts and Technology (IDeATe) network. IDeATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in state-of-the-art maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of eight areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, and Physical Computing.

For more information about IDeATe, please see the Undergraduate Options (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateoptions/#ideate) section of the Catalog.

The minor in Innovation and Entrepreneurship is a cross-university initiative that brings together STEM disciplines with arts, humanities, and business.

In this minor, you will work collaboratively in hands-on explorations of the complete 21st century innovation ecosystem. You will experience integrated models of innovation that increase the likelihood of home-run products and services that will captivate society and/or the marketplace. Your contributions can fulfill deep-felt needs or connect culture and lifestyle in a way that galvanizes users and customers. Leveraging the diverse maker culture of Carnegie Mellon, this minor involves collaborative rapid prototyping and iteration.

Innovation & Entrepreneurship Minor Requirements

One Global Business Course

		Units
70-100	Global Business	9
70-106	Business Science	9

One Portal Course

For students with no prior design or product design coursework, one of the following:		Units
15-294	Rapid Prototyping Technologies	5
51-236	Information Design	9
62-478	IDeATe: digiTOOL	6

For students with no prior programming or computer science coursework:		Units
15-104	Introduction to Computing for Creative Practice	10

One Entrepreneurship Course

		Units
70-415	Introduction to Entrepreneurship	9

One Venture Creation Course

		Units
70-395	Funding Entrepreneurial Ventures	9
70-416	New Venture Creation	9

One Innovation Process Course

		Units
70-438	Commercialization and Innovation	9

One Product Development Course

		Units
49-300	Integrated Product Conceptualization	12
49-313	Designing for the Internet of Things	12

Practice/Experience

Multiple possibilities, including:

- 70-416 New Venture Creation (if you did not take it as your Venture Creation option)
- The Swartz Center for Innovation and Entrepreneurship Innovation Scholars Program (http://www.cmu.edu/swartz-center-for-entrepreneurship/education-and-resources/experiential-learning/innovation-scholars)
- The Swartz Center for Innovation and Entrepreneurship Project Olympus Probe (http://www.cmu.edu/swartz-center-for-entrepreneurship/education-and-resources/project-olympus/probes/student-probe-projects.html) - Working on your own startup (12 weeks full-time in summer or throughout one full academic year);
- Students may also, with prior approval of the Executive Director of the Swartz Center, Dave Mawhinney, fulfill this requirement through an internship with a qualifying startup or product design firm (12 weeks, full-time). If interested in this option, students should contact Dave Mawhinney (http://www.cmu.edu/swartz-center-for-entrepreneurship/about/staff.html) during their internship search.

Double-Counting

No more than two minor courses may double-count toward a student's major core requirements or an additional minor's core requirements.

Minor in Operations and Supply Chain Management

Students interested in study with a focus mainly on operations, logistics, and supply chain may choose this alternative business-related minor. Even though one of the requirements is a course in engineering project management, the minor is NOT limited to engineering students. Students interested in the minor must consult with the Undergraduate Business Administration program and meet the requirements outlined on the declaration form.

Required:

73-102	Principles of Microeconomics	9
70-371	Operations Management	9
70-257	Optimization for Business	9
or 21-257	Models and Methods for Optimization	
or 21-292	Operations Research I	
70-471	Supply Chain Management	9
70-460	Mathematical Models for Consulting	9
or 70-477	Real Options: Creating Value Beyond NPV	

Engineering Project Management - choose one:

06-421	Chemical Process Systems Design	12
12-411	Project Management for Construction	9
18-540	Rapid Prototyping of Computer Systems	12
18-578	Mechatronic Design	12
19-451-19-452	EPP Projects-EPP Projects	24
24-370	Engineering Design I: Methods and Skills	12
27-399	Professional Development II	1
42-402	BME Design Project	9
88-451-88-452	Policy Analysis Senior Project-Policy Analysis Senior Project	24

Some courses have prerequisites that might include specific mathematics or other Business courses. These may be found in the course descriptions and should be discussed with a Business advisor.

Double-Counting Restriction

Students pursuing the minor in Operations and Supply Chain Management may double-count two minor courses with requirements outside the minor.

There are no double counting restrictions between the minor and the student's home college general education requirements.

Policies & Procedures

Selected curricular policies are listed below. The Student Handbook (https://www.cmu.edu/tepper/programs/undergraduate-business/curriculum) contains all policies for students pursuing the BA degree, additional major, and minor and should be consulted for the complete set of program policies.

Graduation Requirements

In order to graduate with the Bachelor of Science in Business Administration, students must meet all requirements specified for the program with a cumulative QPA of at least 2.00 and 364 earned units. Students must also meet all university residence requirements and all financial obligations to the university before being awarded a degree.

Dean's List

Students who receive a semester QPA of 3.75 or higher (with at least 36 factorable units and receiving no grades of "incomplete") are placed on the Tepper School's Dean's List for that semester.

Academic Standing

At the end of each semester, the progress and performance of each student is reviewed by the UBA Academic Actions Committee.

Academic Progress

UBA students are expected to make adequate academic progress to ensure they complete their Business Administration degree. For most students, this is enrollment and completion of at least 45 units per semester. There are times when it is appropriate for students to enroll and complete less than 45 units and students should consult with their advisor to make the decision that is best for their immediate and long-term success. If a student enrolls and completes less than 45 units, they may be reviewed by the Academic Actions Committee to ensure they are making adequate progress toward degree completion. Full time status as defined by the university is 36 units. Students must receive advisor approval to take less than 36 units per semester. Taking less than 36 units may have financial implications and students are responsible for consulting their HUB liaison to understand the impact. International students who drop below full time status may have visa implications and must consult with the Office of International Education before dropping to less than 36 units.

Good Standing (Departmental Status)

To graduate in eight semesters, students need to earn an average of 45 units per semester and maintain at least a 2.0 QPA.

Students who are not making adequate progress toward the degree, demonstrated either through QPA or semester course load, may receive a warning notification. Receiving this letter notifies students that they need to consult with their advisor to address their progress and to determine a plan for degree completion. Students who receive a warning notification are required to complete an Academic Success Plan with their advisor (instructions are included in the notification).

Academic Probation (Departmental Status)

Students with a semester QPA below 2.0 and/or did not earn at least 36 factorable units are reviewed for departmental probation. Students with a cumulative QPA below 2.0 may also be placed on probation. When a student is placed on probation, the Academic Actions Committee identifies conditions during the probation semester to support student success that must be met. Students on probation are required to complete an Academic Success Plan with their advisor (instructions are included in the notification). Students with probation status are not permitted to overload.

Students with probation status will be reviewed by the UBA Academic Actions Committee at the end of their probation semester. Students will return to good standing if they meet their probation conditions, earn at least a 2.0 semester QPA, complete at least 36 units, and earn a cumulative QPA at or above 2.0. The Academic Actions Committee may place conditions on students returning to good standing to support student success.

Academic Suspension (University Status, Departmental Decision)

Students who do not meet their probation requirements qualify for academic suspension. When a student is placed on academic suspension, they must meet with their academic advisor and the executive director to develop a plan for their future success. The University defines the suspension policy (https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html):

"University Suspension is a forced, temporary leave from the university… Academic Suspension is the result of poor academic performance or violation of academic regulations and is imposed by the student's college or academic department (see university and college academic policies)."

Suspended students may not:

- register for courses;
- attend classes;
- live in student or fraternity/sorority housing;
- use campus facilities, including athletic facilities, library and computer clusters;
- participate in student activities;
- be members of student organizations; or
- have student jobs. (note: students on academic suspension may have a summer campus job if they accepted the job before they were suspended.)

When a student is academically suspended, the UBA program remains committed to student success and works with students on suspension throughout the suspension in targeted ways to ensure successful return and sustained recovery during their CMU career. There are three phases that define the BA framework: phase one (immediately after suspension decision); phase two (during the suspension); phase three (preparing for the return).Information about these phases is provided in the suspension notification. Each phase includes advisor outreach to check-in with the student.

To return from Academic Suspension, UBA students are required to submit material for review by the Academic Actions committee which will determine if a student is permitted to return. Information about the materials required to return from suspension and the deadline for submission are communicated within the academic actions letter.

Final Probation (Departmental Status)

Following an academic suspension, UBA students return on final probation. When a student is placed on final probation, the Academic Actions Committee identifies conditions during the probation semester to support student success that must be met. Students on final probation are required to complete an Academic Success Plan with their advisor (instructions are included in the notification). Students with final probation status will be reviewed by the UBA Academic Actions Committee at the end of the semester.

Drop (University Status)

Drop means permanent expulsion from the University. This normally follows a student's failure to meet minimal academic performance while on final probation following academic suspension.

Appeals

Students have the right to appeal Academic Actions Committee decisions to the Senior Associate Dean of Education of the Tepper School. All appeals must be received in writing by the deadline printed in teh academic standing notification. Additional information about appealing an Academic Actions' decision is found in *The Word: Student Handbook* (https://www.cmu.edu/student-affairs/theword).

Transfer into Business

The undergraduate Business Administration Program accepts applications for transfer admission from any academic institution outside of Carnegie Mellon University on a limited basis. External transfer is limited to students who have just completed their first year of study in another institution. Students interested in transfer should contact Carnegie Mellon's Office of Admission.

The Program also accepts applications for transfer from current Carnegie Mellon students who are in other colleges. Current students interested in transferring must meet with a Business academic advisor to discuss their plans and qualifications as well as the application for transfer. Successful transfer is limited by both space and academic performance criteria.

Transfer of Course Credit

Courses taken at institutions of higher education outside of Carnegie Mellon can be considered for transfer credit if the courses and the institution offering them are of a comparable level and rigor as determined by CMU faculty. Transfer credit for any Business Administration course must be submitted by the posted deadlines and must be approved by the UBA process. Students must earn a final grade of C or higher to receive transfer credit unless otherwise noted by an individual class. If transfer credit is intended to be used to satisfy a requirement outside of the Tepper School, the respective department must approve the credit. Please refer to the Student Handbook for the complete policy including courses that must be taken at the Tepper School of Business and Carnegie Mellon.

External transfer students admitted to UBA may transfer up to 182 units (including AP credit) for the BA degree. External transfer students are not permitted to earn additional transfer credit. Special exceptions will be considered for one course if a course previously approved for transfer credit is forfeited. Non-UBA students interested in pursuing a business minor/ additional major can transfer, including study abroad, no more than one course toward the business minor and no more than two courses toward the additional major BA core requirements.

Pass/No Credit

Students may use a maximum of 9 units of grades of "P" (pass) credit towards their graduation requirement. This does not include the course 99-101 Computing @ Carnegie Mellon.

The College Honors Program

Students can earn College Honors from the Tepper School by completing a senior honors thesis. The thesis is a two-semester research project with a written thesis as a final product and a presentation at the University's *Meeting of the Minds* research symposium in May. Eligible students must have at least 270 units by the end of the junior year and a 3.5 or higher cumulative QPA.

The honors thesis is 18 units and students receive College Honors upon graduation.

Full-Time Faculty

MUSTAFA AKAN, Associate Professor of Operations Management – Ph.D., Northwestern University; Carnegie Mellon, 2008–

SERKAN AKGUC, Assistant Teaching Professor of Finance, Carnegie Mellon Qatar – Ph.D., Temple University; Carnegie Mellon, 2018–

JAMES F. ALBERTUS, Assistant Professor of Finance – Ph.D., New York University; Carnegie Mellon, 2016–

LAURENCE ALES, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2008–

JAY APT, Professor of Technology; Co-Director, Carnegie Mellon Electricity Industry Center – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000–

LINDA ARGOTE, David M. Kirr and Barbara A. Kirr Professor of Organizational Behavior and Theory; Director, Center for Organizational Learning, Innovation and Performance – Ph.D., University of Michigan; Carnegie Mellon, 1979–

BRANDY L. AVEN, Associate Professor of Organizational Behavior and Theory – Ph.D., Stanford University; Carnegie Mellon, 2010–

KATHRYN BARRACLOUGH, Head, MBA Program; Distinguished Service Professor of Finance – Ph.D., Australian National University; Carnegie Mellon, 2015–

ILKER BAYBARS, Deputy Dean Emeritus, Tepper School of Business; George Leland Bach Chair; Professor of Operations Management – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1979–

JAMES A. BEST, Assistant Professor of Economics – Ph.D., University of Edinburg; Carnegie Mellon, 2018–

CARLA BEVINS, Assistant Teaching Professor of Business Communication – Ph.D., University of Kentucky; Carnegie Mellon, 2017–

ANDREW BIRD, Assistant Professor of Accounting – Ph.D., University of Toronto; Carnegie Mellon, 2013–

PETER BOATWRIGHT, Carnegie Bosch Professor of Marketing – Ph.D., University of Chicago; Carnegie Mellon, 1997–

PIETRO BONALDI, Assistant Professor of Accounting – Ph.D., University of Chicago; Carnegie Mellon, 2017–

ARTHUR A. BONI, The John R. Thorne Distinguished Career Professor of Entrepreneurship, Emeritus – Ph.D., University of California, San Diego; Carnegie Mellon, 2001–

SERRA BORANBAY-AKAN, Assistant Professor of Economics, Carnegie Mellon-Qatar – Ph.D., Northwestern University; Carnegie Mellon, 2013–

CLARA BURKE, Assistant Professor of Business Communication – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2015–

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SOO-HAENG CHO, Associate Professor of Operations Management – Ph.D., University of California, Los Angeles; Carnegie Mellon, 2008–

ROSALIND M. CHOW, Associate Professor of Organizational Behavior and Theory – Ph.D., Stanford University; Carnegie Mellon, 2008–

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W. ROBERT DALTON, Associate Teaching Professor of Economics, Emeritus – Ph.D., University of Missouri; Carnegie Mellon, 1985–

ROBERT M. DAMMON, Dean; Professor of Financial Economics – Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 1984–

TETIANA DAVYDIUK, Assistant Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 2017–

MATTHEW DENES, Assistant Professor of Finance – Ph.D., University of Washington; Carnegie Mellon, 2017–

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KENNETH B. DUNN, Professor of Financial Economics, Emeritus – Ph.D., Purdue University; Carnegie Mellon, 1979–

DENNIS N. EPPLE, Thomas Lord University Professor of Economics – Ph.D., Princeton University; Carnegie Mellon, 1974–

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JOHN GASPER, Assistant Dean of Strategic Initiatives; Associate Teaching Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008–

MARTIN GAYNOR, E. J. Barone University Professor of Economics and Health Policy, H. John Heinz III College and Joint Appointment at the Tepper School of Business – Ph.D., Northwestern University; Carnegie Mellon, 1995–

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MARVIN GOODFRIEND, The Friends of Allan Meltzer Professor; Professor of Economics – Ph.D., Brown University; Carnegie Mellon, 2005–

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OLIVER HAHL, Assistant Professor of Organizational Behavior and Strategy – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2013–

DALE HERSHEY, Associate Teaching Professor of Law, Emeritus – LL.B., Harvard Law School; Carnegie Mellon, 1987–

GEOFFREY HITCH, Associate Teaching Professor of Acting and Business Communication – M.F.A., Carnegie Mellon; Carnegie Mellon, 1992–

BURTON HOLLIFIELD, Head, Undergraduate Business Program, PNC Professor of Finance; Professor of Financial Economics – Ph.D., Carnegie Mellon; Carnegie Mellon, 1998–

JOHN HOOKER, T. Jerome Holleran Professor of Business Ethics and Social Responsibility; Professor of Operations Research; Director, Center for International Corporate Responsibility – Ph.D., Vanderbilt University; University of Tennessee; Carnegie Mellon, 1984 –

YAN HUANG, Assistant Professor of Business Technologies; BP Junior Faculty Chair – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–

RUBAB JAFRY-O'CONNOR, Distinguished Service Professor of Management – Ed.D., University of Pittsburgh; Carnegie Mellon, Carnegie Mellon 2019–

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FALLAW B. SOWELL, Associate Professor of Economics – Ph.D., Duke University; Carnegie Mellon, 1988–

CHESTER S. SPATT, Pamela R. and Kenneth B. Dunn Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 1979–

STEPHEN E. SPEAR, Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 1982–

KANNAN SRINIVASAN, H. J. Heinz II Professor of Management, Marketing, and Information Systems – Ph.D., University of California, Los Angeles; Carnegie Mellon, 1986–

ANTHONY P. STANTON, Teaching Professor of Graphic Media Management – Ph.D., University of Pittsburgh; Carnegie Mellon, 1996–

V. EMILY STARK, Assistant Teaching Professor of Business Communication – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2013–

PETER STUETTGEN, Associate Teaching Professor of Marketing – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–

PETER STUETTGEN, Assistant Teaching Professor of Marketing, Carnegie Mellon Qatar

AUSTIN SUDBURY, Assistant Professor of Accounting – Ph.D., Ohio State University; Carnegie Mellon, 2014–

SRIDHAR R. TAYUR, The Ford Distinguished Research Chair; Professor of Operations Management – Ph.D., Cornell University; Carnegie Mellon, 1991–

RAUL TELANG, Professor if Information Systems, Heinz College, and by courtesy, Tepper School of Business – Ph.D., Carnegie Mellon University ; Carnegie Mellon, 2002–

CHRISTOPHER I. TELMER, Associate Professor of Financial Economics – Ph.D., Queen's University at Kingston (Canada); Carnegie Mellon, 1992–

MICHAEL A. TRICK, Dean, Carnegie Mellon University, Qatar; Harry B. and James H. Higgins Professor of Operations Research – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 1988–

DAVID E. TUNGATE, Distinguished Service Professor of Law – LL.B., University of Illinois School of Law; Carnegie Mellon, 1991–

WILLEM-JAN VAN HOEVE, Professor of Operations Research – Ph.D., University of Amsterdam; Carnegie Mellon, 2007–

STEPHEN VARGO, Assistant Teaching Professor of Business Administration, Carnegie Mellon-Qatar – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1997–

BETH WALTER, Assistant Teaching Professor of Business Communication – Ph.D., Duquesne University; Carnegie Mellon, 2014–

SHU LIN WEE, Assistant Professor of Economics – Ph.D., University of Maryland; Carnegie Mellon, 2014–

LAURIE R. WEINGART, Carnegie Bosch Professor of Organizational Behavior and Theory – Ph.D., Northwestern University; Carnegie Mellon, 1989–

GEORGE M. WHITE, Distinguished Career Professor of Entrepreneurship - Carnegie Mellon-Qatar – Ph.D., University of Oregon; Carnegie Mellon, 2007–

JEFFREY R. WILLIAMS, Professor of Business Strategy, Emeritus – Ph.D., University of Michigan; Carnegie Mellon, 1977–

ANITA WILLIAMS WOOLLEY, Associate Professor of Organizational Behavior and Theory – Ph.D., Harvard University; Carnegie Mellon, 2008–

JOSEPH XU, Assistant Professor of Operations Management – Ph.D., The University of Pennsylvania; Carnegie Mellon, 2016–

SEVIN YELTEKIN, Senior Associate Dean, Education; Professor of Economics – Ph.D., Stanford University; Carnegie Mellon, 2005–

RICHARD O. YOUNG, Teaching Professor of Business Management Communication – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1985–

ERINA YTSMA, Assistant Professor of Accounting – Ph.D., University of Minnesota; Carnegie Mellon, 1985–

ARIEL ZETLIN-JONES, Associate Professor of Economics – Ph.D. , University of Minnesota; Carnegie Mellon, 2012–

Visiting Faculty

MANMOHAN ASERI, Visiting Assistant Professor of Business Technologies – Ph.D., The University of Texas at Dallas; Carnegie Mellon, 2018–

ROBERT C. BLATTBERG, Executive Director, Center for Marketing Technology and Information; Timothy W. McQuire Distinguished Service Professor of Marketing – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008–

CECILE LE ROUX, Visiting Assistant Professor, Organization and Behavior, Carnegie Mellon Qatar – Ph.D., University of Sydney; Carnegie Mellon, 2018–

CHARLES ZHENG, Visiting Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2019-2020–

Adjunct Faculty

SEAN AMMIRATI, Adjunct Professor of Entrepreneurship – B.S., Grove City College; Carnegie Mellon, 2002–

GERARD BEENEN, Adjunct Professor of Organizational Behavior and Theory – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008–

STEVEN BOLLINGER, Adjunct Professor of Entrepreneurship

RICHARD L. BRYANT, Adjunct Professor of Business; Executive Director, Master of Science in Computational Finance Program – M.B.A., Carnegie Mellon University; Carnegie Mellon, 1999–

LEONARD CARIC, Adjunct Professor of Entrepreneurship – M.S.I.A., Carnegie Mellon University; Carnegie Mellon, 1994–

CLYDE (NED) COLLINS, Adjunct Professor of Entrepreneurship – M.B.A., Carnegie Mellon University; Carnegie Mellon, 2004–

LLOYD CORDER, Adjunct Professor of Marketing – Ph.D., University of Pittsburgh; Carnegie Mellon, 2000–

TIM CUNNINGHAM, Adjunct Professor of Entrepreneurship – M.A., University of California, Los Angeles; Carnegie Mellon, 2014–

CHRIS CYNKAR, Adjunct Professor of Entrepreneurship – M.S.I.A., Carnegie Mellon University; Carnegie Mellon, 2008–

L. FRANK DEMMLER, Adjunct Professor of Entrepreneurship – M.B.A., University of California at Los Angeles; Carnegie Mellon, 2002–

CLIFFORD T. EARLY, Adjunct Professor of Law – J.D., University of Pittsburgh; Carnegie Mellon, 2000–

JIM FOSTER, Adjunct Professor of FinanceCarnegie Mellon, 2019–

COLLEN FRANK, Adjunct Professor of ManagementCarnegie Mellon, 2017–

CAROL B. GOLDBURG, Executive Director, Undergraduate Economics Program; Adjunct Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

JOSEPH HORNACK, Adjunct Professor of Law – J.D., Rutgers University; Carnegie Mellon, 1981–

ELAINE HYDER, Adjunct Professor of Organizational Behavior and Theory – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2009–

RAZI IMAM, Adjunct Professor of Entrepreneurship – MBA, Indiana University of Pennsylvania;

HARRIS JONES, Adjunct Professor of Entrepreneurship – MBA, University of Virginia; Carnegie Mellon, 1991–

ROBERT E. KELLEY, Distinguished Service Professor of Organizational Behavior and Theory – Ph.D., Colorado State University; Carnegie Mellon, 1981–

PANOS MOUTIS, Adjunct Professor of Management – Ph.D., National Technical University of Athens; Carnegie Mellon, 2018–

MELISSA MURPHY, Adjunct Professor of Marketing – B.A., University of Pittsburgh; Carnegie Mellon, 2013–

ROBB MYER, Adjunct Professor of EntrepreneurshipCarnegie Mellon, 2018–

ADAM PAULISICK, Adjunct Professor of Entrepreneurship

MARGARITA PORNYKH, Adjunct Professor of Economics – Ph.D., Clemson University; Carnegie Mellon, 2016–

JAMES H. ROBERTS, Adjunct Professor of Law – J.D., Syracuse University School of Law; Carnegie Mellon, 2011–

JOSEPH RUDMAN, Adjunct Professor of Business Communication – D.A., Carnegie Mellon University; Carnegie Mellon, 1974–

MARIA TOMPROU, Adjunct Professor of Organizational Behavior and Theory – Ph.D., Athens University of Economics and Business; Carnegie Mellon, 2018–

REHA TUTUNCU, Adjunct Professor of Operations Research – Ph.D., Cornell University; Carnegie Mellon, 2015–

Undergraduate Business Administration Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

70-100 Global Business
Fall and Spring: 9 units
The course is for non-Tepper BA students and provides a comprehensive overview of business, including how enterprises determine goals, strategies and operational tactics in competitive markets and the increasingly global environment. It covers different types of businesses - entrepreneurial and corporate, industries, markets, and economies. Students learn about the role of business in society, the various functional areas that make business work, and how companies develop plans and processes to achieve their goals for customers, shareholders, and employees. The course has special emphasis on providing a broad overview of business to augment students' major area of study for their professional development. Declared Tepper BA students are not eligible to enroll.

70-104 Business Leadership Endeavor I
Fall and Spring: 3 units
Business Leadership Endeavor (BLE) is a required 3-mini course sequence (70-104,70-204,70-304) offered to undergraduate business students only. BLE 70-104 is the first mini of the BLE course sequence. Each previous mini will serve as a pre-requisite for the next in sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-104 will introduce students to the fundamental building blocks required for their development. Students will learn to develop and improve habits, sharpen personal and professional development skills, and develop meaningful networks.

70-105 Business Leadership Endeavor: Intern
Intermittent: 1 unit
Business Leadership Endeavor (BLE) is a 3-year undergraduate business course sequence that provides personal development and professional preparation. 70-105 Business Leadership Endeavor: Intern starts the BLE sequence, ideally in the first year. Students in 70-105 become familiar with leadership competencies that will contribute to achievement of personal goals, conduct a self assessment and put together a personal development plan. Students should expect to devote a minimum of 18 hours to preparation of their personal development plan, including attendance at class, events and presentations, self assessment, learning about activity opportunities, and discussing options with upper class students for completion over their sophomore and junior years. The outcome of the 70-105-205-305 BLE course sequence is student readiness for a professional life of leadership and global citizenship. This course is available to business students only.

70-106 Business Science
Fall: 9 units
This course is Business Science. It will prepare Tepper Business Majors for the study of business to come. The focus on the class is on the three core "lenses" used to study and advance the science and practice of business. We will study: the mathematics of optimization, economics, and the behavior in and of organizations. These are the foundations of the disciplines of finance, accounting, marketing, ..., that follow in the curriculum. Over the course of the semester, we will tackle complex multifaceted business problems. Think of examples like, bike-share and the "share-economy," international trade and supply chain, AI and the impact on work. For each case, we will work to apply the three lenses. A pillar for the semester is that business problems are not siloed in narrow disciplines, we must draw resources from disciplines across the entire university. The second pillar of our class is solving all problems - across all of society - requires your understanding of business science.

70-110 Business Computing
Intermittent: 9 units
Students will learn how individuals and organizations use computing technologies to support and improve their businesses. At an individual level, students will build their skills with Microsoft Excel and other personal productivity tools. At an organizational level, the class looks at ways in which businesses of all sizes and types leverage computing technologies to run their businesses more efficiently, make better business decisions, and create new business opportunities. This course is reserved for first-year Business students; others may enroll by special permission from the UBA office only.

70-122 Introduction to Accounting
Intermittent: 9 units
This course provides the knowledge and skills necessary for the student to understand financial statements and financial records and to make use of the information for management and investment decisions. Topics include: an overview of financial statements and business decisions; the balance sheet, the income statement, and the cash flow statement; sales revenue, receivables, and cash; cost of goods sold and inventory; long-lived assets and depreciation, and amortization; current and long-term liabilities; owners' equity; investments in other corporations; an introduction to financial statement analysis and international issues dealing with financial statements.

70-160 Graphic Media Management
Intermittent: 9 units
This course covers fundamental topics related to graphic media. Modern graphic techniques are studied in context of the historical developments that underlie them. The greatest emphasis is placed on the current graphic processes, but studying their historical development gives the learner better understanding of their applications today, as well as a sense of the direction in which technology can be expected to move in the future. Information from this course can provide professionals in all industries with tactical advantages in choosing among graphic media options when allocating their media budgets. This course is designed to equip students with a measure of graphic literacy, which refers to the skills and knowledge needed to produce graphic documents that enhance the communication aims of the author. Graphic literacy is an invaluable skill for success in the communication age wherein most professionals are engaged in some aspect of producing graphic documents. Topics of investigation include: traditional printing methods, typography, color reproduction, digital photography, digital cinema, papermaking, electronic paper, graphic displays, inks & coatings, finishing techniques, document security, electrophotographic printing, inkjet printing, large format printing, and holography. Open to undergraduates of all class years. No prerequisites.

70-196 Publishing on the World Wide Web
Intermittent: 9 units
This is an introductory course in Publishing on the World Wide Web. The class has both a classroom component and a lab component. Over the past two decades, the World Wide Web has become an essential communications venue for private individuals and businesses alike. The classroom component of this course examines a variety of topics related to web publishing including: the design and usability of web sites, the appropriate use of file formats, the emergence of e-commerce, the integration of other media, the increased use of mobile devices, the sudden rise of social media, the increased use of 3D environments on the web, the delivery of streaming media across the web, and other topics. The lab component of the class takes the students through a series of exercises beginning with HTML and CSS and progressing to the use of Adobe Dreamweaver, one of the premiere web development software programs. Students use these tools to make well-designed functional websites exhibiting the principles learned in the classroom component of the class. The students are instructed in some of the latest web publishing methods, such as the use of HTML5, CSS3, and fluid grid design which allows the same HTML file to be automatically reconfigured for mobile devices, tablets, and desktop computers. Scripting languages and the development of databases for websites are beyond the scope of this class. Open to undergraduates of all class years. No prerequisites. Formerly course number 70-643.

70-204 Business Leadership Endeavor II
Intermittent: 3 units
Business Leadership Endeavor (BLE) is a required 3-mini course sequence offered to undergraduate business students only. BLE 70-205 is the second mini of the BLE course sequence. Each previous mini will serve as a pre-requisite for the next in sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-205 will help students assemble their fundamental building blocks in a way that supports their continued development. The course will continue to emphasize the importance of strong habits, meaningful networks, and ongoing skill development. Students will begin to connect this development with personal and professional goals.

70-205 Business Leadership Endeavor: Analyst
Intermittent: 4 units
Business Leadership Endeavor (BLE) is a 3-year undergraduate business course sequence that provides students with personal development and professional preparation. 70-205 Business Leadership Analyst is a 4-unit semester course that continues the BLE sequence for all Tepper School of Business BA students. Students registered for 70-205 track their progress on leadership development activities and competency building contributing to achievement of personal goals according to their development plan. Students should expect to devote time to planning, participating, and reflecting on activities in addition to completing an updated personal development plan for completion during their junior year. The outcome of the BLE course sequence is student readiness for a professional life of self reliant leadership and global citizenship.
Prerequisite: 70-105

70-207 Probability and Statistics for Business Applications
Spring and Summer: 9 units
Elementary ideas in probability, statistics, and data analysis are presented in the context of their importance to modern business management.
Prerequisites: 21-112 or 21-120

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70207/probability-and-statistics-for-business

70-208 Regression Analysis
Fall and Summer: 9 units
This class focuses on the statistical analysis of the relationship between two or more random variables. In particular, we examine the estimation of the conditional mean of the dependent variable as a function of independent variables using linear regression. We draw on statistical theory to determine the precision of our estimates and to conduct inference about the population, and we examine a number of applications to business, finance, and economics throughout the course.
Prerequisites: (21-112 or 21-120) and (36-247 or 36-207 or 36-220 or 36-201 or 36-200 or 70-207) and (73-100 or 73-102)

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70208/regression-analysis

70-246 Innovation & Entrepreneurial Mindset
Fall and Spring: 6 units
This course is designed to introduce students to the theory and frameworks used to develop and implement innovative solutions to societal and entrepreneurial problems. The curriculum incorporates the latest on innovative behavioral traits and frameworks with a highly experiential format to expose undergraduate students to out of the box thinking. For example, the instructor would use the lecture section of the class to explain the behavioral techniques that lead to innovative solutions (based on the Innovator's DNA by Clayton Christensen). Teams of 3-6 students each would then examine a problem and be asked to generate 3 potential solutions and a proposed solution, using the techniques presented. Volunteers from the local Carnegie Mellon and entrepreneurial community will serve as mentors and judges, thereby providing a real world learning and networking experience. Ultimately, the best solution will be selected, using a shark tank format. While the selection of a winning solution will be fun for the class, the students will be graded on their having demonstrated the theory & techniques presented in class. Each week will address a new and important topic related to the innovative & entrepreneurial mindset. Weekly format will include one day of lecture and one day of application of the theory introduced in a fun and competitive format.

70-257 Optimization for Business
Intermittent: 9 units
This course provides a mathematical foundation for the application of optimization techniques to business problems, as well as the practical implementation of these methods. Mathematical optimization techniques have been applied for decades in the context of logistics, supply chain management, and strategic planning, with great success. In recent years, the application of mathematical optimization has penetrated, and in some cases (re-)defined, many other areas such as the (financial) service industry, analytical marketing, health care, and web-based businesses. In this course, the most important methods and techniques underlying mathematical optimization are studied. These include linear programming, integer programming, and nonlinear programming as basic mathematical methodologies. Based on these, we also consider methodologies for particular problem classes such as network models and traveling salesman problems. During the course we will emphasize mathematical modeling, that is, creating a mathematical description that reflects a given practical problem described in words. Motivated by these mathematical models, we then discuss the necessary mathematical techniques for finding optimal solutions. Lastly, we consider the solution of these problems using optimization software, i.e., we represent the mathematical models in Excel and use Excel Solver to compute an optimal solution.
Prerequisites: 21-259 or 21-256

70-258 Developing Blockchain Use Case
All Semesters: 6 units
Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token—-CMU Coin—-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. http://tinyurl.com/cmucoincourse The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended.

70-304 Business Leadership Endeavor III
Intermittent: 3 units
Business Leadership Endeavor (BLE) is a required 3-mini course sequence offered to undergraduate business students. BLE 70-305 is the third mini of the BLE course sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-305 will continue to build strong personal and professional skills as students get closer to their professional endeavors. Students will be applying learned skills in and out of the classroom and will begin to see the how the assembled skills are beneficial to themselves and others. This course will emphasize the importance of continued broad growth and lifelong learning.

70-305 Business Leadership Endeavor III
Fall and Spring: 4 units
Business Leadership Endeavor (BLE) is a required 3-mini course sequence offered to undergraduate business students. BLE 70-305 is the third mini of the BLE course sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-305 will continue to build strong personal and professional skills as students get closer to their professional endeavors. Students will be applying learned skills in and out of the classroom and will begin to see the how the assembled skills are beneficial to themselves and others. This course will emphasize the importance of continued broad growth and lifelong learning.
Prerequisite: 70-205

70-311 Organizational Behavior
Intermittent: 9 units
This course examines the factors which influence individual, group and firm behavior in the context of the workplace. Topics covered include perception, group behavior, decision making, motivation, leadership and organizational design and change.
Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108) or 76-245 or 76-331 or 76-347 or 76-327 or 76-102

70-321 Negotiation and Conflict Resolution
Intermittent: 9 units
This course will complement the technical and diagnostic skills you have learned in other courses. A basic premise of the course is that, while you will need analytical skills to discover optimal solutions to problems, you will also need a broad array of negotiation skills to implement these solutions and make sure that they are truly effective. Your long-term effectiveness - both in your professional and personal life - is likely to depend on your negotiating abilities. This course will give you the opportunity to develop these skills experientially and to understand the analytical frameworks that underlie negotiations.
Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

70-332 Business, Society and Ethics
Intermittent: 9 units
The course draws upon actual cases to explore fundamental questions faced by businesses operating in the United States and elsewhere in the world. What justifies governmental regulation of your business? What are the rights of employers and employees? How does the law protect consumers? What laws protect the environment? How do you choose the best legal form for your business? What are the lines of power within a corporation? What protections are available to shareholders? How do the antitrust laws protect competition? What responsibilities does a business have to the community in which it operates? What is the ethical foundation on which business ought to be conducted? The course puts businesses in their legal and ethical context.
Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

70-339 FinTech
Intermittent: 9 units
The financial services industry is a leader in the use of information technology. Firms in banking, securities, investments, insurance and financial marketplaces are among the most information intensive and innovative users of technology. The course will examine the role and potential of technology in this industry. The course begins with a description of the financial markets, specifically equity, foreign exchange, and derivatives, and the systems that enable them. It considers exchanges, ECNs, ATS's Order Management Systems, Straight through Processing, Fix Protocol, and post trading clearance and settlement. It covers the design, evaluation and execution of popular trading strategies that are used by professionals in the various markets. There is increasing interest, in particular, on systematic trading strategies and execution systems because of their scalability and transparency. The course covers both Algorithmic and High Frequency Trading and analyzes issues regarding latency, scalability, and reliability.
Prerequisite: 70-391

70-340 Business Communications
Intermittent: 9 units
Business Communications develops and sharpens your written, oral, and interpersonal communication, introducing you to common forms of professional writing and speaking in specific business situations. The course explores crucial rhetorical issues that impact your ability to communicate and achieve your objectives as a business leader.
Prerequisites: 76-102 or 76-101 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

70-341 Team Dynamics and Leadership
Intermittent: 9 units
Much of the work in groups and organizations consists of communication. You communicate to get information that will be the basis of decisions, to provide a vision for the people who work for and with you, to coordinate activity, and to sell yourself and your work. The goal of this course is to identify sources of communication problems within an organization and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. This course is not a practicum in public speaking or writing, although you will get some experience writing, speaking and managing impressions. Rather the intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly do when you return to work. Readings come from both the research and the managerial literatures. Among the topics considered are managerial communication, persuasion and conformity, self presentation and person perception, social networks. Cases and group projects give you an opportunity to apply what you've learned.
Prerequisites: 36-220 or 36-247 or 36-225 or 36-217 or 36-207 or 36-201 or 36-200 or 70-207

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70341/organizational-communication

70-342 Managing Across Cultures
Spring: 9 units
This course is designed for students who expect to do business in other countries or work with people from other cultures. It provides an intellectual framework for understanding other cultures (and eventually one's own), as well as detailed studies of particular countries. It discusses how culture defines organizations, contracts, personal relationships, attitudes toward authority, time and space, ethics, wealth, and subcultures, and how these affect business. Student teams study a culture of their choice and make presentations, based on interviews and literature research.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-108) or (76-107 and 76-106) or (76-106 and 76-108)

70-345 Business Presentations
Intermittent: 9 units
In this course, students prepare, present, discuss, and critique the different oral presentations currently practiced in business. Topics include developing verbal and physical presence; planning presentations based on audience needs and expectations; projecting personal credibility, professionalism, and appropriate emotional responses; and using various multi-media technology. Assignments and cases will cover informative and persuasive presentations, which will vary from term to term and may include talks such as formal public introductions; explanations of policy and/or procedures; employee training sessions; state-of-the-company addresses; sales presentations; team-driven strategic plans; public interviews with a hostile press; and talks on other more free-ranging topics.
Prerequisites: 73-270 or 70-340

70-347 Publishing Management in the Information Age
Fall and Spring: 9 units
In this course, the publishing industry is studied from a variety of perspectives, but, primarily, with reference to the changes that have been caused by the phenomenon referred to as the information age. The information age is characterized by the ability of individuals to transfer information freely and have instant access to knowledge that would have been difficult or impossible to find previously. The digitization of information and the rise of electronic media have confounded the traditional publishing houses who have struggled to find their footing in this new environment. The information age has also provided new forms of information dissemination and inexpensive means of self-publishing and on-demand publishing. This course examines the history of the publishing industry in western society including books, magazines, and newspapers. It then looks at the disruptive effect that the information age has had in this industry and at the new publishing paradigms that are evolving to take advantage of digital media. The course also includes lab experiences using Adobe InDesign to help students develop skills in designing and preparing pieces for publication by a variety of media. The lab experiences culminate in an independently published book that is written, designed, and assembled entirely by the students in this course. The book stands as a showcase for the research and journalistic skills of the students, as well as, a clear demonstration of the students' proficiency in the content and skills taught in this course. Although this course is open to undergraduates of all class years, it is aimed at 3rd and 4th year students. No prerequisites. The course has been previously listed as number 70-194.

70-348 Cross-Cultural Business Communications
Intermittent: 9 units
This course considers cultural behaviors, assumptions, values, and conflicts surrounding business communication across cultures. It will begin with an evolving definition of "culture" and consider several cultural variables that may affect communicative success (i.e. collectivist/individualist cultures, high-/low-context languages, monochronic/polychronic cultures). Students will research and present findings on the characteristics of specific cultures. They will prepare business documents and presentations that build on the knowledge and skills acquired in 70-340, Business Communication, and reflect new sensitivities to the needs of specific cross-cultural audiences. This course is offered only at the Carnegie Mellon-Qatar campus.
Prerequisites: 76-270 or 70-340 or 15-221

70-349 Color Reproduction & Management
Intermittent: 9 units
Today, we are bombarded by color media in many forms. In the competitive advertising world, the accurate reproduction of color in various media is both a challenge and a necessity. This course examines topics related to the use of color and its reproduction in a variety of media, including photography, print, television, cinema, the Internet. Of prime importance are issues related to the successful specification, transfer, measurement, and application of color to maximize communication efficiency. Students will study the physical nature of light and properties of color, as will the perceptual and psychological aspects of color. The separation of color and the control parameters for optimum color realism will be examined. Modern methods for managing color files to achieve consistent color appearance through different media will be an important focus of the course. The course contains a laboratory component consisting of a series of in-depth exercises in Adobe PhotoShop giving students an opportunity to apply color correction and image manipulation techniques, and to become more adept at using this important software tool. Although this course is open to undergraduates of all class years, it is aimed at 3rd and 4th year students.

70-350 Acting for Business
Intermittent: 9 units
Acting for Business (formerly entitled "Business Acting") is an opportunity to unlock your potential as a communicator through becoming proficient, thorough and masterful at the principles and through a practical interpretation of the techniques of Acting. The course concerns itself with: a new self-awareness and greater confidence in public communication; the expansion and diversification of one's range of personal expression; methods to more effectively shape a public performance and of empowering the student to put his/her best self forward when in contact with an audience; and a re-investment in passion. The course focuses on the goals of: 1) solving issues regarding personal confidence; 2) commanding the space; 3) expanding one's personal comfort zone; 4) achieving the "Audience-Pleasing Form;" 5) utilizing the V.A.T. Communication Tools and 6) beginning to learn the stages in the "Seven Stages to Executive Presence." The participants identify their individual challenges and confront those challenges head-on through the various assignments.

70-352 Business Acting
Spring: 3 units
This is a one-week course that is offered only at CMU in Qatar. This course provides a uniquely broadening educational experience for business students through an exploration & understanding of the process of Acting & the unique performer/audience relationship. Using techniques of Acting, the course will concern itself with: a new self-awareness & greater confidence in public communication; the expansion & diversification of one's range of personal expression; methods to more effectively shape a public performance & of empowering the student to put his/her best Self forward when in contact with an audience; & a re-investment in passion.

70-364 Business Law
Intermittent: 9 units
This course covers the fundamental principles of law that govern business affairs in the United States, with some reference to the laws of other countries. The topics include constitutional sources of business law, administrative agencies, contract law, agency, employment, business forms (corporations, partnerships, limited partnerships, limited liability companies, agency arrangements, franchises), intellectual property and unfair competition, legal liability of professionals, international trade and antitrust.
Prerequisites: 70-340 or 76-102 or 76-101 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

70-365 International Trade and International Law
Intermittent: 9 units
The course discusses the international legal system and laws that affect international trade. It covers the Foreign Corrupt Practices Act, treaties and concessions, shipping and customs, appointment of foreign sales agents, resolution of trade disputes, international mergers and joint ventures, international competition law, UN sales convention, international trade organizations (IMF, WTO, World Bank, etc.), risk insurance, cultural factors, international E-Commerce and intellectual property.
Prerequisites: 73-100 or 73-102

70-366 Intellectual Property and E-Commerce
Intermittent: 6 units
The course is intended to instruct students on the creation of the Internet and the World Wide Web, including the creation of the Domain Naming System. The course will provide an understanding of how the WWW "Web" operates (from its creation to the present), how the laws of various contries interact with the Web; how issues of privacy are addressed and the role of private parties and government in monitoring privacy. The course will examine how intellectual property is created and protected; who owns the property; and the role of ownership of the intellectual property interacts with antitrust laws. The course examines how contracts are formed and administered on the Web by entities created to minimize taxes and personal liability risks for the owners/shareholders of those entities.
Prerequisites: 76-102 or 76-101 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

70-371 Operations Management
Fall and Spring: 9 units
This course is an introduction to production and operations management that covers both manufacturing and services. It deals with strategic issues (design of flexible supply), planning issues (capacity management), and operational issues (inventory management and information). The linkage between strategy and tactics will be emphasized. The students will learn concepts and tools that will help them to manage from the "boardroom" to the "toolroom."
Prerequisites: 36-247 or 36-201 or 36-200 or 36-220 or 36-207 or 36-225 or 70-207

70-374 Data Mining & Business Analytics
Intermittent: 9 units
Interest in big data analytics has skyrocketed recently. The recent explosion in large-scale high-resolution data enables managers to ask and answer questions regarding businesses and consumers at a whole new level. Managers are faced with data about businesses and consumers that are growing faster than they can be utilized. Data mining enables business to extract useful consumer behavior and preferences from seemingly tremendous and unorganized data, which then can be utilized for data-driven decision-making and competitive advantage. Applications can be found in e-commerce, sales, marketing, finance, operations, etc. In this hands-on introductory class, you will learn the basic concepts and techniques of data mining in addition to when and how they can be applied to improve many aspects of business and consumers' welfare. We will discuss the marvelous power of data mining concepts and tools applied to data via troves of current real-world examples, such as recommender systems, customer segmentation, etc. Throughout the course, we will use R, a powerful open-source statistical language and one of the main tools in data mining and business analytics, fast becoming a mainstream tool. With this tool, you will learn about variety of exploratory and predictive data analytics techniques such as Naïve Bayes classifier, nearest neighbor approaches, decision trees, clustering algorithms, etc.
Prerequisites: 36-208 or 70-208 or 36-202

70-376 Energy Systems
Fall: 9 units
This course will provide students with an understanding of the systems and markets that provide energy to businesses and consumers. Students will be introduced to the sources and uses of energy, and how they have evolved and the possible paths over which they may evolve in the next decades. The course places an emphasis on electric energy, the single largest energy source in many industrial economies, but also covers natural gas, oil, and selected other primary energy sources. Students will learn the energy flows in the USA and the world, as well as the business-relevant characteristics of the engineered systems that provide the energy in various forms. Both traditional and emerging energy sources will be discussed, and students will understand the difference between an energy carrier and an energy source. We will also discuss some of the issues that arise without proper management of the physical risks of energy systems. Students will learn some of the history of electric power regulation and the inconsistent subsidy structures that have provided opportunities and challenges for energy companies and investors, including discussion of how emissions restrictions affect fuel, engineering, investment, and project finance choices. The history of electric power markets will be discussed, with an eye to examining the opportunities that market changes create for business.

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70376/energy-systems

70-381 Marketing I
Fall and Spring: 9 units
An introduction to the nature and fundamentals of marketing and consumer behavior. Topics include an analysis of the economic and psychological factors influencing buyer behavior, marketing research, market segmentation, and the development of marketing programs (new product, price, advertising and distribution decisions).
Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

70-385 Consumer Behavior
Intermittent: 9 units
Marketing, in particular, begins and ends with the consumer from determining consumer needs to ensuring customer satisfaction. In this course, we will explore the most recent scientific research in marketing, psychology, and behavioral economics on judgment and decision-making. We will develop your ability to understand and influence what people want, how people decide what and when to buy, and whether people will be satisfied or dissatisfied with their decisions. These psychological insights are particularly useful for marketing strategy, brand positioning, and marketing communication decisions, but also yield insight into common biases in judgment and decision making, beyond marketing, to which you would otherwise fall prey. Why people are willing to drive across town to save $5 on a tank of gasoline, for example, when they would not drive a minute to save $5 on a refrigerator. We will discuss some of these applications in class. In addition, we will examine the methodology of market research (specific to consumer behavior) to build the tools you will need to interpret and base decisions on it.
Prerequisite: 70-381

70-386 Applied Behavioral Decision Making For Business
Intermittent: 6 units
This course is intended to give future managers, consultants, and policy makers an introduction to the insights and applications of behavioral decision making. Behavioral decision making is the interdisciplinary study of how people make decisions. It draws together research from psychology, economics, political science, and management, among other fields. Topics include heuristics and biases in inference and prediction, risk perceptions and attitudes, and the roles of group and emotional processes in decision making. In this course we will address applications of these findings from the various behavioral sciences to the study of business.This course is offered only at the Carnegie Mellon-Qatar campus.
Prerequisites: (36-201 or 70-207 or 36-200) and 73-100

70-391 Finance
Intermittent: 9 units
Firms create value by making good investment decisions. Finance is the field of management science tasked with making this happen. It is a set of tools with which firms identify good investments and decide how to pay for them. Paying for them ultimately involves getting money from households. Therefore, finance also describes the investment decisions of households and the resulting allocation of the economy's resources across firms and time. This course is the introductory finance course in the undergraduate business program. The main topics covered in the course are Financial Markets, Net Present Value, The Objective of the Firm, Discounted Cash Flow, Portfolio Theory and the Cost of Capital, The Efficient Markets Hypothesis, The Capital Structure of the Firm, and Business Valuation. Time permitting, the course will also provide an introduction to option markets and derivative securities. Upon completing the course a student will be able to consider a large and complex business problem, make some assumptions, structure the firms' cash flows in a spreadsheet, calculate the value of different solutions to the problem, and make a decision.
Prerequisites: (73-102 or 73-100) and (70-207 or 36-200 or 36-207 or 36-201 or 36-217 or 36-225)

70-395 Funding Entrepreneurial Ventures
Intermittent: 9 units
So you want to do a startup and you know that you need funding. There are multiple ways to fund a new venture: bootstrapping, economic development, angels, venture capitalists. The question is what are these funders looking for in an early stage investment? What is important to them? How do they decide which companies to invest in and which not? This class looks at funding from the funder's point of view and provides the student with a framework of the investment process: investment criteria, sourcing, selection, due diligence, deal structure, valuation, post investment involvement. Real companies seeking funding are used for the final project in which students will be expected, as investment teams, to make investment decisions and convince their fellow investors (the class) to join them (or not). This is a highly interactive and project class. There will be multiple guest speakers. Prerequisites: Students are highly encouraged to take any of the introductory entrepreneurship classes offered in various schools and departments. While no financial background is required, this class will not cover the basics of entrepreneurship from the entrepreneur's perspective, but will be looking from the investor point of view.

70-398 International Finance
Intermittent: 9 units
International Finance is an elective course designed to give students the opportunity to analyze real-world problems in international capital markets. Topics covered include: exchange rate determination and quoting, international parity relations, foreign exchange hedging strategies using forwards and options, foreign exchange exposure management, international bond market, currency swap market, global equity market, international portfolio risk assessment and performance measurement. Students develop problem solving and communication skills with presentations and critical discussions of case studies.
Prerequisite: 70-391

70-401 Management Game
Intermittent: 12 units
This course is designed to integrate the managerial concepts and techniques studied earlier in the curriculum and to focus on elements of organizational structure and behavior. Student teams assume the role of top management of firms competing in an international economy simulated by the Carnegie Mellon University Management Game. Each team is responsible to a Board of Directors comprised of alumni of the MBA program and business masters students. Emphasis is placed on the development and implementation of sound organizational decision structures as well as the formulation of effective competitive strategies. The course is for senior-year business majors (including business additional majors). Other students who meet the course prerequisites may enroll only with permission of the instructor.
Prerequisites: 70-391 and 70-381 and 70-122 and 70-371

70-412 Advanced Business Communications: Power, Persuasion, and Problem-solving
All Semesters: 9 units
Challenges such as communicating leadership and expertise to a newly formed team, receiving unclear expectations, limited time to complete a complex problem, persuading a reluctant colleague, showcasing yourself in a crucial performance review all occur in business. This advanced course digs deeper into how leaders and successful professionals navigate the complex workplace of surprise, ambiguity, crisis, and diversity. You'll explore varied, often high-stakes workplace scenarios to build your persuasive ability, linguistic skill, communicative flexibility, agility, and confidence.
Prerequisites: (70-345 and 70-340) or 73-270

70-415 Introduction to Entrepreneurship
Intermittent: 9 units
This course is designed primarily to provide an overview of entrepreneurship, develop an entrepreneurial frame of mind and learn the rudiments of how to differentiate an idea from an opportunity. Students come up with a business idea and explore its potential for becoming a viable business. They learn to do market research and experience first-hand the rewards and difficulties in dealing with people in the real world. They will meet entrepreneurs and business professionals as part of the course and learn how to make effective presentations - both written and oral. Other important aspects of the course include self-assessment to determine one's strengths and weaknesses, understanding the "magic" of leadership and gaining an entrepreneurial perspective on life.

70-416 New Venture Creation
Intermittent: 9 units
This course exposes students to the nuances of financing new ventures, getting them started legally and marketing their products or services. Students pull together all the ideas and information from different functional aspects of their projects into coherent and persuasive mini-business plans that serve as roadmaps for building their businesses; and useful instruments to find sufficient financing for the new ventures, so that they can convince the outside world that these opportunities are viable, with substantial potential for success.
Prerequisites: 70-414 Min. grade C or 70-425 or 70-415 Min. grade C or 70-420 Min. grade C or 70-421 Min. grade C or 15-390

70-421 Entrepreneurship for Computer Scientists
Intermittent: 9 units
This course is primarily for non-business school students; it includes most of Introduction to Entrepreneurship (70-415), assumes no background courses in business and involves additional sessions for core business concepts. Students with majors in science, technology, engineering or computer science are exposed to fundamental concepts and issues in innovation, business and entrepreneurship. Students can expect to gain a basic understanding of functional areas such as finance, funding, marketing, sales and management. Student Status: Sophomore year or higher.

70-422 Managerial Accounting
Intermittent: 9 units
The purpose of this course is to provide an introduction to the measurement and allocation of costs. Emphasis will be given to the use of cost information in decision making in organizations. The course will cover standard topics in cost accounting, such as cost behavior and relevant costs, and will connect these to broader issues in microeconomics, decision theory, corporate finance, and operations management. Classes will be a mixture of conventional lectures and laboratory experiments.
Prerequisites: 70-122 and (36-207 or 36-200 or 70-207 or 36-201)

70-423 Technology-Based Entrepreneurship
Spring: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. This course is designed as an introduction to entrepreneurship and basic business concepts for engineering and science students. There are no prerequisites. Students learn basic business concepts, business models, entrepreneurial thinking, idea generation, opportunity recognition, and the basics of accounting, marketing and strategy development. There is no final examination. Instead, students, working in teams, generate an original idea for a startup business and prepare a business plan and an investor presentation, which sets forth the basic strategies, business models and evaluates the opportunity afforded by their original idea. This course also is consistent with the broad mission of Carnegie Mellon University in Qatar's entrepreneurship program, which is described below. The broad mission of the entrepreneurship program at Carnegie Mellon University in Qatar is three-pronged: a.To encourage and develop entrepreneurial and innovative thinking in a business setting, whether or not it is a startup company; b.To obtain the basic skills to start a new venture; c.To stimulate self-evaluation for life direction.

70-424 Corporate Financial Reporting
Intermittent: 9 units
This course is designed to strengthen your ability to correctly interpret financial statements and their accompanying disclosures. The course is aimed at anyone whose career might involve working with accounting data, and should be especially useful for those interested in consulting and financial analysis. Throughout the semester we will discuss the key disclosure rules in the United States, the communication methods available to managers, managers' incentives and ability to exert discretion over reported earnings, and the interplay between a company's corporate strategy and its financial reporting policies and practices. The course emphasizes a number of topics of recent interest to the business community including the quality of earnings, mergers and acquisitions, purchased R&D, post employment benefits, executive compensation, and intangible assets.
Prerequisite: 70-122

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70424/corporate-financial-reporting

70-425 Entrepreneurship for the Creative Industries
Intermittent: 9 units
This is an introductory course designed primarily for undergraduates in the College of Fine Arts who want to create new businesses, products, services, or thriving careers as independent artists. Students can expect to develop an entrepreneurial mindset, learn how creative firms and industries are structured, and build practical skills for finding, evaluating and putting entrepreneurial opportunities into action. We will analyze real world examples, for-profit and not-for-profit, from film, art, architecture, fashion, music, media, theater, retail, and design. The class will explore the core functional areas critical to building entrepreneurial entities, including teams, ideation, marketing and sales, financial analysis, and funding. Interdisciplinary teams will generate ideas and explore their potential as viable businesses or sustainable not-for-profits. Lectures, guest speakers, case studies, and exercises will also be integrated.

70-427 Modern Banks: Strategy and Regulation
Intermittent: 9 units
This course focuses on (1) the financial statement analysis of banks and bank-like financial institutions (thrifts, mortgage banks, and commercial banks); and (2) the accounting and disclosure rules for financial instruments they hold (interest rate risk disclosures, loan loss disclosures, fair value accounting for financial instruments, securitization accounting, derivatives and hedge accounting, and market risk disclosures). The main goal of the course is to provide students with an in-depth understanding of how financial reports provide unusually specific and detailed (but not perfect) information about certain risks and performance of these financial institutions. Their financial statements increasingly are based on fair value accounting and their financial reports include increasingly extensive risk and estimation sensitivity disclosures. Both fair value accounting and risk and estimation sensitivity disclosures are necessary ingredients for financial reports to convey financial institutions' risk and performance in today's world of complex, structured, value and risk partitioning financial instruments and transactions. While financial institutions often report imperfect (or worse) fair value measurements and risk and estimation sensitivity disclosures, careful joint analysis of the information they do provide invariably yields important clues about their risks and performance. While this course is most relevant to students interested in financial institutions, much of the accounting material also pertains to a varying extent to other types of firms. For example, many firms securitize their accounts receivable or hedge their commodity, interest rate, or foreign exchange risk using derivatives.
Prerequisites: 70-391 and 70-122

70-428 Financial Statement Analysis
Intermittent: 9 units
This course is about fundamental analysis using financial statements. We develop and apply technologies for understanding and identifying firm activities that generate shareholder value and for developing valuation benchmarks. The ultimate goal of such analysis is to aid the security valuation and risk analysis exercises. This course is intended to help students establish a good foundation and introduce students the basics of equity and debt analysis techniques. Taking Finance (70-391) before this course is recommended, though not a formal prerequisite.
Prerequisite: 70-122

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70428/financial-statement-analysis

70-429 Accounting for Financial Institutions
Fall: 9 units
The banking sector is important because it drives the financial growth of an economy. This sector accepts deposits from the public and issues loans, and thus the banking sector expands in response to positive changes in retail, corporate and government business demand. Similarly, if a slowdown occurs this results in a reduction in demand for banking sector services. As a result, the important starting point for a financial analyst, who wants to assess current and future economic growth, are the financial statements of banks and the information they contain. To extract this information, however, requires being able to read and interpret the financial statements of a bank. These statements are very different from reading traditional corporate financial statements. As a result, the first objective of this course is to learn how to read financial statements generated from the banking sector including how to interpret and evaluate these statements. The banking sector in Qatar is unique because it has two important and separate subsectors —- Islamic and conventional banking. Each of these subsectors have a different banking business model which in turn generate differences in their financial statements. As a result a second important objective for this course is to learn how to read and evaluate the financial statements from each of these subsectors.
Prerequisite: 70-122

70-430 International Management
Intermittent: 9 units
This course uses the case method to examine the strategic and operational issues in management practice and decision-making that are important in operating a business that spans national borders. Topics include political and economic risk assessment, technology transfer, cultural analysis, negotiation, social responsibility, organization structure, supply chain management and trends in foreign direct investment and their impact on developing strategies for entering and becoming successful in international markets.

70-437 Organizational Learning and Knowledge Management
Intermittent: 9 units
Managing knowledge effectively is key to the performance and competitiveness of both entrepreneurial and established organizations. The course examines why some organizations are better than others at learning from experience and developing new knowledge. The course focuses on how organizations innovate or create new knowledge, how they retain knowledge, and how they transfer knowledge throughout enterprises. Strategic implications of new results on organizational learning and knowledge management are also developed. Students will acquire a greater appreciation of the dynamics of organizations and factors contributing to their successful performance. A mix of lectures, cases and exercises are used to increase your ability to create, retain and transfer knowledge effectively in organizations.
Prerequisites: 36-208 or 36-202 or 36-217 or 36-220 or 36-225 or 36-226 or 70-208

70-438 Commercialization and Innovation
Intermittent: 9 units
This course targets innovators and entrepreneurs who are interested in introducing innovations to the marketplace through start-up, emerging and established organizations. Class participants will learn how to evaluate, develop and implement opportunities for innovation, using an emergent or iterative approach (the lean methodology). Selected industries of interest of importance for economic growth are analyzed. Opportunities for driving or anticipating change are examined using prevailing SET factors (societal, economic, technology). Students then learn a methodology to identify Signals of change involving three customer groups and one non-customer group - undershot customers, non-consumers, overshot customers, in addition to the nonmarket contexts. The Competitive set is analyzed and strategic choices are made. The Resources, Processes and Values (RPV) of the competitive set are analyzed and utilized for informed decision making.
Prerequisites: (73-102 or 73-100) and (15-390 or 70-414 or 70-421 or 70-425 or 70-415 or 70-420)

70-440 Corporate Strategy
Intermittent: 9 units
This course is designed to provide the student with a general management perspective and an understanding of the total business enterprise. It builds upon previous course work in functional areas and provides insights and analytical tools which a general manager should have in order to plan and implement successful business strategy. The student will analyze complex business problems and formulate realistic strategic solutions. Emphasis is placed on the practical application of business theory by the student in his/her business career.

70-443 Digital Marketing and Social Media Strategy
Intermittent: 9 units
This course explores issues related to digital and social media marketing. This is a hands-on class where you will use real world data, case studies and participation in Google online marketing challenge. The following topics would be covered in detail: (a) Search Engine Optimization - you will learn how search engines, keyword auctions, and search engine marketing work, and how to optimize your pay per click advertisement efforts; (b) Econo-Mining - you will also learn on how firms are getting or can get useful information from user generated content using text mining and opinion mining capabilities to drive their product development, placement and advertisement decisions. Using real world data you will analyze whether the traditional approaches for driving advertising or product development strategy are in alignment with what you learn from user generated content; (c) Social Media Marketing - you will learn how to design a social media marketing campaign. What are the key ingredients that make such campaigns successful? How do you run a campaign for a viral product; (d) Forecasting Demand Using Publicly Available Online Search Data - you will learn how to build better forecasting models for demand using Google search data (Google Trends and Insights); (e) Wisdom of the Crowds: we will cover how to design crowdsourcing contests, what and how to crowdsource. You will also learn what prediction markets are, how they work, how to design them, when prediction markets are successful and what kinds of questions are best suited for prediction markets.

70-447 Client Consulting Project: Strategic Management of the Enterprise
Intermittent: 12 units
This is a project course for senior business majors offered in partnership with real-world client companies. Teams of five to six students are given a client to engage with for the semester on a specific consulting project assignment. Students will learn about the challenges of the multi-dimensional and complex issues faced by managers, including learning the concepts and skills to handle ambiguity, perform a persuasive data analysis, and communicate the findings effectively. Students will develop a deeper understanding of how organizations can co-ordinate and leverage synergies across a range of disciplines by effective deployment of technologies and organizational structures and processes. Teams will have an opportunity to work with clients on a wide mix of problems spanning multiple functions, including strategy, operations, technology and marketing. Specifically, teams will address issues such as big data, mobile application strategies, supply chain, digital media, complexity management, health care delivery models and healthcare marketing strategy. Regular meetings with the instructor will be scheduled to guide teams during client engagement and co-ordinate with the executives at their client company. The deliverables will be in the form of a report/prototype and a final presentation to the client's executive team. No classes to attend, but weekly team meetings with times to be determined. The course is for undergraduate business seniors only, and enrollment is by special permission.
Prerequisites: 70-391 and 70-371 and 70-381

70-449 Social, Economic and Information Networks
Spring: 9 units
Interaction is a fundamental part of social science: firms market products to consumers, people share opinions and information with their friends, workers collaborate on projects, agents form alliances and coalitions. In this course, we will use the emerging field of social networks to put structure on this diverse mass of connections. Using a mixture of theoretical, empirical, and computational methods, we will learn about the structure and function of social networks. We will look at how an individual's position in a social network reflects her role in the community. We will learn to identify tastemakers and trendsetters by looking at how information moves through our increasingly connected society. We will consider how our own position in the social network affects our behavior, opinions, and outcomes. And we will explore where social networks come from, and what affects their structure. The material in this course will be interdisciplinary, drawn from the fields of math, computer science, physics, sociology, political science, and economics. By the end of the course, you will have the tools and knowledge needed to analyze social networks on your own. The course is capped with a project where you will use your skills to answer your own questions.
Prerequisites: (36-201 or 36-200 or 73-230 Min. grade C) and (36-201 or 36-207 or 70-207)

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70449/social-economic-information-networks

70-453 Business Technology for Consulting
Intermittent: 9 units
In this course, you will learn to how to effectively lead and undertake information system analysis and design projects. In doing so you will develop your 'intellectual toolbox' for business technologies consulting by learning to apply specific tools and techniques such as BPMN and Agile development methodologies. You will practice applying these techniques on a variety of case studies, examples, and a substantial semester-long project. Beyond the concrete analysis and design techniques, you will develop a set of work practices and habits of thought that should serve you well in your consulting career. This will be a very hands-on course in which you will largely learn by doing. Most class sessions will include a combination of some presentation by the instructor, some discussion (possibly of a case study), and exercises to practice working with the day's tools and concepts. Homework assignments, in-class presentations, and a semester-long term project are essential parts of the course.
Prerequisites: 70-110 or 70-451

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70453/business-technology-for-consulting

70-455 Modern Data Management
Intermittent: 9 units
The goal of this class is to learn organizing, analyzing, querying, interpreting and drawing conclusions from structured data, and modeling business scenarios in relational databases. Thus, the notion of "Data Management" here includes both data analysis and synthesizing conclusions into fact-based, data-driven recommendations. CONTENT 1. advanced Excel functions (e.g., Pivot tables, lookup functions, connecting Excel to relational databases) 2. synthesis (i.e. the ability to create data-driven charts and top-down recommendations) 3. the use of SQL to create and query relational databases 4. data modeling and relational design, i.e. the abstraction and representation of business situations as Entity Relationship (ER) diagrams and the transformation of those into normalized database schemas. CLASSROOM EXPECTATIONS: 1) Cold-calling: I follow an active learning approach requiring high introspection/ reflection/ learning via readings/ preparations before classes, and high interaction during class where students share their insights. This "flipped classroom" requires that you learn the material I post before coming to class. In class, I like to focus on applying skills as much as possible. It also implies that I will cold call students as integral part of our classroom experience. 2) Final exam: This class has proctored midterm and final exams that are comprehensive and by design difficult. But class grades are "soft-curved," i.e. overall class participation and class performance across years determines cut-off percentages. One of the homeworks for this class is solving the final exam from a prior year. 3) The class cannot be audited nor taken pass/fail.

70-460 Mathematical Models for Consulting
Intermittent: 9 units
This course will cover a wide variety of mathematical models and techniques that are used by consultants and lie at the heart of modern decision-support systems. We will discuss the benefits and limitations of different models and follow a practical spreadsheet-based approach to provide hands-on experience with Excel Solver. The course will build on the knowledge you have gained from the prerequisite courses; we will develop your model-building skills, explore some technique-oriented skills such as linear, integer, and nonlinear programming, and experiment with heuristic solution methods. While going through different models and techniques, we will also see real-world examples of how these models are actually used in practical business environments.
Prerequisites: 70-257 or 21-257 or 21-292

70-462 Uncertainty and Risk Modeling
Intermittent: 9 units
This is a hands-on course on modeling and simulation of business systems under uncertainty. It takes the perspective of the consultant whose job is to analyze existing or potential business processes and provide recommendations for managerial decision-making. Recognizing that most businesses are subject to high levels of variability, risk and uncertainty, it will adopt a stochastic approach to characterize the behavior of business systems and processes, and explore the effects of alternative decisions in this context. Two modeling methodologies will be covered: (i) stochastic modeling, and (ii) stochastic simulation. Examples are drawn from different managerial domains, such as supply chain management, risk management, marketing, and project management. The lectures, homework assignments, exam and term project will focus on modeling, computational, and analytical skills. Computational implementations will be done in Excel using the @Risk add-in (during the first half of the course to build simple simulation models) and the Arena software (during the second half of the course to build more complex models based on discrete-event simulation). Course objectives: 1. Recognize uncertainty in business systems and processes, and their impact on managerial decisions (e.g., demand uncertainty, financial risk, etc.) 2. Model uncertainty and risk quantitatively using probabilistic tools 3. Specify probabilistic distributions for inputs from available data 4. Generate probabilistic distributions for outputs and relevant performance metrics (e.g., average, standard deviation, distribution tails) 5. Develop computational models to simulate complex stochastic processes using appropriate software 6. Communicate outputs of uncertainty analyses and implications for managerial decision- making.
Prerequisites: 70-207 or 36-225 or 36-220 or 36-207 or 36-200 or 36-201

70-465 Technology Strategy
Intermittent: 9 units
This course is about business strategy for technology-intensive industries. Examples of such industries are computer hardware and software, media and entertainment, telecommunications and e-commerce. We will explore the unique economic circumstances facing firms in these industries and identify strategies that enable firms to succeed given these circumstances. You will learn to analyze pricing strategies including versioning and bundling; product standardization decisions; managing product complements; exploiting network effects; managing platform competition. This course will help you understand the unique economic characteristics seen in today's technology-intensive markets and how they impact the strategic interactions among firms and consumers. We will study, for example: Why firms in the IT industry give away their best products for free. Why makers of video gaming consoles subsidize end users (but tax game developers) while computer operating system makers subsidize software developers (but overcharge end users). Why Sony won the Blu-Ray format war against HD-DVD which was sponsored by a whole array of companies. In order to understand how firms strategically interact with consumers in technology-intensive industries this course will use a combination of simple but rigorous analytical models, emerging theories, and formal case studies.
Prerequisites: 21-120 and (21-259 or 21-256) and 73-100 and 73-230

70-471 Supply Chain Management
Intermittent: 9 units
During the course we will discuss the basic issues of Supply Chain Management like inventory management, risk pooling, network planning, and supply contracts as well as some of the more concurrent issues. In the face of a globalizing economy we will discuss procurement and outsourcing strategies, global logistics and risk management. As supply chains generally cross firm boundaries we will look at supply chain integration, and alliances from a supply chain perspective. Also, as more and more information can be gathered about customers you will learn how to judge the value of this information and whether or not one should adopt a customer specific pricing model. The above issues will be covered at a general strategic level but whenever possible you will also learn how to quantitatively make trade-offs between alternatives.
Prerequisite: 70-371

70-477 Real Options: Creating Value Beyond NPV
Intermittent: 9 units
Real options analysis is an approach to the management of operational assets that exploits managerial flexibility in decision-making and combines it with market-driven valuation of cash flows. This approach assumes that managers use all the available information when making decisions. It is thus particularly useful when managing projects that involve dynamic and state-contingent choices among alternatives (options), especially of a strategic nature. Examples include investing in and developing new products or technology, expanding/reducing manufacturing capacity, and suspending/resuming production. The valuation of financial options is the conceptual basis of real options management (but this course does not assume prior knowledge of this topic). Real options analysis extends this fundamental market-driven valuation approach to a much broader spectrum of business applications that feature dynamic decision-making. It thus contrasts the standard net present value rule used by static discounted cash flow analysis. The resulting managerial decisions and asset valuations can be very different when real options analysis is used rather than static discounted cash flow analysis. The course learning objectives are to (i) develop the students ability to take an unstructured problem and implement real options analysis in a structured manner; (ii) integrate market-driven valuation and dynamic decision-making techniques into a practical, yet rigorous, business analytics toolkit; and (iii) provide examples of successful practice and applications in a variety of industries.

70-480 International Marketing
Intermittent: 9 units
This course is designed to provide students with a basic understanding of global marketing opportunities, key issues, and strategies. It introduces the main characteristics of international markets and addresses the impact of global environmental factors (economic, social, legal, and cultural) on marketing decisions such as market entry, product development, pricing, promotion, and distribution. The objective of the course is to help students acquire knowledge of major international marketing concepts and develop cross-cultural sensitivities and skills that would enable them to identify, analyze, and solve international marketing problems.

70-481 Marketing Research
Intermittent: 9 units
The purpose of this course is to teach multiple research techniques used in marketing. This course is an applied marketing course that gives insight into how various techniques are used in marketing research firms. There are three projects and a final. The first project is designed to teach students about research survey methods. The second is an experiment in which the whole class is involved. The third, an individual project, is designed to teach quantitative research techniques.
Prerequisites: (36-202 or 70-208) and 70-381

70-482 Pricing Strategy
Intermittent: 9 units
Pricing is a critical marketing decision which enables a firm to translate customer value into profit. This course provides a first survey of pricing concepts. Instead of discussing pricing in isolation, we focus on the interplay between pricing and other aspects of marketing, such as positioning, branding and advertising. To this end, we provide a formal treatment of pricing concepts in the framework of game theory. Finally, we also discuss non-pricing tools that firms can use in order to capture customer value. Specifically, we cover cases wherein firms generate a profit while keeping their services free, a phenomena that is widely observed among Internet firms. This course has no formal prerequisite, but a willingness to study formal (i.e., mathematical) models is assumed. Any previous exposure to microeconomics analysis and game theory will be helpful.

70-483 Advertising and Marketing Communications
Intermittent: 9 units
"Integrated Marketing Communications (IMC) is a strategic business process used to plan, develop, execute, and evaluate coordinated, measurable, persuasive brand communication programs over time with consumers, customers, prospects, and other targeted, relevant external and internal audiences." (source: Don Schultz). IMC is specifically designed to ensure that all communication strategies and messages are unified and integrated across all channels and, importantly, begin with the consumer/customer. It is critical that marketers understand the limitations of marcom tactics as well as how to best leverage and integrate marcom tactics for the strongest, most consistent and authentic brand voice in the targeted marketplace. The entire IMC process is driven by the customer, and in the case of our discussions in this class, the consumer. The course is designed to help students understand the integrated marketing communications model, the strategy and tools of the marketing mix and what makes an iconic brand. The course is designed in five sections: Part One focuses on understanding brands - iconic brands, terminology and types of branding. Part Two focuses on the understanding of consumer behavior - one of the, if not the most critical part of understanding marketing. Brands are built and defined in the minds of consumers. Part Three focuses on IMC and the framework used by brand management to develop strategy, and understand audience segmentation and brand positioning to drive IMC. Part Four focuses on understanding the IMC tactics available to marketers including advertising, social media and digital marketing, events and public relations. Part five concludes with the deeper study of an iconic brand.
Prerequisite: 70-381

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70483/advertising-and-marketing-communication

70-485 Product and Brand Management
Intermittent: 9 units
Product managers are essentially the "CEO" of the product line. Brand and product management provides strategic vision and leadership for the product and service, both 1) understanding the market opportunity and what must be done for successfully delivering on the brand promise and 2) leading across the organization, often without authority, to achieve that success. Product/service success in a dynamic market is subject to many factors, including marketplace needs, reactions and activities of competition, the strategy and change within one's own firm, operating and financial constraints, demand forecast uncertainty, and more. By taking this course, you will learn the principles of product and brand management and understand what it is like and what it takes to be a successful marketing leader.
Prerequisite: 70-381

70-488 Marketing Digital Media
Spring: 6 units
(Formerly titled "Interactive Marketing") In this course we analyze how marketing practice changes when products are distributed and consumed in digital formats. This course focuses on several areas where digitization is likely to have the most profound affect on the field of marketing. These areas include promotion, competitive strategy, channel conflict, pricing, and identifying and differentiating customers. We will use both lectures, cases, and analysis of real-world datasets to analyze these issues.
Prerequisite: 70-381

70-491 Responsible Finance
Fall: 9 units
One of the outcomes from the financial crash of 2008 and the resulting credibility gap faced by traditional financial institutions has been a strong growth in the Responsible Finance sector with Thomson Reuters estimating investments in this sector at US$59 trillion. The purpose of the Responsible Finance course is to introduce the students to this rapidly growing sector and help them gain an understanding of the driving forces behind the growth as well as the knowledge of the products in this space. The course be delivered in modules covering Islamic Finance, Social Banking and challenges posed by FinTech to the conventional Banking Market. Given that these markets are expected to challenge the traditional banking sector, this course complements our existing selection of finance electives to help students get a comprehensive view of the global financial sector and gain access to a broader job market that goes beyond traditional banking.
Prerequisite: 70-391

70-492 Investment Analysis
Intermittent: 9 units
Students build a strong foundation in Modern Portfolio Theory as well as equilibrium and no arbitrage approaches to asset pricing. Common stocks and fixed income securities (including mortgage-backed securities) are the principal markets of interest, with tangential coverage of forward, option, and currency markets. Empirical projects entail applications of trading strategies, portfolio management, and the characteristics of financial market data.
Prerequisites: 21-370 or 70-391

70-495 Corporate Finance
Spring: 9 units
Students develop an advanced financial perspective on how firms make investment, financing, and management decisions. The course starts with simple net present value rules and builds the theoretical framework to address more sophisticated issues and problems including risk management, mergers, acquisitions, executive compensation, corporate governance, and dividend payout policies. Theory is supplemented with numerous case study examples.
Prerequisites: 21-370 or 70-391

70-496 Entrepreneurial Finance: Valuation & Deal
Spring: 9 units
This case-based course studies the financing and valuation of high-growth entrepreneurial firms in the venture capital market. We address the requirements and limitations of a wide array of valuation techniques from the perspective of both the demand and supply side of the market. The entrepreneur's perspective (demand) concerns identifying financing needs and value. The investor's perspective (supply) requires the use a set of tools to evaluate, structure and price financing deals. The tools include discounted cash flow, the VC method, comparables analysis and real options. Venture capitalists act as financial intermediaries and provide both capital and guidance to entrepreneurial firms. These facts introduce unique twists on valuation and deal selection. The course will include four cases over the mini which require group work, class participation and group presentations.
Prerequisite: 70-391

70-497 Derivative Securities
Intermittent: 9 units
This course has two goals. The first goal is to help you to master the tools to price and hedge and understand the risk exposures of any contingent claim on any underlying variable. The second goal in this course is to practice using these pricing and hedging tools in derivative structuring and sales. The focus here is on designing and pricing derivative securities to trade on specialized market views and to hedge customized risk exposures. The course also highlights practical issues about model calibration, model risk, and dynamic and static hedging.
Prerequisites: 21-370 or 70-391

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70497/derivative-securities

70-499 Internship
Intermittent: 3 units
Students doing a business-related internship for academic credit may enroll in this course for three units with a pass/no pass grade. Students must submit an internship agreement form to the instructor for approval prior to the start of the internship. A summary writing assignment must be submitted after the internship in order to receive credit. Business majors may enroll directly; non-business majors may enroll with special permission.

70-500 Honors Thesis I
Intermittent
Business students with outstanding academic records may undertake an Honors Thesis. The topic is of the student's choice but must have some original aspect in the question being explored, the data set, or in the methods that are used. It must also be of sufficient academic rigor to meet the approval of a faculty advisor with expertise in the project's area. Students enroll each semester in a 9-unit independent study course with their faculty advisor for the project (70-500 in the fall and 70-501 in the spring). Students and their faculty advisor develop a course description for the project and submit it for approval as two 9-unit courses to the BA department. Enrollment by permission of the BA Program.

70-501 Honor Thesis II
Intermittent
Business students with outstanding academic records may undertake an Honors Thesis. The topic is of the student's choice but must have some original aspect in the question being explored, the data set, or in the methods that are used. It must also be of sufficient academic rigor to meet the approval of a faculty advisor with expertise in the project's area. Students enroll each semester in a 9-unit independent study course with their faculty advisor for the project (70-500 in the fall and 70-501 in the spring). Students and their faculty advisor develop a course description for the project and submit it for approval as two 9-unit courses to the BA Director. Enrollment by permission of the BA Program.

70-502 Independent Study in Management
Fall and Spring
Students with a special interest in Management/Production not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA program.

70-503 Independent Study in Marketing
All Semesters
Students with a special interest in Marketing not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-504 Independent Study in Organizational Behavior
All Semesters
Students with a special interest in Organizational Behavior not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-505 Independent Study in Finance
All Semesters
Students with a special interest in Finance not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-506 Independent Study Management Information Systems
All Semesters
Students with a special interest in Management Information Systems not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-507 Independent Study in Business Communications
All Semesters
Students with a special interest in Business Communications not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-508 Independent Study in International Management
All Semesters
Missing Course Description - please contact the teaching department.

70-514 Independent Study: Graphic Media Management
Fall and Spring
This course enables students to independently pursue special topics related to graphic media. Enrollment is by permission of the Instructor and the Executive Director of the Business Administration program. Formerly course number 70-650.

Undergraduate Economics Program

Chris Telmer, Head of Economics
Carol B. Goldburg, Executive Director of Undergraduate Economics (Tepper Quad 2406)
Kathleen Conway, Senior Academic Advisor and Program Manager (Tepper Quad 2407)
Location: Tepper Quad, Suite 2400
Email: econprog@andrew.cmu.edu
Advising Appointment Online Scheduler: http://meetme.so/CMUEconomics
www.tepper.cmu.edu/prospective-students/undergraduate/economics

At its most fundamental level, economics is the study of how scarce resources are allocated. What will be produced and consumed, how much, and by whom? These questions are central to the well-being of people throughout the world. Economists identify, model, and analyze problems with the objective of developing practical and efficient solutions to challenges confronting society. Economists are also active participants in the processes and institutions through which economic policies are implemented. In the public arena sphere, economists contribute to design of programs and incentive systems to foster efficient implementation of policies. In the private sector, economists bring modeling and data-analytic skill to bear, both in identifying ways to enhance productive efficiency within the firm and in developing strategies to enhance effectiveness of the firm as it competes in the global marketplace. Increasingly, economists are taking advantage of advances in technology to design new exchange systems in applications as diverse as global electronic markets, kidney exchanges, pollution control, and school choice mechanisms.

Carnegie Mellon University enjoys a rich history of innovative research in the field of economics. The university has a distinctive culture that fosters collaborative, problem-oriented, theoretically rigorous, and empirically tested research. The success of this distinctive approach is manifest in the international recognition accorded past and present faculty, including nine Nobel Prizes in Economics. In the classroom, faculty bring the same rigorous, innovative approach to help develop the tremendous intellectual potential and analytic skills of students who are drawn to study economics at Carnegie Mellon. Project courses and hands-on applications in classes enable our students to gain valuable practical experience in honing their skills in economic reasoning, modeling, and data analysis.

The Undergraduate Economics Program has a unique position at Carnegie Mellon University. It is the sole undergraduate program that is a joint program of the Tepper School of Business and the Dietrich College of Humanities and Social Sciences. The combination of research strength (Tepper has been home to nine Nobel Laureates in Economics) and commitment to liberal arts and interdisciplinary studies (Dietrich has "the most creative general education program of any American university" – New York Times) provides our undergraduates with a world-class economics program.

Economics majors are considered members of both colleges and enjoy the full support and services of both. Undergraduate economics students should consult the program's website for details about applicable Tepper and Dietrich academic policies and procedures.

Educational Objectives

The Undergraduate Economics Program offers a range of degrees in economics designed to develop strong analytical skills and a solid foundation in the discipline of economics. More specifically, measurable objectives for our economics curriculum are the following:

- Students should be able to identify, explain, and use economic concepts, theories, models, and data-analytic techniques.
- Students should acquire and use knowledge of economics, mathematics, statistics, and computing flexibly in a variety of contexts, providing the foundation for success in graduate studies and careers in the public and private sectors.
- Students should be able to apply their economic tools to formulate positions on a wide range of social and economic problems and engage effectively in policy debates.
- Students should use the investigative skills necessary for conducting original economic research and participating effectively in project teams.
- Students should be able to deliver effective presentations in which they combine visual communication design with oral arguments and/or the written word.

Academic Standards and Policies

Undergraduate economics students are in the unique position of belonging to two CMU colleges, Marianna Brown Dietrich College of Humanities and Social Sciences and the Tepper School of Business. To find a detailed description of the college and program policies governing economics students, please visit the program website (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum).

Advising

The Undergraduate Economics Program is committed to providing students with the opportunity to have meaningful and informative discussions about their academic, intellectual, and career interests with a wide range of advisors and mentors. Advising meetings are extended discussions which may address both immediate and long-term interests, concerns, and desires/needs. Students pursuing a degree in economics are assigned an economics advisor who meets with them on a regular basis. Any CMU undergraduate student interested in taking an economics courses is invited to meet with an economics advisor. To facilitate scheduling advising meetings, please use the online appointment scheduler (https://meetme.so/CMUEconomics).

The economics curriculum is cumulative; higher-level courses build upon the foundations learned in the core courses. This results in students needing to be aware of course-sequencing and the schedule of classes. Students are encouraged to meet frequently with their Undergraduate Economics Program academic advisor to ensure that their courses fulfill the requirements towards their degree and are appropriately sequenced. Successful students check-in with their advisor frequently and seek the advice of their academic advisor in selecting courses, pursuing additional degrees, and planning ahead for study abroad.

First-Year Advising

First-year students who major in economics enter Carnegie Mellon University as Dietrich College students, and are assigned a Dietrich College Academic Advisory Center (http://www.cmu.edu/hss/advisory-center) (AAC) advisor. While the AAC advisors are the advisors of record until students formally declare their majors, students who are considering majoring in economics are encouraged to contact the Undergraduate Economics Program academic advisor so that they will have access to program resources; program-level advising; and the community of faculty, staff, and students.

First–year students are **not** expected to know which degree option they wish to pursue. For this reason, the first–year curricula are quite similar for the four primary degrees awarded by the program. As students become involved in their course work, participate in the extra– and co–curricular activities sponsored by the Undergraduate Economics Program, and have discussions with faculty and economics advisors, the decision of which degree to pursue becomes evident.

Study Abroad

The Undergraduate Economics Program encourages students to consider enriching their undergraduate experience by studying abroad at some point during their undergraduate tenure. Studying abroad is widely defined as either study, work, internship, volunteer, or research opportunities abroad during your college career. Studying abroad provides students with not only more awareness of cultural literacies, but it further enhances their education by providing them with the opportunity to compare and contrast different economies and regimes. Many students consider their study abroad experience to be a watershed moment in their studies. With a bit of careful planning, study abroad can be worked into most any economics student's 4-year schedule.

Preparation for Professional School Programs

Many economics students will attend professional graduate school programs (e.g., DDS, JD, MBA, MD, MPP, M.Sc. Finance, etc.) immediately after graduation or within the first five years of earning their undergraduate degree. Students who are considering applying to professional graduate schools are encouraged to discuss their interests with an economics advisor early in their career at CMU. The economics advisors can provide structure and information that are invaluable during a student's intellectual and career exploration. Knowing that the choice of courses, student achievement, extra- and co-curricular activities, professional school entrance exam test scores (e.g., GMAT, LSAT, MCAT, etc), and faculty recommendations are key determinants of acceptance into these varied programs, the economics advisors will help you plan your time at CMU.

Preparation for Ph.D. Programs in Economics

The Undergraduate Economics Program has been successful in preparing students for admission into the nation's most competitive doctoral programs. The life of a researcher (whether in academia or in the private research sector) requires a set of skills that undergraduate students will begin to acquire through course work, research, and focused conversations with faculty and advisors. Doctoral programs in economics are looking for specific analytical skills. Key determinants of acceptance into these programs are the choice of courses, student achievement, research experience, graduate school entrance exam test scores (specifically the GRE), and faculty recommendations. Students who are considering pursuing a higher academic degree are encouraged to discuss their interests with an economics advisor early in their career at CMU. Interested students are encouraged to consider the B.S. in Economics and Mathematical Sciences curriculum.

Curriculum

In order to accommodate students' wide variety of goals, five primary degree programs are available: Bachelor of Arts in Economics, Bachelor of Science in Economics, Bachelor of Science in Economics and Mathematical Sciences (jointly administered by the Department of Mathematics and the Undergraduate Economics Program), Bachelor of Science in Economics and Statistics (jointly administered by the Department of Statistics and Data Science and the Undergraduate Economics Program), and Bachelor of Science in Economics and Politics (jointly administered by the Institute for Politics and Strategy and the Undergraduate Economics Program).

The five major degree programs have been designed to provide students with a solid understanding of the central theories and analytical tools of the field of economics, while maintaining the flexibility necessary to meet the needs of a diversity of career paths. The five degrees produce strong analytical thinkers who are able to model and analyze complex problems. Graduates of the Undergraduate Economics Program gain employment as economic analysts in both the private and public sectors; pursue advanced professional degrees in business, law, and public policy; as well as enter into Ph.D. programs in economics, statistics, finance, and related fields.

For students who major in other academic fields, additional major programs in Economics, Economics and Statistics, and Economics and Politics and a minor degree program in Economics are available.

Concentrations

The Undergraduate Economics Program offers six concentration areas which allow students to specialize in:

- Advanced Quantitative Economic Methods: For students considering a career in a field that requires expertise in both data analytics and economics, or those considering a graduate degree in economics.
- Strategy and Markets: Gain a more comprehensive perspective on the economics of modern business for a career path in consulting or industry.
- Global Markets and Finance: Essential for students interested in a career in international finance, central banking or macroeconomic consulting, this area explores the causes of financial crises, the role of the Federal Reserve in the economy, and the determination of exchange and interest rates.
- Policy and Social Impact: Understand the role of economics in healthcare, taxation, regulation, law, and education as a foundation for a career in government or industries impacted by policy making.
- Global Change and Disruption: Gain an understanding of the key trends reshaping the world economy — such as globalization and technological change — as an essential foundation for a career in strategic consulting, public policy or international organizations such as the IMF or World Bank.
- Market Design and the Digital Economy: For tech firms, consultancies, and many areas of business and public policy, market design — the new frontier of economics — is the key to success. Here, you'll explore why market arrangements succeed or fail, and how markets might be better designed.

Concentrations consist of groups of mutually reinforcing economics electives that build off the economics core curriculum. These focused sets of electives allow a student to explore a group of allied topics, and/or develop a specialized and advanced skill set appropriate for a desired career. Students are not required to complete a concentration in order to earn a degree. See the program website (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum) for more details.

Major Degree Requirements and Sample Schedules

In addition to completing a minimum 360 units and fulfilling both the Dietrich General Education requirements and all University requirements, recipients of an undergraduate degree in economics must complete courses in mathematics, probability and statistics, writing, economic theory, and economic analysis, as well as a set of advanced electives and other specialized courses. It is important for students to realize that degree requirements are actually the "minimum" set of degree requirements. In fact, most economics students take more courses in their major than is strictly required.

Following the list of requirements for each degree are sample four-year course schedules for a student pursuing an undergraduate degree in economics. As there are many different ways of completing the requirements, students are strongly encouraged to meet with an economics advisor to tailor their courses to their own particular needs. Students are responsible for ensuring that they understand all of the program requirements and that they meet the necessary conditions for graduation. When planning course schedules, students must give consideration to all prerequisite and co-requisite requirements.

In addition to meeting university and college graduation requirements, the Undergraduate Economics Program has the additional requirement: Economics courses counting towards any economics primary degree, additional major, or minor must be completed with a grade of "C" or higher.

B.A. in Economics

The B.A. in Economics provides a strong foundation in economic analysis and quantitative methods. The curriculum's breadth incorporates the study of political, historical, and social institutions so that students may use the economic toolkit to address the current challenges humanity faces. Built into the degree is the opportunity to study political, historical, cultural, and social institutions from other CMU departments; these courses are referred to as "Special Electives". The capstone of the curriculum is the Senior Project course where students use their qualitative and quantitative skills to contribute to the body of knowledge in empirical, experimental, and/or theoretical studies. Students pursuing this degree will be well-equipped to pursue graduate work (professional and academic), enter directly into the business world, or pursue public service.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

B.A. in Economics Curriculum

Total Number of Units for the Major:	**157/166**

Mathematics Prerequisites (19 units)

Courses		Units
21-120	Differential and Integral Calculus Passing the MCS assessment test is an acceptable alternative to completing 21-120.	10
21-256	Multivariate Analysis	9

Sophomore Economics Colloquium (3 units)

		Units
73-210	Economics Colloquium I	3

Writing Requirement (9 units)

		Units
73-270	Professional Communication for Economists	9

Economic Theory Requirements (36 units)

		Units
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

Quantitative Analysis Requirements (27 Units)

		Units
36-200	Reasoning with Data	9
or 36-207	Probability and Statistics for Business Applications	
or 70-207	Probability and Statistics for Business Applications	
73-265	Economics and Data Science	9
73-274	Econometrics I	9

Advanced Economics Electives (36 Units)

Students must take four advanced elective courses. Advanced elective courses are those numbered 73-300 through 73-495. Students have the option of earning a concentration (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Special Electives (18 Units)

Students must take two special elective courses in the humanities and social sciences. Students should consult the degree audit system for courses that satisfy the special electives requirement. The list below is a sample of the courses that qualify as special electives; this is not a full list of qualifying courses. Students should consult an academic advisor when choosing special electives.

Course List

Sample List of Special Elective Courses		Units
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-421	Emerging Energy Policies	9
19-424	Energy and the Environment	9
19-443	Climate Change Science and Adaptation	9
19-425	Sustainable Energy for the Developing World	9
66-221	Topics of Law: Introduction to Intellectual Property Law	9
79-245	Capitalism and Individualism in American Culture	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-266	Russian History and Revolutionary Socialism	9
79-280	Coffee and Capitalism	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-300	Guns in American History: Culture, Violence, and Politics	9
79-305	Moneyball Nation: Data in American Life	9
79-310	Modern U. S. Business History: 1870 to the Present	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-320	Women, Politics, and Protest	9
79-343	Education, Democracy, and Civil Rights	9
79-383	The History of Capitalism	9
79-386	Entrepreneurs in Africa, Past, Present and Future	9
80-136	Social Structure, Public Policy & Ethics	9
80-249	AI, Society, and Humanity	9
80-305	Choices, Decisions, and Games	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
84-310	International Political Economy	9
84-318	Politics of Developing Nations	9
84-362	Diplomacy and Statecraft	9
84-414	International and Subnational Security	9
84-387	Technology and Policy of Cyber War	9
88-411	Rise of the Asian Economies	9

Senior Work (9 Units; 18 Units for students working on an honors thesis in economics)

		Units
73-497	Senior Project	9
or 73-500 & 73-501	Tepper College Honors Thesis I and Tepper College Honors Thesis II	
or 66-501 & 66-502	H&SS Senior Honors Thesis I and H&SS Senior Honors Thesis II	

Sample Schedule for B.A. in Economics

The sample schedule below is an illustration of how students might plan their four-year schedules. This schedule has been designed to highlight the following characteristics of the degree program: 1) the work load is roughly 45-50 units per semester, hence there is no need for course overloading; and 2) room has been built into the schedule that would allow students to pursue additional degrees and/or study abroad. It is important for students to realize that degree requirements are the actually the "minimum" set of degree requirements. In fact, most economics students take more courses in their major than is strictly required.

Freshman		Sophomore	
Fall	Spring	Fall	Spring
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	73-240 Intermediate Macroeconomics
21-120 Differential and Integral Calculus	73-103 Principles of Macroeconomics	73-210 Economics Colloquium I	73-274 Econometrics I
73-102 Principles of Microeconomics	-----	73-265 Economics and Data Science	Economics Elective
73-060 Economics: BaseCamp	-----	"Special Elective"	-----
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Junior		Senior	
Fall	Spring	Fall	Spring
73-270 Professional Communication for Economists	Economics Elective	73-497 Senior Project	Economics Elective
"Special Elective"	-----	Economics Elective	-----
-----	-----	-----	-----
-----	-----	-----	-----
-----	-----	-----	-----

*In each semester, ----- represents courses that are not directly required for the major.

B.S. in Economics

The B.S. in Economics provides a strong foundation in economic theory and advanced quantitative analysis. The curriculum focuses on using "real-world" data to forecast behavior and to investigate the relationships between observed phenomenon and economic models. Combining these sophisticated economic modeling data analytic skills with our wide range of upper-level economic electives provides students with a rigorous analytical foundation that will allow them to pursue any career that interests them. The capstone of the curriculum is the Senior Project course where students use their qualitative and quantitative skills to contribute to the body of knowledge in empirical, experimental, and/or theoretical studies. Students completing this degree will be well-equipped to pursue graduate work (professional and academic) or enter directly into the business world or public service.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

B.S. in Economics Curriculum

Total Number of Units for the Major	167/176

Mathematics Requirement (29 Units)

		Units
21-120	Differential and Integral Calculus Passing the MCS assessment test is an acceptable alternative to completing 21-120.	10
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	

Sophomore Colloquium (3 Units)

		Units
73-210	Economics Colloquium I	3

Quantitative Analysis Requirements (27 Units)

		Units
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9

Writing Requirement (9 Units)

		Units
73-270	Professional Communication for Economists	9

Economic Theory Requirements (36 Units)

		Units
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

Advanced Economics Electives (54 Units)

Students must take six advanced elective courses. Advanced elective courses are those numbered 73-300 through 73-495 (excluding 73-374 Econometrics II). Students have the option of earning a concentration (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Senior Work (9 Units; 18 Units for students working on an honors thesis in economics)

		Units
73-497	Senior Project	9
or 73-500 & 73-501	Tepper College Honors Thesis I and Tepper College Honors Thesis II	
or 66-501 & 66-502	H&SS Senior Honors Thesis I and H&SS Senior Honors Thesis II	

Sample Course Schedule for the B.S. in Economics

The sample schedule below is an illustration of how students might plan their four-year schedules. This schedule has been designed to highlight the following characteristics of the degree program: 1) the work load is roughly 45-50 units per semester, hence there is no need for course overloading; and 2) room has been built into the schedule that would allow students to pursue additional degrees and/or study abroad. It is important for students to realize that degree requirements are the actually the "minimum" set of degree requirements. In fact, most economics students take more courses in their major than is strictly required.

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-265 Economics and Data Science	73-240 Intermediate Macroeconomics
21-120 Differential and Integral Calculus	73-103 Principles of Macroeconomics	73-230 Intermediate Microeconomics	73-274 Econometrics I
73-102 Principles of Microeconomics	-----	73-210 Economics Colloquium I	Economics Elective
73-060 Economics: BaseCamp	-----	21-240 Matrix Algebra with Applications	-----
-----*	-----	-----	-----

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
73-270 Professional Communication for Economists	Economics Elective	73-497 Senior Project	Economics Elective
73-374 Econometrics II	Economics Elective	Economics Elective	-----
Economics Elective	-----	-----	-----
-----	-----	-----	-----
-----	-----	-----	-----

*In each semester, ----- represents courses not directly required for the major.

B.S. in Economics and Mathematical Sciences

The B.S. in Economics and Mathematical Sciences is a collaborative effort between the Department of Mathematical Sciences and the Undergraduate Economics Program. Combining advanced mathematics with advanced economic theory is the hallmark of this curriculum. The curriculum provides students with courses that complement and develop depth of understanding of economic theory, applied economics, and applied mathematics. This degree offers an integrated curriculum, guiding students through a program of coursework that exploits and builds upon the synergies between mathematics and economics. This degree program equips students with the mathematical tools that are essential for success in Ph.D. programs in economics; mathematics; and key functional areas of business including finance, accounting, marketing, and information systems. Students pursuing this degree will be well prepared for the beginning of their research careers in academia, government, and industry. There are a limited number of student openings in this program; interested students may apply as early as their sophomore year. Acceptance into the degree program is based on academic performance, rigor of coursework, and initiative while at Carnegie Mellon. In order to graduate with the B.S. in Economics and Mathematical Sciences, students must maintain a cumulative Q.P.A. of 3.33.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

B.S. in Economics and Mathematical Sciences Curriculum

Total Number of Units for the Major	239

Economic Theory Requirements (36 Units)

		Units
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

Quantitative Analysis Requirements (45 Units)

		Units
36-225	Introduction to Probability Theory	9
or 36-217	Probability Theory and Random Processes	
or 21-325	Probability	
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9

73-274	Econometrics I	9
73-374	Econometrics II	9

Mathematical Sciences Requirements (85 Units)

		Units
21-120	Differential and Integral Calculus Passing the MCS assessment test is an acceptable alternative to completing 21-120.	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	10
21-259	Calculus in Three Dimensions	9-10
or 21-256	Multivariate Analysis	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
21-355	Principles of Real Analysis I	9
21-356	Principles of Real Analysis II	9

Programming Requirement (10 Units)

		Units
15-110	Principles of Computing	10

Writing Requirement (9 Units)

		Units
73-270	Professional Communication for Economists	9

Advanced Economic Electives (27 Units)

Students must take three advanced economics elective courses. Advanced Elective courses are those courses numbered 73-300 through 73-495, (excluding 73-374 Econometrics II). Students are encouraged to work with their advisors to structure a set of courses which meet these requirements based on their particular interests, subject to course availability. Students have the option of earning a concentration (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Recommended Advanced Economics Electives:

73-315	Market Design	9
73-338	Financial Crises and Risk	9
73-347	Game Theory for Economists	9
73-365	Firms, Market Structures, and Strategy	9
73-421	Emerging Markets	9

Mathematical Science Depth Electives (27 Units)

Students must take three advanced mathematics depth courses. Students are encouraged to work with their advisors to structure a set of courses which meet these requirements based on their particular interests, subject to course availability.

Recommended Mathematical Science Depth Electives:

21-292	Operations Research I	9
21-329	Set Theory	9
21-365	Projects in Applied Mathematics	9
21-366	Topics in Applied Mathematics	9
21-371	Functions of a Complex Variable	9
21-374	Field Theory	9
21-441	Number Theory	9
21-484	Graph Theory	9
21-499	Undergraduate Research Topic	9

Note: Only one of the following three courses may count towards the required Mathematical Sciences Depth Electives: 21-365, 21-366, or 21-499.

Sample Course Schedule for the B.S. in Economics and Mathematical Sciences

The sample schedule below is an illustration of how students might plan their four-year schedules. This schedule has been designed to highlight the following characteristics of the degree program: 1) the work load is roughly 45-50 units per semester, hence there is no need for course overloading; 2) room has built into the schedule that would allow students to pursue additional degrees and/or study abroad; and 3) the demands of this degree require students to carefully plan their degree program while keeping in mind the college-level and university-level graduation requirements. It is important for students to realize that degree requirements are the actually the "minimum" set of degree requirements. In fact, most economics students take more courses in their major than is strictly required.

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	15-110 Principles of Computing	21-122 Integration and Approximation	21-241 Matrices and Linear Transformations
73-102 Principles of Microeconomics	21-256 Multivariate Analysis	21-127 Concepts of Mathematics	36-226 Introduction to Statistical Inference
36-200 Reasoning with Data	73-103 Principles of Macroeconomics	73-230 Intermediate Microeconomics	73-240 Intermediate Macroeconomics
73-060 Economics: BaseCamp	-----	36-225 Introduction to Probability Theory	73-274 Econometrics I
-----*	-----	-----	Economics Elective

Junior		Senior	
Fall	**Spring**	**Fall**	**Spring**
21-260 Differential Equations	21-355 Principles of Real Analysis I	21-228 Discrete Mathematics	21-356 Principles of Real Analysis II
73-374 Econometrics II	Economics Elective	36-401 Modern Regression	-----
73-270 Professional Communication for Economists	Mathematics Elective	Mathematics Elective	-----
Economics Elective	-----	-----	-----
Mathematics Elective	-----	-----	-----

*In each semester, ----- represents courses not directly required for the major. Please note that students pursuing the B.S. in Mathematical Sciences and Economics must fulfill the Mellon College General Education requirements and not the Dietrich College General Education requirements.

Bachelor of Science in Economics and Politics

Politics and economics are deeply interconnected. Political institutions and decision-making impact economic growth, income distribution, and many other aspects of economic life. Both fiscal and monetary policies affect the economy, but these policies are often employed with political considerations in mind and can influence political activity. Conversely, economic outcomes shape political preferences and policy choices. The overlap between these two disciplines is endless. For example, while the United Nations is often thought of in purely political terms, the Security Council can and does impose sanctions on countries- an example of an economic policy used for political change.

The Economics and Politics major is offered jointly between the Undergraduate Economics Program (https://www.cmu.edu/tepper/programs/undergraduate-economics) (UEP) and the Institute for Politics and Strategy (https://www.cmu.edu/ips) (IPS). Students are equal members of both academic units and receive advising from both units. The major will appeal to any student interested in the design, evaluation, and political implementation of policy. It will be especially attractive to students considering careers in politics, government agencies, political and business consulting, lobbying, or the law.

The B.S. in Economics and Politics is an interdisciplinary major. The major will develop the political context and underpinnings of economic policy making. It will explore how political institutions resolve the tradeoffs and disagreements associated with policymaking and how they can facilitate or impede desirable economic outcomes.

IPS strengths lie in topics like national security, grand strategy, and globalization. Economic policy is just one facet of grand strategy, through which an administration pursues domestic and international goals. This major will also address key issues such as the complementarity between the multilateral economic institutions such as the IMF and World Bank and the use of economic coercion, and enable students to understand economic statecraft more broadly. Whether coercion is successful depends not just on the levers of power but on also on variations in authoritarian regime structure, and complex linkages in the international economy. This is also important for our understanding of the relationship between international economics on human rights practices, extending even to how treaty commitments can facilitate compliance with a global initiative to combat climate change. And, not least important, there is broad recognition that the viability of the “Euro Zone” depends on whether the political-economic agreements necessary to mitigate institutional weaknesses are politically feasible or destined to failure.

Economics and Politics is available as both a primary and additional major.

Curriculum

Students must earn a grade of "C" or better in all courses taken in the Department of Economics (73-xxx).

Prerequisites

Students must complete all of the following courses.

21-120	Differential and Integral Calculus	10
or 21-112	Integral Calculus	
36-200	Reasoning with Data	9

Foundations (48 units)

Students must complete all of the following courses.

21-256	Multivariate Analysis	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-275	Comparative Politics	9
73-210	Economics Colloquium I	3

Core (63 units)

Students must complete all of the following courses.

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9
84-265	Political Science Research Methods	9
84-326	Theories of International Relations	9
84-310	International Political Economy	9

Communication (9 units)

Students must complete one course from the following list.

73-270	Professional Communication for Economists	9
84-250	Writing for Political Science and Policy	9

Electives (27 units)

Majors are required to take 27 units (three courses) from the elective lists below. At least one course (9 units) must be taken from Economics (73-xxx) and at least one course (9 units) must be taken from the Institute for Politics and Strategy (84-xxx). Students may complete electives through coursework in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/ips/cmuwsp) Politics and Public Policy elective sequence.

Economics Electives

73-328	Health Economics	12
73-332	Political Economy	9
73-338	Financial Crises and Risk	9
73-352	Public Economics	9
73-353	Economic Foundations of Regulation: Applications to Financial Markets	9
73-359	Benefit-Cost Analysis	9
73-365	Firms, Market Structures, and Strategy	9
73-367	Technology Jobs and the Future of Work	9
73-372	International Money and Finance	9
73-415	Data Driven Business and Public Policy Decision Making	9
73-421	Emerging Markets	9
73-427	Sustainability, Energy, and Environmental Economcs	9

Politics and Strategy Electives

84-308	Political Economy of Latin America	9
84-309	Political Behavior	9
84-311	International Development: Theory and Praxis	9
84-313	International Organizations and Law	9
84-318	Politics of Developing Nations	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	6
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-363	Comparative Legal Systems	9
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-366	The American Presidency	9
84-369	Decision Science for International Relations	9
84-370	Global Nuclear Politics	9
84-372	Space and National Security	9
84-373	Emerging Technologies and the Law	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6
84-405	The Future of Warfare	9
84-414	International and Subnational Security	9

CMU/WSP Politics and Public Policy Electives

84-330	The Shading of Democracy: The Influence of Race on American Politics	6
84-331	Money, Media, and the Power of Data in Decisionmaking	6
84-332	Effects of US Policy on Businesses: Perspectives of Asian Americans	6
84-333	Power and Levers for Change in Washington, DC	12
84-334	Presidential Power in a Constitutional System	6
84-336	Implementing Public Policy: From Good Idea To Reality	12
84-337	Biomedical Science Research, Policy, and Governance	6
84-340	Making Change: How Organized Interests Work in Washington	12
84-343	Language and Power: How to Understand and Use Political Speech	6
84-346	Legal Issues in Public Administration	6
84-348	Advocacy, Policy and Practice	6

Additional Electives

19-411	Global Competitiveness: Firms, Nations and Technological Change	9
19-425	Sustainable Energy for the Developing World	9
70-365	International Trade and International Law	9
70-430	International Management	9
79-280	Coffee and Capitalism	9
79-318	Sustainable Social Change: History and Practice	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-321	Causation, Law, and Social Policy	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
88-366	Behavioral Economics of Poverty and Development	9

88-419	International Negotiation	9
88-444	Public Policy and Regulation	9

CAPSTONE (15-21 units)

Students must complete all of the following courses.

84-450	Policy Forum 12 units if taken during CMU/WSP, 6 units if taken in Pittsburgh	6
73-497	Senior Project or Senior Honors Thesis	9

SAMPLE Four Year Plan

Freshman		Sophomore	
Fall	Spring	Fall	Spring
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	73-210 Economics Colloquium I	73-240 Intermediate Macroeconomics
36-200 Reasoning with Data	73-103 Principles of Macroeconomics	73-230 Intermediate Microeconomics	Communication Course (84-250 or 73-270)
73-102 Principles of Microeconomics	84-275 Comparative Politics	73-265 Economics and Data Science	84-265 Political Science Research Methods
84-104 Decision Processes in American Political Institutions	Freshman Seminar	84-310 International Political Economy	73-274 Econometrics I
76-101 Interpretation and Argument	79-104 Global Histories	84-326 Theories of International Relations	Economics & Politics Elective 1
99-101 Computing @ Carnegie Mellon		Open 1	

Junior		Senior	
Fall	Spring	Fall	Spring
Economics & Politics Elective 2	Open 5	73-497 Senior Project or Senior Honors Thesis	84-450 Policy Forum May also be taken during the CMU/WSP
Economics & Politics Elective 3	Open 6	Open 10	Open 14
Open 2	Open 7	Open 11	Open 15
Open 3	Open 8	Open 12	Open 16
Open 4	Open 9	Open 13	Open 17

Economics and Politics students are highly encouraged to participate in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/ips/cmuwsp) during the junior year. Study abroad is also encouraged.

B.S. in Economics and Statistics

Samantha Nielsen, *Statistics & Data Science Lead Academic Advisor*
Kathleen Conway, *Economics Senior Academic Advisor*
Rebecca Nugent and Edward Kennedy, *Faculty Advisors*
Carol Goldburg, Executive Director, *Undergraduate Economics Program*

Statistics & Data Science Location: Baker Hall 132
statadvising@stat.cmu.edu

Economics Location: Tepper 2400
econprog@andrew.cmu.edu

The B.S. in Economics and Statistics is jointly advised by the Department of Statistics and Data Science and the Undergraduate Economics Program.

The Major in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. With joint curriculum from the Department of Statistics and Data Science and the Undergraduate Economics Program, the major provides students with a solid foundation in the theories and methods of both fields. Students in this major are trained to advance the understanding of economic issues through the analysis, synthesis and reporting of data using the advanced empirical research methods of statistics and econometrics. Graduates are well positioned for admission to competitive graduate programs, including those in statistics, economics and management, as well as for employment in positions requiring strong analytic and conceptual skills - especially those in economics, finance, education, and public policy.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

The requirements for the B.S. in Economics and Statistics are the following:

I. Prerequisites — 38-39 units

1. Mathematical Foundations — 38-39 units

Calculus

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	9

Note: Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Note: Taking/having credit for both 21-111 and 21-112 is equivalent to 21-120. The Mathematical Foundations total is then 48-49 units. The Economics and Statistics major would then total 201-211 units.

Linear Algebra

One of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	10
21-242	Matrix Theory	10

Note: 21-241 and 21-242 are intended only for students with a very strong mathematical background.

II. Foundations — 18-36 units

2. Economics Foundations — 18 units

73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9

3. Statistical Foundations — 9-18 units

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data	9
36/70-207	Probability and Statistics for Business Applications	9
36-220	Engineering Statistics and Quality Control	9
36-247	Statistics for Lab Sciences	9

Note: Students who enter the program with 36-225 or 36-226 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for the Economics and Statistics Major may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

36-202	Statistics & Data Science Methods **	9
36-208	Regression Analysis	9
36-290	Introduction to Statistical Research Methodology	9
36-309	Experimental Design for Behavioral & Social Sciences	9

* Or extra data analysis course in Statistics
** Must take prior to 36-401 Modern Regression.

Advanced
Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9

36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Sequence 2 (For students beginning later in their college career)

Advanced
Choose *three* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

III. Disciplinary Core 126 units

1. Economics Core 45 units

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-270	Professional Communication for Economists	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9

2. Statistics Core 36 units

36-225	Introduction to Probability Theory *#	9

and *one* of the following two courses:

36-226	Introduction to Statistical Inference *	9
36-326	Mathematical Statistics (Honors) *	9

and *both* of the following two courses:

36-401	Modern Regression *	9
36-402	Advanced Methods for Data Analysis	9

*In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-225 (or equivalents), 36-226 or 36-326 and 36-401.

#It is possible to substitute 36-217, 36-218, or 21-325 for 36-225 36-225 36-22536-225. (36-225 36-225 36-22536-225 is the standard introduction to probability, 36-217 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 21-325 21-32521-325 is a rigorous Probability Theory course offered by the Department of Mathematics.)

3. Computing 9 units

36-350	Statistical Computing *	9

*In rare circumstances, a higher level *Statistical* Computing course, approved by your Statistics advisor, may be used as a substitute.

4. Advanced Electives 36 units

Students must take two advanced Economics elective courses (numbered 73-300 through 73-495, excluding 73-374) and two (or three - depending on previous coursework, see Section 3) advanced Statistics elective courses (numbered 36-303, 36-311, 36-315, 36-46x, 36-490, or 36-497).

Students pursuing a degree in Economics and Statistics also have the option of earning a concentration area (https://www.cmu.edu/tepper/programs/undergraduate-economics/curriculum/concentrations) by completing a set of interconnected electives. While a concentration area is not required for this degree, it is an additional option that allows students to explore a group of aligned topics and/or develop a specialized and advanced skill set appropriate for a desired career path. The electives required for this degree may count towards your concentration area. To fulfill a concentration, students must take four courses from the designated set of electives. Please make sure to consult an advisor when choosing these courses.

Total number of units for the major	**191-201 units**
Total number of units for the degree	**360 units**

Professional Development

Students are strongly encouraged to take advantage of professional development opportunities and/or coursework. One option is 73-210 Economics Colloquium I, a fall-only course that provides information about careers in Economics, job search strategies, and research opportunities. The Department of Statistics and Data Science also offers a series of workshops pertaining to resume preparation, graduate school applications, careers in the field, among other topics. Students should also take advantage of the Career and Professional Development Center.

Additional Major in Economics and Statistics

Students who elect Economics and Statistics as a second or third major must fulfill all Economics and Statistics degree requirements. Majors in many other programs would naturally complement an Economics and Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least six courses (three Economics and three Statistics) that do not count for their primary major. If students do not have at least six, they typically take additional advanced data analysis or economics electives, depending on where the double counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Economics and Statistics.

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Economics and Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Economics and Statistics.

Sample Program

The following sample program illustrates one way to satisfy the requirements of the Economics and Statistics Major. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule).

Freshman		Sophomore	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	36-202 Statistics & Data Science Methods	36-225 Introduction to Probability Theory	21-240 Matrix Algebra with Applications
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	36-226 Introduction to Statistical Inference
73-102 Principles of Microeconomics	73-103 Principles of Macroeconomics	73-210 Economics Colloquium I *not required	73-240 Intermediate Macroeconomics
73-060 Economics: BaseCamp *not required	-----		73-274 Econometrics I
-----	-----	73-265 Economics and Data Science	-----

Junior		Senior	
Fall	Spring	Fall	Spring
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	Statistics Elective	Economics Elective
36-401 Modern Regression	73-270 Professional Communication for Economists	Economics Elective	Statistics Elective
73-374 Econometrics II	-----	-----	-----
-----	-----	-----	-----
-----		-----	-----

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Prospective PhD students might add 21-127 fall of sophomore year, replace 21-240 with 21-241, add 21-260 in spring of junior year and 21-355 in fall of senior year.

Supplemental Programs

Honors Program in Economics

Outstanding students are eligible for the honors programs in both the Tepper School of Business and the Dietrich College of Humanities and Social Sciences. For more information, consult the Dietrich Honors Program website (http://www.cmu.edu/dietrich/undergraduate/programs/shp).

The Tepper Senior Honors Program in Economics (http://tepper.cmu.edu/prospective-students/undergraduate/economics/curriculum/research/senior-honors-program) provides qualified students with the opportunity to engage in original research during their senior year at Carnegie Mellon. The primary rewards of participating in the Honors Program in Economics are three-fold. First comes the satisfaction of undertaking and completing an original piece of research. Working independently or with a faculty member to identify a research question and claim ownership of its discovery process is a rewarding experience. Second is the opportunity to challenge oneself intellectually. The third advantage is the opportunity to graduate with Tepper Honors. For many, this process of intellectual inquiry and knowledge creation is the highlight and culmination of their undergraduate academic experience.

Students are invited into the Tepper Senior Honors Program in Economics during their junior year. Invitation is based on academic achievement at Carnegie Mellon University, ability to work independently, and tenacity of spirit.

Accelerated Master’s Degree Programs

Accelerated Master’s Degree programs enable exceptional students to earn both an undergraduate degree and a masters degree by remaining one additional year at Carnegie Mellon. The Heinz College of Information Systems and Public Policy offers seven professional accelerated masters degree options for CMU undergraduates: a Master of Science in Arts Management (https://www.heinz.cmu.edu/programs/arts-management-master), Master of Entertainment Industry Management (https://www.heinz.cmu.edu/programs/entertainment-industry-management-master), Master of Science in Health Care Analytics and IT (https://www.heinz.cmu.edu/programs/health-care-analytics-master), Master of Information Systems Management (https://www.heinz.cmu.edu/programs/information-systems-management-master), and Master of Science in Health Care Policy and Management (https://www.heinz.cmu.edu/programs/health-care-policy-management-master), Master of Science in Information Security Policy and Management (https://www.heinz.cmu.edu/programs/information-security-policy-management-master), and Master of Science in Public Policy and Management (https://www.heinz.cmu.edu/programs/public-policy-management-master). The Tepper School of Business offers one accelerated professional degree, a Master in Business Administration.

Dual Degree in Economics

A student pursuing a primary degree outside of the department may obtain a dual degree by completing all of the requirements for the B.S. in Economics or the B.S. in Economics and Statistics along with the Dietrich College general education requirements. In addition, the student’s total units completed must be at least 90 units in excess of the requirement for the student’s other degree(s) or at least 450 units, whichever is greater. Interested students should meet with an economics advisor.

Additional Major in Economics Curriculum

All university students are eligible to pursue an additional major in economics in conjunction with a major in any department in the university other than economics. The requirements for the Additional Major in Economics are the same as those for the B.S. in Economics, except that the Dietrich College General Education requirements are waived. In order to avoid “double counting” issues, students are encouraged to meet with an economics advisor. When courses are shared across degrees, students pursuing an Additional Major in Economics are asked to take additional advanced economics electives.

Additional Major in Economics and Statistics Curriculum

All university students are eligible to pursue a major in economics and statistics in conjunction with a major in any department in the university other than statistics or economics. The requirements for the Additional Major in Economics in Statistics are the same as those for the B.S. in Economics and Statistics, except that the Dietrich College General Education requirements are waived. In order to avoid “double counting” issues, students are encouraged to meet with an economics or statistics advisor. When courses are shared across degrees, students pursuing an Additional Major in Economics and Statistics are asked to take additional advanced economics or statistics electives.

Additional Major in Economics and Politics Curriculum

All university students are eligible to pursue a major in economics and politics in conjunction with a major in any department in the university other than economics or the Institute for Politics and Strategy. The requirements for the Additional Major in Economics in Politics are the same as those for the B.S. in Economics and Politics, except that the Dietrich College General Education requirements are waived. In order to avoid “double counting” issues, students are encouraged to meet with an economics or Institute for Politics and Strategy advisor. When courses are shared across degrees, students pursuing an Additional Major in Economics and Politics are asked to take additional electives.

Minor in Economics

In addition to preparing students to be better informed global citizens and consumers, the Minor in Economics provides students with the economic and data analytical toolkit that is the foundation of business/organizational decision-making.

All university students are eligible to pursue the Minor in Economics in conjunction with a major in any other department in the university. In order to avoid “double counting” issues, students are encouraged to meet with an economics advisor. When courses are shared across degrees, students pursuing a minor in Economics are asked to take additional advanced economics electives.

All economics courses counting towards the minor must be completed with a grade of "C" or higher.

Minor in Economics (Total Number of Units for the Minor: 82)

Mathematics Requirements (10 Units)

		Units
21-120	Differential and Integral Calculus	10

Economic Theory Requirements (27 Units)

		Units
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-160	Foundations of Microeconomics: Applications and Theory *	9

*Students may choose to replace 73-160 with 73-230 Intermediate Microeconomics or 73-240 Intermediate Macroeconomics. Most of the advanced economics electives require 73-230 and/or 73-240. Please note that 21-256 is a pre-requisite for 73-230.

Quantitative Analysis Requirements (18 Units)

The quantitative analysis path is often determined by the major requirements. The sequence is designed to give students an understanding of probability theory, regression analysis, and quantitative economic analysis. Students are encouraged to talk with an economics advisor to determine which requirements best complement their primary fields of study.

Option One		Units
36-200	Reasoning with Data	9
or 36-207	Probability and Statistics for Business Applications	
or 70-207	Probability and Statistics for Business Applications	
73-265	Economics and Data Science	9

Option Two		
36-220	Engineering Statistics and Quality Control	9
73-265	Economics and Data Science	9

Option Three		
36-217	Probability Theory and Random Processes	9
or 36-225	Introduction to Probability Theory	
73-265	Economics and Data Science	9

Advanced Economics Electives (27 Units)

Students must take three advanced elective courses. Advanced elective courses are those numbered 73-3xx through 73-49x. Students are encouraged to work with their economics advisor to structure a set of courses to meet these requirements based on their particular interests, subject to course availability.

Faculty

LAURENCE ALES, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2008–

JAMES A. BEST, Assistant Professor of Economics – Ph.D., University of Edinburgh; Carnegie Mellon, 2018–

AISLINN BOHREN, Associate Professor of Economics – Ph.D., University of California, San Diego; Carnegie Mellon, 2018–

DAVID CHILDERS, Assistant Professor of Economics – Ph.D., Yale University; Carnegie Mellon, 2016–

KAREN B. CLAY, Professor of Economics and Public Policy, H. J. Heinz III College – Ph.D., Stanford University; Carnegie Mellon, 1998–

ROBERT M. DAMMON, Dean; Professor of Financial Economics – Ph.D., University of Wisconsin; Carnegie Mellon, 1984–

TIMOTHY P. DERDENGER, Associate Professor of Marketing and Strategy – Ph.D., University of Southern California; Carnegie Mellon, 2009–

KENNETH B. DUNN, Professor of Financial Economics, Emeritus – Ph.D., Purdue University; Carnegie Mellon, 1979–

DENNIS N. EPPLE, Thomas Lord University Professor of Economics – Ph.D., Princeton University; Carnegie Mellon, 1974–

SELMAN EROL, Assistant Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2016–

CHRISTINA FONG, Senior Research Scientist in Social and Decision Sciences, Dietrich College of Humanities and Social Sciences – Ph.D., University of Massachusetts; Carnegie Mellon, 2001–

JOHN GASPER, Associate Teaching Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2010–

MARTIN GAYNOR, E.J. Barone University Professor of Economics and Health Policy, H. J. Heinz III College – Ph.D., Northwestern University; Carnegie Mellon, 1995–

MARVIN GOODFRIEND, Friends of Allan Meltzer Professorship; Professor of Economics – Ph.D., Brown University; Carnegie Mellon, 2005–

BURTON HOLLIFIELD, Head, B.S. in Business Administration Program; PNC Professor of Finance; Professor of Financial Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1999–

KARAM KANG, Assistant Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2012–

ONUR KESTEN, Associate Professor of Economics – Ph.D., University of Rochester; Carnegie Mellon, 2005–

ALEXEY KUSHNIR, Assistant Professor of Economics – Ph.D., Pennsylvania State University; Carnegie Mellon, 2014–

FINN KYDLAND, The Richard P. Simons Distinguished Professorship; University Professor of Economics; Nobel Laureate (2004) – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1977–

REBECCA LESSEM, Assistant Professor of Economics – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2011–

BENNETT T. MCCALLUM, H. J. Heinz Professor of Economics, Emeritus – Ph.D., Rice University; Carnegie Mellon, 1981–

ROBERT A. MILLER, Richard M. Cyert and Morris DeGroot Professor of Economics and Statistics – Ph.D., University of Chicago; Carnegie Mellon, 1982–

NICHOLAS MULLER, Associate Professor of Economics, Engineering, and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2017–

ANH NGUYEN, Assistant Professor of Economics – Ph.D., Columbia University; Carnegie Mellon, 2018–

JOHN R. O'BRIEN, Associate Dean, Carnegie Mellon University-Qatar; Associate Professor of Accounting and Experimental Economics – Ph.D., University of Minnesota; Carnegie Mellon, 1984–

MARYAM SAEEDI, Assistant Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2016–

ALI SHOURIDEH, Assistant Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2016–

CHRISTOPHER SLEET, Head, Economics Programs; Professor of Economics – Ph.D., Stanford University; Carnegie Mellon, 2005–

FALLAW B. SOWELL, Associate Professor of Economics – Ph.D., Duke University; Carnegie Mellon, 1988–

CHESTER S. SPATT, Pamela R. and Kenneth B. Dunn Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 1979–

STEPHEN E. SPEAR, Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 1982–

V. EMILY STARK, Assistant Teaching Professor of Business Communications – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2013–

CHRISTOPHER I. TELMER, Associate Professor of Financial Economics – Ph.D., Queen’s University (Canada); Carnegie Mellon, 1992–

SHU LIN WEE, Assistant Professor of Economics – Ph.D., University of Maryland; Carnegie Mellon, 2014–

SEVIN YELTEKIN, Senior Associate Dean, Education; Professor of Economics – Ph.D., Stanford University; Carnegie Mellon, 2005–

ARIEL ZETLIN-JONES, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2012–

Visiting Faculty

CHARLES ZHENG, Visiting Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2019–

Adjunct Faculty

CAROL B. GOLDBURG, Executive Director, Undergraduate Economics Program; Adjunct Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

MARGARITA PORTNYKH, Adjunct Professor of Economics – Ph.D., Clemson University; Carnegie Mellon, 2018–

Undergraduate Economics Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

73-060 Economics: BaseCamp
Fall: 3 units
This short course will launch you into the economics intellectual space and get you thinking like an economist. Through a series of presentations by some of CMU's great economics thinkers you will learn how economic reasoning harnessed to data can lead to better policy design and better business decision making. Presentations may cover the economics of bitcoin and crypto-currency, online market design, financial crises, the future of work, how to become involved in economics research, healthcare, the environment, and other topics. The presentations will be curated by one of CMU's research economists and there will be plenty of opportunities for discussion and debate. The course will also introduce you to the CMU approach to economics and map out the CMU economics major landscape.

73-102 Principles of Microeconomics
Fall and Spring: 9 units
A one-semester course that teaches the fundamentals of microeconomics. Students will learn how microeconomic analysis can explain market successes, market failures, and how government intervention might improve outcomes. In addition to an investigation of firm behavior and consumer behavior, attention will be paid to: Game Theory, Behavioral Economics, Economics of Time and Risk, Economics of Information, Experimental Economics, and Auctions and Market Design. Students will also learn how to integrate basic data analysis and statistics. Not open to students who have received credit for 73-100. (Lecture, 2 hours; Recitation, 1 hour).

73-103 Principles of Macroeconomics
All Semesters: 9 units
A one-semester course that teaches the fundamentals of macroeconomics. Students will learn how macroeconomic analysis can explain national economic activity and how government intervention might stabilize an economy. Topics include: defining and measuring national wealth, economic growth, credit markets, unemployment, interest rates, inflation, and the monetary system. Additional emphasis will be paid to: long-term economic development, political economy, financial crises and topics that are central to contemporary macroeconomic debates such as the impact of technological change, migration, and trade on the macroeconomy. Students will access macroeconomic databases, and then use basic statistics to describe and isolate empirical patterns in macro-data. Not open to students who have received credit for 73-100. (Lecture, 2 hours; Recitation, 1 hour).
Prerequisite: 73-102 Min. grade C

73-111 Internship I
All Semesters
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, and Economics and Statistics majors.

73-112 Internship II
All Semesters: 3 units
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, and Economics and Statistics majors.

73-113 Internship III
All Semesters: 3 units
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, and Economics and Statistics majors.

73-160 Foundations of Microeconomics: Applications and Theory
Spring: 9 units
Intermediate level microeconomics stresses individual economic decision making in the context of consumer behavior, and firm behavior, and examines in detail how these behaviors interact in competitive market settings to answer the fundamental economic questions of what gets produced, how it gets produced, and who gets the output. These component theories of economic behavior are the building blocks of higher level economic analysis, as well as the basis for examining empirically-motivated deviations from classical economic predictions. As such, most of the course will be methodological in its focus, although many of the problems in the weekly assignments will involve everyday personal and business applications. The experiments we do will also give students hands-on experience with the phenomena that economic theories try to explain. (Lecture, 3 hours: Recitation: 1 hour). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-102 Min. grade C or 73-100 Min. grade C)

73-210 Economics Colloquium I
Fall: 3 units
Economics majors meet weekly for discussions about current research by faculty or students, presentations on economics from economists outside academia, and expository talks on selected economics topics not part of the usual curricula. The colloquium provides students with opportunities to grow personally and intellectually by introducing them to campus resources (including special interest to undergraduates such as preparation for graduate school) and using the economic toolbox to examine current economic topics in the press. It is recommended that students take this course during the sophomore year so that economics majors realize the range of resources that exist on campus. (Colloquium, 1 hour)

73-230 Intermediate Microeconomics
Fall and Spring: 9 units
This course is a calculus-based study of microeconomics. Topics in partial equilibrium analysis include supply and demand, consumer theory, theory of the firm, profit maximizing behavior, monopoly theory, and perfect competition. The course concludes with an introduction to general equilibrium analysis and the welfare laws. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics pre-requisite courses. Not open to first year student during S18.
Prerequisites: (21-268 or 21-269 or 21-256 or 21-259) and (73-100 Min. grade C or 73-102 Min. grade C)

73-240 Intermediate Macroeconomics
Fall and Spring: 9 units
Through macroeconomic models built upon microeconomic foundations, insights are developed into economic growth processes and business cycles. Topics include aggregation and measurement, national income, business cycle measurement, economic welfare theorems and social inefficiencies, the effect of government fiscal policy upon employment and productivity, and the relationship between investment, interest rates and economic growth. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 and 73-100 Min. grade C) or (21-256 and 73-102 Min. grade C and 73-103 Min. grade C) or (73-100 Min. grade C and 21-259) or (21-259 and 73-103 Min. grade C and 73-102 Min. grade C)

73-255 Independent Study in Economics
Fall and Spring
The Independent Study course in economics allows students to pursue their own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor; the project proposal must be approved by an Undergraduate Economics Program staff member. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and 73-160 Min. grade C

73-258 Developing Blockchain Use Case
Intermittent: 6 units
Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token—-CMU Coin—-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. http://tinyurl.com/cmucoincourse The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended.

73-265 Economics and Data Science
Fall: 9 units
This course is at the intersection of economic analysis, computing and statistics. It develops foundational skills in these areas and provides students with hands-on experience in identifying, analyzing and solving real-world data challenges in economics and business. Students will learn the basics of database and data manipulation, how to visualize, present and interpret data related to economic and business activity by employing statistics and statistical analysis, machine learning, visualization techniques. Students will also be taught a programming language suitable for data science/analysis. Databases will include leading economic indicators; emerging market country indicators; bond and equity returns; exchange rates; stock options; education and income by zip code; sales data; innovation diffusion; experimental and survey data and many others. Applications will include analyzing the effectiveness of different Internet pricing strategies on firm sales, the impact of taking online classes on a worker's earnings, the relationship between regional employment and trade policies; constructing investment risk indices for emerging markets; predicting employee productivity with machine learning tools; assessing health (sleep and exercise) improvements associated with wearable technologies (e.g. FitBit). Additionally, the course will provide students with communication skills to effectively describe their findings for technical and non-technical audiences. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (36-200 Min. grade C or 36-201 Min. grade C) and (73-100 Min. grade C or 73-102 Min. grade C)

73-270 Professional Communication for Economists
Fall and Spring: 9 units
A writing course specifically designed for third-year Economics majors and additional majors. Students gain experience with technical writing techniques and skills needed for both their senior thesis and their eventual professional careers. The course emphasizes both individual and group projects. (Seminar, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 76-101 and (73-230 Min. grade C or 73-240 Min. grade C)

73-274 Econometrics I
Spring: 9 units
This course will provide an introduction to the analysis of economic field data. The first part of the course will discuss how data is generated and how this affects the inferences we can make. In particular, we will look at the difficulties of working with field data and learn how non-random sampling leads to poor inferences. We will then move on to some simple statistical techniques, in particular OLS and its extensions as well as Maximum Likelihood Estimators. We will also learn about the large sample properties of these estimators. At the end of the course, students should be able to understand what inferences can be made with field data and some basic statistical techniques that can be used to uncover patterns in the data. (Lecture, 3 hours; Recitation, 1 hour). Pre-reqs for those entering Fall 2018 and later: (21256 or 21259 or 21268 or 21269) and (73265) and (73230 or 73240). Students pursuing the ECOMTH or MTHECO degrees may enroll in 73-274 after the completion of 36-225. Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-265 Min. grade C and (73-240 Min. grade C or 73-230 Min. grade C)

73-315 Market Design
Spring: 9 units
The market design class is going to cover three main subjects: matching, auctions, and, time allowing, marketplaces. Matching topics may include: Two-Sided Matching and Medical Residents House Allocation and Kidney Exchange School Choice Law Clerks and College Early Admission Auction/ Marketplace topics may include: Designing Optimal Auctions Common Value Auctions Multi-Unit Auctions and Treasury Auctions Multi-Item Auctions and The Assignment Model Sponsored Search Auctions The FCC and Simultaneous Ascending Auctions Package Auctions and Radio Spectrum Introduction to the Economics of Platforms Internet Platforms: e-Commerce Internet Markets: Advertising (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-257 or 21-269 or 21-256 or 21-268) and 73-230 Min. grade C

73-327 Advanced Topics In Macroeconomics And Real Business Cycles
Intermittent: 9 units
For analysts and decision makers in a variety of positions, such as business managers and government policy makers, a thorough understanding of the economy as a whole helps to make well-informed decisions. Examples of important knowledge about the economy are its sources of growth, the main impulses that cause the economy to fluctuate over time and enter into booms and recessions, the way in which these impulses propagate over time, and the state of the economy in general. The main objective of this course is to lay the foundation for such an understanding and present a framework within which we can (and will) evaluate a variety of aggregate phenomena. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-256 or 21-259) and 73-240 Min. grade C

73-328 Health Economics
Fall: 12 units
This course will teach the student to use economic analysis to understand critical issues in health care and and health policy. We will address issues such as the following: 1. What factors best explain the level and rate of growth of U.S. health expenditures? 2. Does the recent high rate of growth of U.S. health care expenditures make U.S. firms less competitive in international markets? 3. What are some of the likely consequences (intended and unintended) of the proposed reforms to Medicare? 4. Can physicians induce demand for their services? 5. What are the impacts of managed care on the health care system? 6. Do strong affiliations between physicians and health plans hurt competition? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Junior standing required.
Prerequisites: 21-120 and (73-230 Min. grade C or 73-160 Min. grade C)

73-332 Political Economy
Spring: 9 units
The Political Economy course looks at how groups within society organize for self-governance. The course will begin with an overview of the ways groups of individuals organize for collective action by examining different types of political institutions, the role these institutions play in different contexts, and the economic and strategic micro-foundations that give rise to these institutions. We will then examine the empirical evidence supporting this taxonomy, leading to a more detailed consideration of institutions that moderate social conflicts. The next part of the course examines basic results in social choice theory: the Condorcet paradox, Arrow's Impossibility Theorem, majority rule, median voter theories, and modern treatments of probabilistic voting models that allow for strategic behavior, misrepresentation of preferences, and policy manipulation. From this basis for understanding collective choice mechanisms, we will then examine how institutions foster cooperation, looking in detail at problems of public goods allocation, redistribution of income, the organization of clubs - interest groups and lobbying associations —in the private sector, and the organization of legislative activities in the public sector. In our examination of voting and electoral mechanisms, we will look at practical applications of the theory to problems of gerrymandering, voter suppression, and propaganda that feature prominently in contemporary political discourse.
Prerequisites: 73-230 Min. grade C and (84-275 Min. grade C or 84-104 Min. grade C)

73-338 Financial Crises and Risk
Fall: 9 units
This course provides an in-depth examination of the causes of financial crises as well as what governments can do to prevent them or at least reduce their cost. The course is designed to provide an understanding of individual attitudes towards risk and individual decision making about savings and investment under uncertainty, and to use this understanding to evaluate the various economic roles played by financial institutions in helping individuals manage risk, especially those roles which may lead to economic instability and crises. In addition, the course may cover bubbles and swindles, especially when these spillover to the broader macroeconomy; the role of information in banking in normal times and in bank runs; crisis resolution techniques; and the extensive history of attempts to improve regulation so as to reduce the frequency and cost of crises. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C and 73-240 Min. grade C

73-341 Within the Firm: Managing through Incentives
Spring: 9 units
We are living in an exciting age of information and knowledge when inspiring employees with a firm becomes increasingly more important Aligning the objectives of workers, managers, and owners by providing them with appropriate incentives becomes an emerging paradigm in the modern business world. In this course we learn how to reason about incentives both between managers and employees, managers and owners, and within a team of co-workers. We cover a broad range of topics including principle-agent problem, moral hazard, asymmetry of information, incentive in teams, collective decision making, and repeated interactions. These theoretical underpinnings will be illustrated with actual business experience and case studies. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-259 or 21-269 or 21-256) and (36-225 or 36-220 or 36-200 or 36-217) and 73-230 Min. grade C

73-347 Game Theory for Economists
Fall: 9 units
An introduction to the theory of non-cooperative games with an emphasis on economic applications. After an initial examination of two-person, zero-sum games, the notion of a Nash equilibrium in an n-person, non-cooperative game is considered. Existence of and refinements to the equilibrium concept are discussed in the context of both normal and extensive form games. Economic applications may include various topics, including Cournot and Bertrand oligopoly models, general competitive exchange equilibrium, and free rider problems. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C

73-348 Behavioral Economics
Spring: 9 units
This course introduces students to behavioral economics which is a subfield of economics that incorporates insights from other social sciences, such as psychology, into economic models and aims to explain the anomalies challenging some of the classical economic models. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-230 Min. grade C

73-352 Public Economics
Fall: 9 units
In this course, students analyze the role of governments in market economies and their impact on the behavior and welfare of citizens. Reasons for government intervention in markets are examined in light of some of the economic challenges faced by modern societies in an increasingly globalized marketplace. Topics include: taxation and expenditure policies, externalities and market failure, social security, public assistance and income redistribution programs. There will also be some coverage of the role of local governments in the economy with respect to such issues as crime, urban development and education. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C

73-353 Economic Foundations of Regulation: Applications to Financial Markets
Spring: 9 units
The financial crisis has focused attention on the role of regulation for our financial system and the broader economy. The course will address the foundations of regulation (?why regulate??) from various perspectives within the context of a market economy, highlighting the sources of "market failure" (such as externalities, adverse selection, and natural monopoly) and potential remedies (such as taxes and fees, disclosure, price regulation, guarantees). The conflicting goals among regulators (and why we have multiple regulators) and their impact on the meaning of regulation will be considered along with regulatory competition/arbitrage. Portions of the course will tackle relatively broad questions such as: Why regulate? What is the law of unintended consequences? What is the objective of a policy advocate? Are regulators and regulatory policies a systemic risk? Are our markets rigged? How can regulators enhance the predictability and credibility of their policies? How costly were government guarantees during the financial crisis? Should we bar insider trading? Should regulations be determined and motivated based upon cost-benefit analysis? How can we evaluate the success or failure of particular regulations and whether they have achieved their objectives? How does the Dodd-Frank Act promote financial stability? What basic aspects of the financial crisis did Dodd-Frank not address? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C

73-359 Benefit-Cost Analysis
Intermittent: 9 units
The evaluation of public private sector projects. The theory of benefit-cost analysis and related techniques, such as cost-effectiveness analysis. Attention is given to such issues as valuing goods and services that are not normally traded in the marketplace (e.g., the value of an individuals life) and the social rate of discount. Applications are considered in detail. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-256 or 21-259 or 21-269) and 73-230 Min. grade C

73-365 Firms, Market Structures, and Strategy
Fall: 9 units
This course is concerned with the economic analysis of industrial markets that are not perfectly competitive. The effects of imperfect competition on firms' decisions (pricing, location, advertising, research and development, among others) are reviewed. Implications of these effects in terms of public policy are also discussed from a variety of perspectives. Finally, applications to actual markets are considered. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-269 or 21-268) and 73-230 Min. grade C

73-366 Designing the Digital Economy
Spring: 9 units
This class analyzes the economics of e-commerce and technology. It will identify the critical features that differentiate the technology firms from traditional industries, and examine the implications for business strategy. The class will discuss topics such as network effects, switching costs, and platform markets. To complement the economic theory, we will also consider a case study of a firm each week. These have three aims: to provide applications for the concepts developed in the lectures; to inform you about different industries; and to help develop your written, rhetorical and presentation skills. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-259 or 21-269 or 21-268 or 21-256) and 73-230 Min. grade C and (70-208 or 73-265 Min. grade C or 73-274 Min. grade C or 73-374 Min. grade C or 73-407 Min. grade C or 36-202 or 36-208 or 36-220 or 36-226)

73-367 Technology Jobs and the Future of Work
Spring: 9 units
The aim of this course to provide students with an in-depth analysis of the US labor market and what role technology has in shaping labor market outcomes. This course will look at the factors influencing wage returns, the outcomes of job-search and also require students to undertake a hands-on analysis of data. Topics of interest are as follows: 1. What affects wage outcomes of workers? 2. What's happening to the labor share and what are the reasons for its decline? 3. What is the role of comparative advantage and how has increasing automation changed the returns to job-search for some individuals? 4. What is job polarization and what are the factors affecting the mobility of workers between occupations and jobs? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-259 or 21-256 or 21-269) and 73-230 Min. grade C and 73-240 Min. grade C

73-372 International Money and Finance
Spring: 9 units
The course introduces students to a micro-founded model of the global monetary system. The model is employed to assess the roles of money, banking, and central banking in the management of inflation, employment, and financial stability. Interest rates, the international exchange rate, the trade balance, and international capital flows are explored in terms of the model. The model is used to address controversial issues in international trade and financial relations, as well as current macroeconomic stabilization problems in China, the Euro area, the United States, and elsewhere. Theoretical points are illustrated with references to historical central bank practices from around the world in recent decades. The course concludes with student briefings on current central bank policies from around the world. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-256 or 21-259) and 73-240 Min. grade C

73-374 Econometrics II
Fall: 9 units
The material covered in this course extends from the material covered in Econometrics I (73-274). The course will include both the theory behind the methods and a hands-on analysis of actual data, providing students the tools for both research and industry jobs. Theories and methodologies covered will include: nonlinear regression models, qualitative response regression models, panel data estimators, simultaneous-equation models, and time series. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-256 or 21-259) and 73-230 Min. grade C and 73-274 Min. grade C

73-395 Independent Study in Economics
Fall and Spring
The Independent Study course in economics allows the student to pursue his or her own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor; the project proposal must be approved by an Undergraduate Economics Program staff member. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-259 or 21-256 or 21-269) and (73-240 Min. grade C or 73-230 Min. grade C)

73-408 Law and Economics
Intermittent: 9 units
This course will provide a broad overview of the scholarly field known as "law and economics." The focus will be on how legal rules and institutions can correct market failures. We will discuss the economic function of contracts and, when contracts fail or are not feasible, the role of legal remedies to resolve disputes. We will also discuss at some length the choice between encouraging private parties to initiate legal actions to correct externalities and governmental actors, such aas regulatory authorities. Extensive attention will be given to the economics of litigation, and to how private incentives to bring lawsuits differ from the social value of litigation. The economic motive to commit crimes, and the optimal governmental response to crime, will be studied in depth. Specific topics within the preceding broad themes include: the Coase Theorem; the tradeoff between the certainty and severity of punishment; the choice between ex ante and ex post sanctions; negligence versus strict liability; property rules; remedies for breach of contract; and the American rule versus the English rule for allocating litigation costs. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-230 Min. grade C or 73-160 Min. grade C)

73-415 Data Driven Business and Public Policy Decision Making
Intermittent: 9 units
In this course students will learn to leverage data to inform business and policy decisions. The course will teach students various methods for data description, including techniques of data visualization and statistical techniques. Students will learn how to assess the precision of estimation techniques. The final part of the course covers examples taken from epidemiology, economics, business and public policy. (Lecture, 3 hours: Recitation: 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-259 or 21-269 or 21-256 or 21-268) and 73-230 Min. grade C and 73-265 Min. grade C

73-421 Emerging Markets
Fall: 9 units
The goal of the course is to study the economic and institutional forces that spur or hinder business activity and growth in emerging economies. The course is designed to provide both quantitative and theoretical foundations for the study of emerging markets. On the quantitative side, the course will introduce students to the empirical analysis of the growth forces and obstacles facing emerging markets by providing numerous hands-on opportunities using real-world data. On the theory side, the course will provide an overview of fiscal, trade and exchange rate policies adopted in emerging economies. The course will focus on successful emerging economies such as India, China, S. Korea and Ireland with broader lessons and comparisons drawn from developed countries. The course will also look at distressed economies, such as North Korea and Venezuela analyzing the challenges and opportunities faced by these developing nations today. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-240 Min. grade C

73-423 Forecasting for Economics and Business
Spring: 9 units
Governments forecast economic indicators (e.g., GDP, job growth, etc.); businesses forecast sales; portfolio managers forecast asset return; the list goes on. Accurate forecasts are critical to robust organizational decision-making. This course will introduce students to modern methods for forecasting in economic and business applications. Topics covered include Bayesian, statistical, and online learning approaches to forecast construction and assessment, univariate and multivariate time series models and algorithms, and principled combination of multiple methods and data sources along with subject matter expertise to improve performance. Methods will be motivated by applications in macroeconomics, technology, marketing, and finance, with cases drawn from forecasting processes in a variety of business and government organizations. Students will implement forecasting methods in R, including in a real data forecasting competition.
Prerequisites: (21-269 or 21-268 or 21-259 or 21-256) and (73-230 Min. grade C or 73-240 Min. grade C or 73-274 Min. grade C)

73-427 Sustainability, Energy, and Environmental Economcs
Fall: 9 units
Topics related to sustainability and the environment are increasingly important to businesses, policymakers, and the general public. This course applies the tools of economic analysis to the problems of environmental protection, natural resource management, and energy production and use. The course will begin by introducing students to how an economist approaches problems of market failure commonly found in environmental contexts. Next, we will explore models that characterize solutions to such environmental issues. We will then address questions regarding measurement, policy design, and, finally, we will apply the tools that we have developed during the semester to the problems of climate change, and the optimal management of non-renewable resources. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-230 Min. grade C

73-469 Global Electronic Markets: Economics and the Internet
Fall: 9 units
The information revolution brought about by the Internet is having a dramatic impact on the organization of economic activity. Long-term contractual relationships that once governed corporate procurement are being dismantled as manufacturers use the Internet to market directly to the public. New transportation networks that used to simply move goods from point A to point B are evolving into dynamic inventory pipelines that allow manufacturers to track and even reroute shipments in real time. At the same time, individuals are making use of sophisticated search engines to comparison shop at a scale that would have been physically exhausting even five years ago. We will use the basic tools of economic analysis to understand how and why the changes in information technology are reshaping the economic landscape. (Lecture, 3 hours). Minimum grade standard of "C" applies only to economics courses.
Prerequisites: (21-259 or 21-256 or 21-269 or 21-268) and (73-160 Min. grade C or 73-230 Min. grade C)

73-476 American Economic History
Fall: 9 units
The study of economic history provides important perspective on current economic institutions and policies. A failure to understand the historical evolution of economic institutions or the variety of past economic experience is perhaps the worst shortcoming of many economists. The study of economic history provides an opportunity to test currently fashionable theories against data different from those used in their construction. In fact, this is a course in applied economics. The theories developed in the intermediate courses will be applied to episodes from the past in ways that increase understanding both of the specific historical episodes considered and the economic theories employed. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-230 Min. grade C or 73-160 Min. grade C)

73-497 Senior Project
Fall: 9 units
A fourth-year project course, open only to Economics primary and additional majors with Senior standing. The senior project is a capstone course in economics. The purpose of the course is to showcase the analytical and quantitative skills that you have acquired as an undergraduate at Carnegie Mellon. The course project should reflect some independent applied research that is genuinely your own work. Thus a "book report" or a "literature review" are not sufficient exercises to satisfy this requirement. The following research approaches are acceptable for the research project: an empirical study based on a data set that you put together, an experimental study based on an experiment that you conducted, an analysis of survey data based on a survey that you conducted, a theoretical analysis based on a model that you have developed, based on your own algorithm. Students who write an honor thesis are exempted from this class. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-269 or 21-256 or 21-259 or 21-268) and (73-374 Min. grade C or 73-407 Min. grade C or 73-265 Min. grade C or 36-226 or 36-303 or 73-274 Min. grade C) and 73-230 Min. grade C and 73-240 Min. grade C

73-500 Tepper College Honors Thesis I
Fall and Spring
Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and (73-265 Min. grade C or 73-274 Min. grade C or 36-226 Min. grade C) and 73-230 Min. grade C and 73-240 Min. grade C

73-501 Tepper College Honors Thesis II
Fall and Spring
Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites include: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses, and a minimum grade of "B" required in Tepper College Honors Thesis I.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-230 Min. grade C and 73-240 Min. grade C and 73-500 Min. grade B and (73-265 Min. grade C or 73-374 Min. grade C)

Carnegie Mellon University in Qatar

Michael Trick, Dean
Selma Limam Mansar, Senior Associate Dean for Education
Undergraduate Programs Office: CMB 1101
www.qatar.cmu.edu

Carnegie Mellon University in Qatar is Carnegie Mellon's first and only undergraduate branch campus. Since 2004, it exists as part of a collaborative effort with the Qatar Foundation to bring outstanding American educational programs to the Middle East.

Degree Offerings

Carnegie Mellon University in Qatar offers five academic programs: Biological Sciences (http://coursecatalog.web.cmu.edu/melloncollegeofscience/departmentofbiologicalsciences), Business Administration (http://coursecatalog.web.cmu.edu/tepper/undergraduatebusinessadministrationprogram), Computer Science (http://coursecatalog.web.cmu.edu/schoolofcomputerscience), Computational Biology (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#bachelorofscienceincomputationalbiology), and Information Systems (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/informationsystems). To examine the requirements for those degrees, see their respective main campus college sections elsewhere in the Undergraduate Catalog. The purpose of this section is to describe the CMU-Q policies that are independent from those of the Pittsburgh campus and outline procedures that are common to students in all programs in Qatar.

Major Sample Schedules

Sample schedules for how CMU-Q students nominally track through the academic programs can be found on the CMU-Q website as follows:

- Biological Sciences (http://www.qatar.cmu.edu/curriculum-bs)
- Business Administration (http://www.qatar.cmu.edu/curriculum-ba)
- Computer Science (http://www.qatar.cmu.edu/curriculum-cs)
- Computational Biology (http://www.qatar.cmu.edu/cb)
- Information Systems (https://www.qatar.cmu.edu/academics-research/academics/information-systems)

Business Administration Concentrations

The Business Administration program requires students to complete a minimum of one concentration (specialization) and three additional Business and Economics electives, which may add up to a second concentration. For advice on specific requirements, contact Program Director J. Patrick McGinnis. The following concentration areas may be completed at Carnegie Mellon University in Qatar:

- Accounting
- Business Analytics
- Business Technology
- Economics, Markets, and Strategy
- Entrepreneurship
- Finance
- International Business
- Leadership and Organizational Effectiveness
- Marketing
- Operations

Information Systems Content Areas

The Information Systems program requires its students to complete a minimum of 27 units of a content area. For advice on specific requirements, contact Program director Chadi Aoun. The following content areas are offered at Carnegie Mellon University in Qatar:

- Computing and Information Systems & Technology
- Social and Global Systems
- User-Centered Information Design
- Applied Informatics

Additional Major in Information Systems

Students who elect Information Systems as a second major must fulfill all Information Systems degree requirements, including prerequisites, Professional Core, Disciplinary Core, and Content Area requirements. With respect to double-counting courses, the program will allow up to two courses to count for both the additional major and a primary major or minor. Students should begin planning their additional major as early as possible, as the Information Systems Professional Core courses are sequential, and are often the constraining resource for the major completion.

Minors

In addition to the major degree programs, Carnegie Mellon also offers a number of minors. Minors typically consist of six courses that provide the student with substantial exposure to the core of that academic discipline. As with the major programs, the requirements of these minors are set by their respective departments on the main campus:

- Arabic Studies (advisor: Zeinab Ibrahim) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Biological Sciences (advisor: Annette Vincent) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Business Administration (advisor: J. Patrick McGinnis) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Cognitive Neuroscience (advisor: Jennifer Bruder) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Computational Biology (advisors: Valentin Ilyin) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Computer Science (advisor: Khaled Harras) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Economics (advisor: J. Patrick McGinnis) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- English Studies (advisor: Dudley Reynolds) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Global Systems and Management (advisor: Selma Limam Mansar) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- History (advisor: Ben Reilly) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Information Systems (advisor: Chadi Aoun) [only offered in Qatar] (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Mathematical Sciences (advisor: Hasan Demirkoparan) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Neuroscience (advisor: Annette Vincent) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Professional Writing (advisor: Thomas Mitchell) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Psychology (advisor: Jennifer Bruder) (https://scotty.qatar.cmu.edu/academic-services/minor-information)
- Student-Defined Minors (contact Selma Limam Mansar for initial declaration) (https://scotty.qatar.cmu.edu/academic-services/minor-information)

Academic Standards and Actions

Academic Standards

Carnegie Mellon University in Qatar complies with common University policies unless otherwise noted. The curriculum requirements for the Biological Sciences, Business Administration, Computer Science, Computational Biology, and Information Systems majors are set by the respective departments of the Mellon College of Science, Tepper School of Business, the School of Computer Science, and the Dietrich College of Humanities and Social Sciences on the main campus. At the university level, the same academic standards, policies, and actions apply to all programs at CMU-Q as at the Pittsburgh campus.

Graduation Requirements

Residency

Candidate for a Bachelor's degree must complete a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework at Carnegie Mellon.

Cumulative QPA

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

University Honors

Students maintaining a cumulative QPA of at least 3.5 after seven semesters of full-time enrollment or raising their QPA to 3.5 upon completing their graduation requirements in their final semester will graduate with University Honors.

Academic Actions

Students carrying either a full-time course load (defined as 36 or more units) or a part-time course load (defined as fewer than 36 units) are subject to academic actions.

Dean's List

Students earn Dean's List recognition in a given semester by achieving one of two minimum standards. They must either earn a semester QPA of 3.75 or higher (while taking at least 36 factorable units and receiving no incomplete grades) or earn a semester QPA of 3.50 or higher (while taking at least 45 factorable units and receiving no incomplete grades). The CMU-Q Dean's List is calculated uniformly for all students across all majors due to the fact that CMU-Q majors are drawn from four different Pittsburgh colleges with varying Dean's List criteria.

Other Academic Actions

Students are subject to academic actions if they fail to meet the minimum standards toward their degree.

Minimum Standards

The minimum standards are defined as follows:

- First-year students: a semester QPA of at least 1.75.
- Beyond the first year: a semester QPA and a cumulative QPA (excluding the first year) of at least 2.0.
- Students who begin a semester enrolled in 36 or more units and later drop below 36 units are subject to academic actions regardless of their semester QPA.

Probation

Probation occurs when a student's semester record fails to meet the minimum standards described above. The term of a probation is one semester as a full-time student. Students are removed from probation if they complete at least 36 units and:

- For a first-year student, probation is removed at the end of the second semester if the second semester's QPA is 1.75 or above.
- For students in the third or above semesters, probation is removed if they raise their cumulative QPA above 2.00, and achieve a semester QPA of 2.0 or higher (excluding the first year).

Probation Continued

Occasionally, a student's probation may be continued if the student's cumulative record does not meet minimum standards, but his or her semester record suggests that the student may do so by the end of the next semester. This action is normally taken only when a student's semester QPA is above 2.0 but their cumulative QPA is not yet above 2.0.

Suspension

A student who fails to meet the minimum standards described above at the end of the probation semester will be suspended.

- A first-year student will be suspended if the QPA from each semester is below 1.75.
- A student in the third or subsequent semester of study will be suspended if the semester factor or the cumulative factor (excluding the first year) is below 2.00 for two consecutive semesters.

Suspension is for a minimum of one year and the student is required to follow University procedures for departing from campus. At the end of the year, the student may petition to return to CMU-Q by:

- Receiving permission in writing from the Senior Associate Dean for Education to resume their studies. This permission would normally be granted after the student would produce evidence for fulfilling return conditions (if any) and for taking convincing steps to ameliorate the cause of the suspension. To get approval to resume their studies, the student must demonstrate that they are better prepared to perform above the minimum standards for graduation than before they were suspended.
- Completing a Return from Leave of Absence Form from Enrollment Services.

Students coming back from suspension are placed on Probation for the semester of their return.

Students who have been suspended or have withdrawn are required to absent themselves from the campus within a maximum of two days after the action and to remain off the campus for the duration of the time specified. This action includes debarment from part-time or summer courses at the university for the duration of the period of the action. Suspended students may not hold student jobs with the university.

Drop

A student who fails to meet minimum standards at any point after returning from a suspension is subject to a drop action. A drop action is a permanent severance; the student is required to follow University procedures for departing from campus and may not enroll again in the future.

The typical progression of academic actions is Probation, Suspension, then Drop but the intent of the academic actions are to take measures that are in the student's best interest, and therefore the school may bypass one or more of these steps in an unusual case and suspend or drop a student without prior probation.

OTHER REGULATIONS AFFECTING STUDENT STATUS

Adding a Class

Students may add classes to their schedule under the following rules:

Students may add a full-semester course through the first 10 class days of the semester.

Students may add half-semester (mini) courses through the first 5 class days of the course.

Dropping/Withdrawing from a Class

Students should refer to the university's policy on dropping/withdrawing from a class: https://www.cmu.edu/hub/registrar/course-changes/index.html

Course Overloads

A normal maximum load for a CMU-Q student is 51 units. In order to overload (i.e., take more than 51 units but no more than 63), a student must have attained a QPA of at least 3.0 in the previous semester, or have a cumulative QPA of 3.0. A student wishing to pursue a greater number of units must petition the Associate Dean for Education to do so.

Non-Carnegie Mellon Courses

Carnegie Mellon University offers students the opportunity to take courses for credit through a cross-registration program and through the receipt of transfer credit from other accredited institutions. The Carnegie Mellon transcript will include information on such courses as follows:

Carnegie Mellon courses and courses taken through the university's cross-registration program will have grades recorded on the transcript and be factored into the QPA. All other courses will be recorded on this transcript indicating where the course was taken, but no grade will be reported. Such courses will not be taken into account for academic actions, honors or QPA calculations. (Note: Suspended students may take courses elsewhere with prior approval; however, they will not receive transfer credit.)

Cross Registration

Courses offered for cross-registration are those taken through an agreement with Texas A&M University at Qatar; Georgetown School of Foreign Service in Qatar; Northwestern University in Qatar; Virginia Commonwealth University in Qatar; and Weill Cornell Medical College in Qatar that full-time students at Carnegie Mellon University in Qatar can take up to one class a semester at their schools. Cross-registration requires the completion of a cross-registration form with the appropriate signatures from the home and host institutions. Completion of the form does not guarantee a space in the requested course. The agreement only applies during the regular academic year, normal course transfer rules apply in the summer.

Course Transfer

Students may receive credit for courses taken outside of Carnegie Mellon if they successfully petition the Associate Dean for Education in advance for permission. Students must take these courses for a letter grade and instruction must be in English for non-language courses. Credit (but not the grade) will normally transfer for courses with a grade equivalent to at least a “B”. The class's course description must be a close match to the Carnegie Mellon course and from an accredited institution. Students may not receive credit for any courses taken on-line unless there is some safeguard to ensure that the actual student took the course (e.g., a proctored final taken under supervision at CMU-Q).

Students may not receive credit for more than five non-CMU courses during their undergraduate career as a Carnegie Mellon student. Classes taken prior to enrolling in Carnegie Mellon, during study abroad semesters, and as cross-registration with other Education City schools do not count toward the course transfer limit. All students must meet the University's residency requirement of completing at least 180 units of Carnegie Mellon coursework.

Campus Exchange and Transfer

Campus Exchange

CMU-Q and Pittsburgh students in good academic standing (not on Probation/Suspension) may study on the other campus for one semester on a space available basis and with the approval of both the home and host departments. Space constraints on both campuses may force programs to limit the number of students who can exchange in any given semester. CMU-Q students may study abroad for a second semester at another institution (not CMU Pittsburgh) if an appropriate additional study abroad opportunity arises and their academic advisor agrees.

Summer studies in Pittsburgh are not subject to any constraint other than being in good academic standing (not on Probation/Suspension).

Transfer

Internally between majors at CMU-Q

Students may transfer between majors at CMU-Q on a space-available and academic performance basis. Students interested in transferring should consult with the Associate Dean for Education and the academic advisor of the new major. First-year students may not apply for transfer until they receive their spring mid-semester grades.

Between CMU-Q and Carnegie Mellon, Pittsburgh

Most majors in Pittsburgh have very few open spaces for transfer students. As a result, decisions about transfers to any major in Pittsburgh will be made by the receiving department, are highly competitive, and are not likely. It has historically been very difficult to be granted transfer to Pittsburgh.

Transfers to CMU-Q from other Universities

Transfer students from other universities must apply through the Admissions Office at Carnegie Mellon University in Qatar. The Admissions Office, the Associate Dean for Education, and the program director will determine if there is space available in the desired program and if the student's past academic performance warrants admission.

Faculty

NESSRINE AFFARA, Assistant Teaching Professor – Ph.D., Ohio State University; Carnegie Mellon, 2017–

MUSTAFA AKAN, Associate Professor of Operations Management – Ph.D., Northwestern University;

SERKAN AKGUC, Assistant Teaching Professor – Ph.D., Temple University;

CHADI AOUN, Associate Teaching Professor – Ph.D., University of New South Wales; Carnegie Mellon, 2014–

RAVICHANDRA BACHU, Assistant Teaching Professor – Ph.D., The City University of New York; Carnegie Mellon, 2015–

HOUDA BOUAMOR, Assistant Teaching Professor – Ph.D. , Université Paris Sud; Carnegie Mellon, 2015–

MOHAMED BOUAOUINA, Assistant Teaching Professor – Ph.D., Pierre and Marie Curie University; Carnegie Mellon, 2013–

JENNIFER BRUDER, Assistant Teaching Professor – Ph.D, University of Munich; Carnegie Mellon, 2017–

LAUREN BURAKOWSKI, Assistant Teaching Professor – Ph.D., University of California; Carnegie Mellon, 2018–

ANIS CHARFI, Associate Teaching Professor – Ph.D., Technische Universitat Darmstadt; Carnegie Mellon, 2015–

MILTON COFIELD, Distinguished Service Professor of Business Management – Ph.D., University of Illinois; Carnegie Mellon, 2017–

HASAN DEMIRKOPARAN, Associate Teaching Professor – Ph.D., Michigan State University; Carnegie Mellon, 2005–

GIANNI DI CARO, Associate Teaching Professor – Ph.D., Université Libre de Bruxelles; Carnegie Mellon, 2016–

KIRA DREHER , Assistant Teaching Professor Carnegie Mellon, 2019–

MUHAMMAD FUAD FAROOQI, Assistant Teaching Professor – Ph.D., Richard Ivey School of Business; Carnegie Mellon, 2013–

SIMON FAULKNER , Assistant Teaching Professor Carnegie Mellon, 2019–

MARIA PIA GOMEZ LAICH, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–

SUSAN HAGAN, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004–

MOHAMMAD HAMMOUD, Assistant Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2014–

KHALED HARRAS, Teaching Professor – Ph.D, University of California-Santa Barbara; Carnegie Mellon, 2007–

ERIK HELIN, Special Lecturer – M.A., Eastern Michigan University; Carnegie Mellon, 2006–

ZEINAB IBRAHIM, Teaching Professor – Ph.D., Georgetown University; Carnegie Mellon, 2009–

AUGUSTIN INDACO, Assistant Teaching Professor Carnegie Mellon, 2019–

VALENTIN ILYIN, Associate Teaching Professor – Ph.D., Shubnikov Institute of Crystallography; Carnegie Mellon, 2012–

LANSINE KABA, Distinguished Visiting Professor – Ph.D., Northwestern University; Carnegie Mellon, 2009–

CHRISTOS KAPOUTSIS, Teaching Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2012–

NIRAJ KHARE, Visiting Assistant Professor – Ph.D., Ohio State University; Carnegie Mellon, 2014–

JASMINE KIRBY , Assistant Librarian Carnegie Mellon, 2019–

CECILE LE ROUX, Visiting Assistant Professor – Ph.D., University of Sydney; Carnegie Mellon, 2017–

DIVAKARAN LIGINLAL, Teaching Professor – Ph.D., University of Arizona-Tucson; Carnegie Mellon, 2009–

SELMA LIMAM MANSAR, Teaching Professor and Senior Associate Dean for Education – Ph.D., National Polytechnic Institute of Grenoble; Carnegie Mellon, 2007–

TERESA MACGREGOR, Senior Librarian and Director, Library – MS in Library Science, University of Kentucky; Carnegie Mellon, 2012–

J. PATRICK MCGINNIS, Distinguished Career Professor – M.A., Pittsburg State University; Carnegie Mellon, 1999–

EDUARDO MIRANDA , Associate Teaching Professor Carnegie Mellon, 2019–

EZZOHRA MOUFID , Lecturer – MS, University of Roehampton; Carnegie Mellon, 2019–

THOMAS MITCHELL, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2013–

JOHN O'BRIEN, Associate Professor and Associate Dean – Ph.D., University of Minnesota; Carnegie Mellon, 1984–

KEMAL OFLAZER, Teaching Professor and Associate Dean for Research – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008–

DEEPA NAIR , Assistant Teaching Professor Carnegie Mellon, 2019–

MARION OLIVER, Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004–

JOAO PALOTTI , Adjunct Faculty Carnegie Mellon, 2019–

TAE YONG PARK, Visiting Assistant Professor – Ph.D., Washington University in St. Louis; Carnegie Mellon, 2017–

SILVIA PESSOA, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2006–

DANIEL PHELPS, Associate Teaching Professor – Ph.D., Florida State University; Carnegie Mellon, 2007–

SAQUIB RAZAK, Associate Teaching Professor – Ph.D., SUNY-Binghamton; Carnegie Mellon, 2008–

BENJAMIN REILLY, Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2004–

GISELLE REIS, Assistant Teaching Professor – Ph.D., Vienna University of Technology; Carnegie Mellon, 2016–

DUDLEY REYNOLDS, Teaching Professor – Ph.D., Indiana University-Bloomington; Carnegie Mellon, 2007–

RYAN RILEY, Associate Teaching Professor – Ph.D., University of Purdue; Carnegie Mellon, 2017–

GORDON RULE, Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1996–

VELI SAFAK , Assistant Teaching Professor Carnegie Mellon, 2019–

VARUN SHARMA , Assistant Teaching Professor Carnegie Mellon, 2019–

JEFFREY SQUIRES , Assistant Teaching Professor Carnegie Mellon, 2019–

MICHAEL TRICK, Harry B. and James H. Higgins Professor of Operations Research, and Dean of Carnegie Mellon University in Qatar – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2017–

SAVANID VATANASAKDUL, Associate Professor – Ph.D., University of South Wales; Carnegie Mellon, 2017–

ANNETTE SHOBA VINCENT, Assistant Teaching Professor – Ph.D., National University of Singapore; Carnegie Mellon, 2012–

PATRICK WALSH , Assistant Teaching Professor Carnegie Mellon, 2019–

GEORGE WHITE, Distinguished Career Professor – Ph.D., University of Oregon; Carnegie Mellon, 2007–

ZELEALEM YILMA, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2014–

IHAB YOUNIS, Assistant Teaching Professor – Ph.D., Ohio State University; Carnegie Mellon, 2015–

MOHAMED ZAYED, Associate Teaching Professor – D.Sc., ETH Zurich; Carnegie Mellon, 2017–

Interdisciplinary Programs

Carnegie Mellon University offers several degree programs and courses of study which are coordinated by multiple colleges, reflecting the interdisciplinary nature of the university. These are detailed below.

Intercollege Majors

- BXA Intercollege Degree Programs
  - Bachelor of Humanities and Arts Program
  - Bachelor of Science and Arts Program
  - Bachelor of Computer Science and Arts Program
- B.S. in Computational Finance
- B.S. in Music and Technology
- B.S. in Neuroscience
- B.S. in Psychology and Biological Sciences

Intercollege Minors

- Minor in Computational Finance
- Minor in Game Design (IDeATe)
- Minor in Health Care Policy and Management

BXA Intercollege Degree Programs

The BXA Intercollege Degree Programs enable students the freedom to individualize their educational experience by promoting integration, balance and innovation. There are three degree programs from which to choose:

- Bachelor of Humanities and Arts
- Bachelor of Science and Arts
- Bachelor of Computer Science and Arts

For detailed information on the BXA Intercollege Degree Programs, go to BXA Intercollege Degree Programs (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/bxaintercollege).

Bachelor of Science in Computational Finance

The Mellon College of Science, the Heinz College of Public Policy and Management and the Tepper School of Business jointly offer a degree uniquely designed to meet the quantitative needs of the finance industry. Modeled after the highly successful Carnegie Mellon Master of Science in Computational Finance, this degree allows students to develop a deep knowledge of mathematics, probability, statistics, and the applications of these disciplines to finance. Students who complete this degree may directly enter the finance industry, enter other industries where applied mathematics training is appropriate, or pursue advanced degrees in economics, finance or the mathematical sciences. Students entering the work force upon completion of this degree may wish to later complement their undergraduate degree with a Master's degree in Business Administration or another professional degree. Students who might eventually pursue doctoral degrees in economics, finance, statistics or mathematics should seek advising on how to use their electives in order to prepare for graduate work in their chosen disciplines.

Students must apply to enroll in the Computational Finance major. Applications are accepted each Fall and Spring semester, just after mid-semester. Applicants must have taken (or be currently taking) 21-270 Introduction to Mathematical Finance at the time of application. Students from any college or program at Carnegie Mellon are welcome to apply to enroll in the major.

The Bachelor of Science in Computational Finance is an Intercollegiate Program. Students who pursue Computational Finance as their primary major may elect to have either the Mellon College of Science (MCS) or the Tepper School of Business (Tepper) as their home college. The coursework required for the major is essentially the same in each case, with a few minor exception outlined below. The general education requirements for the degree depend on the student's home college.

Students who pursue Computational Finance as an additional major will remain in the college of their primary major. Additional majors must complete the Major Requirements outlined below, but not the General Education Requirements outlined for MCS and Tepper students.

Majors in Computational Finance can tailor their degree program by selecting Depth Electives aligned with their interests and ambitions. MCS students are required to take three depth electives. Tepper students must take 70-391 Finance as one of their three depth electives. (MCS students may also select 70-391 as one of their three depth electives.)

Additional information about computational finance and the Undergraduate Computational Finance Program at Carnegie Mellon can be found on the BSCF Program website.

Major Requirements

The major in Computational Finance is built around a core sequence of study in mathematical finance. This core is augmented with coursework in the related areas of Statistics, Computer Science, and Economics. Additionally the major provides training in the "soft skills" required for work in a corporate environment. The major also requires the completion of several depth electives, allowing students to tailor their education to their particular interests and needs.

The major requirements are the same for additional majors as they are for majors whose home college is MCS. There are a few slight differences for students whose home college is Tepper. These differences are described in the sections for Depth Electives and Professional Development below.

Foundations

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	10
21-241	Matrices and Linear Transformations	10
21-259	Calculus in Three Dimensions	9
21-260	Differential Equations	9
21-369	Numerical Methods	12
70-122	Introduction to Accounting	9

Mathematical Finance

21-270	Introduction to Mathematical Finance	9
21-370	Discrete Time Finance	9
21-420	Continuous-Time Finance	9
46-977	MSCF Studies in Financial Engineering	6

Statistics

21-325	Probability	9
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9

Programming

15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	10

Economics

73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-240	Intermediate Macroeconomics	9

Professional Development

Majors in the Tepper School of Business take 70-311 Organizational Behavior as part of the Functional Business Core curriculum. This course counts in place of 94-700 Organizational Design & Implementation.

94-700	Organizational Design & Implementation	6
or 70-311	Organizational Behavior	
95-717	Writing for Information Systems Management	6-9
or 70-340	Business Communications	
90-718	Strategic Presentation Skills	6

Depth Electives

Depth electives give students an opportunity to tailor their coursework to their particular interests. Students completing the major will take three depth electives (the minimum requirement is 24 units - the equivalent of two 9 unit courses and one 6 unit course). Tepper students are required to select 70-391 Finance as one of their depth electives.

Depth electives are intended to develop a student's background in an area that is applicable to the finance industry. Courses in finance or programming generally qualify as depth electives. Mathematics, Statistics, or Economics courses in subjects applicable to finance also qualify. Computational Finance majors may have the opportunity to take MSCF courses (as described below) and these may also be counted as depth electives.

There is no definitive list of approved depth electives. The courses listed below have been taken as depth electives in recent years, but other courses could be approved upon request

10-401	Introduction to Machine Learning (Undergrad)	12
10-601	Introduction to Machine Learning (Master's)	12
10-605	Machine Learning with Large Datasets	12
15-150	Principles of Functional Programming	10
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-351	Algorithms and Advanced Data Structures	12
15-451	Algorithm Design and Analysis	12
21-393	Operations Research II	9
21-355	Principles of Real Analysis I	9
21-366	Topics in Applied Mathematics	9
21-372	Partial Differential Equations and Fourier Analysis	9
21-378	Mathematics of Fixed Income Markets	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
36-462	Special Topics: Data Mining	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Applied Multivariate Methods	9
70-391	Finance	9
70-492	Investment Analysis	9
70-495	Corporate Finance	9
70-497	Derivative Securities	9

MSCF Courses

Computational Finance majors are required to take 46-977 MSCF Studies in Financial Engineering. They may also have the opportunity to take up to four more MSCF courses. Permission to enroll in these courses requires (1) approval from thier BSCF Advisor, (2) approval of the course instructor, and (3) space available in the course. The MSCF curriculum (https://www.cmu.edu/mscf/academics/curriculum) with course descriptions is described on the MSCF website (https://www.cmu.edu/mscf).

Some MSCF courses cover material in the undergraduate curriculum and thus are not generally suitable. Other courses require background that is difficult to obtain as an undergraduate. Students interested in taking MSCF courses are encouraged to discuss their interest with their advisor as early as possible.

General Education Requirements for MCS Students

Students in the Mellon College of Science completing the Computational Finance major as their primary major must complete the requirements below in addition to the major requirements.

99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9

Science Requirement

Two of the following:		
03-121	Modern Biology	9
09-105	Introduction to Modern Chemistry I	10
33-111	Physics I for Science Students	12

Cognition, Choice, and Behavior

One of the following:		
73-240	Intermediate Macroeconomics	9
80-100	Introduction to Philosophy	9
80-130	Introduction to Ethics	9
80-150	Nature of Reason	9
80-180	Nature of Language	9
80-208	Critical Thinking	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-222	Measurement and Methodology	9
80-241	Ethical Judgments in Professional Life	9
80-242	Conflict and Dispute Resolution	9
80-270	Philosophy of Mind	9
80-271	Philosophy and Psychology	9
80-312	Mathematical Revolutions	9
80-330	Ethical Theory	9
85-102	Introduction to Psychology	9
85-211	Cognitive Psychology	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9
85-261	Abnormal Psychology	9
85-390	Human Memory	9
88-120	Reason, Passion and Cognition	9

Though any of these courses will satisfy the Cognition, Choice, and Behavior requirement, students are encouraged to consider taking one of the ethics courses: 80-130, 80-241, or 80-330.

Cultural Analysis

One of the following:		
57-173	Survey of Western Music History	9
57-209	The Beatles	9
70-342	Managing Across Cultures	9
76-227	Comedy	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
79-104	Global Histories	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-205	20th Century Europe	9
79-209	The Art of Historical Detection	6
79-225	West African History in Film	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-235	Caribbean Cultures	9
79-239	The Great Depression in America, 1929-1941	6
79-240	Development of American Culture	9
79-241	African American History: Africa to the Civil War	9
79-242	African American History: Reconstruction to the Present	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-281	Introduction to Religion	9
79-307	Religion and Politics in the Middle East	9
79-345	Roots of Rock & Roll	9
79-350	Early Christianity	9
80-100	Introduction to Philosophy	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism	9
80-261	Experience, Reason, and Truth	9
80-276	Philosophy of Religion	9
82-xxx	Any courses from Modern Languages	

Non-Technical Electives

Two more courses must taken from any of the departments in DC, CFA or Tepper, subject to the list of deletions (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html) and additions (https://

www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html) maintained by MCS.

General Education Requirements for Tepper Students

Students in the Tepper School of Business completing the Computational Finance major as their primary major must complete the requirements below in addition to the major requirements.

Tepper Functional Business Core

The Functional Business Core of the Undergraduate Business Administration Program includes 70-122 Introduction to Accounting, which is required by all Computational Finance majors. It also includes 70-391 Finance, which Tepper students majoring in Computational Finance must select as of one their Depth Electives. In addition, Tepper students pursuing the B.S. in Computational Finance must complete six other courses from the Functional Business Core.

These courses are:

70-106	Business Science	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-371	Operations Management	9
70-381	Marketing I	9
70-401	Management Game	12

Liberal Arts & Sciences Breadth Requirements

Candidates for the B.S. in Computational Finance must complete the Liberal Arts & Sciences Breadth Requirements as described in the catalog entry for the B.S. Degree in Business Administration.

Sample Curricula

MCS Sample Curriculum

What follows is the detailed curriculum for the degree Bachelor of Science in Computational Finance in the Mellon College of Science. This is an example of how an MCS student might meet the requirements of the Computational Finance major. It is not expected that every student will follow this sequence. In particular, well prepared students should consider taking 21-270 Introduction to Mathematical Finance during their Freshman Spring semester. Students intending to do so are encouraged to take 21-127 Concepts of Mathematics or 21-241 Matrices and Linear Transformations during their Freshman Fall semester.

Freshman	
Fall	**Spring**
15-110 Principles of Computing	15-112 Fundamentals of Programming and Computer Science
21-120 Differential and Integral Calculus	21-122 Integration and Approximation
76-101 Interpretation and Argument	70-122 Introduction to Accounting
99-101 Computing @ Carnegie Mellon	xx-xxx Science Requirement
xx-xxx Science Requirement	xx-xxx Elective

Sophomore	
Fall	**Spring**
21-241 Matrices and Linear Transformations	21-270 Introduction to Mathematical Finance
21-259 Calculus in Three Dimensions	21-127 Concepts of Mathematics
21-260 Differential Equations	21-369 Numerical Methods
73-102 Principles of Microeconomics	73-103 Principles of Macroeconomics
xx-xxx Humanities, Social Sciences, or Fine Arts Elective	xx-xxx Elective

Junior	
Fall	**Spring**
21-325 Probability	21-420 Continuous-Time Finance
21-370 Discrete Time Finance	36-226 Introduction to Statistical Inference
73-240 Intermediate Macroeconomics	xx-xxx Humanities, Social Sciences, or Fine Arts Elective
15-122 Principles of Imperative Computation	xx-xxx Humanities, Social Sciences, or Fine Arts Elective
xx-xxx Elective	xx-xxx Depth Elective

Senior	
Fall	**Spring**
46-977 MSCF Studies in Financial Engineering	95-717 Writing for Information Systems Management
94-700 Organizational Design & Implementation	90-718 Strategic Presentation Skills
36-401 Modern Regression	xx-xxx Depth Elective
xx-xxx Depth Elective	xx-xxx Humanities, Social Sciences, or Fine Arts Elective
xx-xxx Elective	xx-xxx Elective
xx-xxx Elective	xx-xxx Elective

Tepper Sample Curriculum

What follows is the detailed curriculum for the degree Bachelor of Science in Computational Finance in the Tepper School of Business. This is an example of how a Tepper student might meet the requirements of the Computational Finance major. It is not expected that every student will follow this sequence. In particular, well prepared students should consider taking 21-270 Introduction to Mathematical Finance during their Freshman Spring semester. Students intending to do so are encouraged to take 21-127

Concepts of Mathematics or 21-241 Matrices and Linear Transformations during their Freshman Fall semester.

Freshman	
Fall	**Spring**
15-110 Principles of Computing	15-112 Fundamentals of Programming and Computer Science
21-120 Differential and Integral Calculus	21-122 Integration and Approximation
73-102 Principles of Microeconomics	21-241 Matrices and Linear Transformations
70-106 Business Science	73-103 Principles of Macroeconomics
76-101 Interpretation and Argument	xx-xxx Breadth Course
99-101 Computing @ Carnegie Mellon	xx-xxx Breadth Course

Sophomore	
Fall	**Spring**
21-127 Concepts of Mathematics	21-270 Introduction to Mathematical Finance
21-259 Calculus in Three Dimensions	21-325 Probability
21-260 Differential Equations	70-311 Organizational Behavior
70-122 Introduction to Accounting	70-381 Marketing I
xx-xxx Elective	73-240 Intermediate Macroeconomics

Junior	
Fall	**Spring**
21-369 Numerical Methods	21-420 Continuous-Time Finance
21-370 Discrete Time Finance	36-226 Introduction to Statistical Inference
70-391 Finance	70-371 Operations Management
15-122 Principles of Imperative Computation	xx-xxx Breadth Course
xx-xxx Breadth Course	xx-xxx Breadth Course

Senior	
Fall	**Spring**
36-401 Modern Regression	95-717 Writing for Information Systems Management
46-977 MSCF Studies in Financial Engineering	90-718 Strategic Presentation Skills
70-332 Business, Society and Ethics	xx-xxx Depth Elective
70-401 Management Game	xx-xxx Breadth Course
xx-xxx Depth Elective	xx-xxx Breadth Course
	xx-xxx Elective

Minor in Computational Finance

There is no application process for the minor in Computational Finance, however in order to declare the minor in Computational Finance, a student must satisfy one of the following sets of requirements:

1. Completion of 21-270 Introduction to Mathematical Finance with a grade of A and an overall QPA of at least 3.20;
2. Completion of 21-270 Introduction to Mathematical Finance and 21-370 Discrete Time Finance with an average grade of B and an overall QPA of at least 3.00; OR
3. Completion of 21-270 Introduction to Mathematical Finance and 21-378 Mathematics of Fixed Income Markets with an average grade of B and an overall QPA of at least 3.00.

When a student has met the necessary requirements, he or she may declare the minor by contacting the Associate Director of the Undergraduate Computational Finance program.

21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	9-10
or 21-256	Multivariate Analysis	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
21-270	Introduction to Mathematical Finance	9
21-370	Discrete Time Finance *	9
21-420	Continuous-Time Finance **	9

To avoid excessive double counting, Computational Finance minors may not count 21-270 Introduction to Mathematical Finance, 21-370 Discrete Time Finance or 21-420 Continuous-Time Finance toward any other requirement.

* The prerequisites for 21-370 are 21-270 and either 21-256 or 21-259 , and the co-requisite is 70-207 , 21-325 , 36-225 or 36-217. Note that 70-207 is not accepted as a prerequisite for 21-420.

** The prerequisites for 21-420 are 21-260 , 21-370 and one of the following three calculus based probability courses: 21-325 , 36-225 or 36-217 . Note that 70-207 is not a sufficient preparation in probability. Also note that 21-122 is a prerequisite for 21-260 and that 21-127 is recommended for 21-241 .

Students minoring in Computational Finance are strongly encouraged to take one or two economics course, e.g., 73-102, 73-103, 73-230 , or 73-240 .

Game Design Minor – IDeATe

The Game Design minor is offered by the Entertainment Technology Center as part of the Integrative Design, Arts and Technology (IDeATe) network. IDeATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in shared labs and maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of eight areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, and Physical Computing. For more information about the IDeATe network, please visit Undergraduate Options (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateoptions/#ideate).

Students in IDeATe's Game Design minor learn both theory and practice of game creation taught by faculty experts from across the university. These experts specialize in: game systems and mechanics design, interactive narrative and character development, visual asset creation and sound synthesis, game programming, and interface design. These disciplines combine with each other in every step of development. In these courses, students learn to apply specialized knowledge from their own majors to enhance these game industry specific areas. In so doing, they work in highly interdisciplinary and collaborative teams to develop effective, engaging, and engrossing games.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-210	Electronic Media Studio: Introduction to Interactivity	10
60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area	10

16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
60-218	IDeATe Portal: Real-Time Animation	10
60-223	IDeATe: Introduction to Physical Computing	10
99-361	IDeATe Portal	9

IDeATe Game Design Courses - Minimum of 27 Units

		Units
05-418	Design Educational Games	12
15-466	Computer Game Programming	12
53-230	Programming for Game Designers	12
53-353	Understanding Game Engines	9
53-371/76-368	Role Playing Games Writing Workshop	12
53-376	360 Story and Sound	12
53-409	Game Design	12
53-451	Research Issues in Game Development: Designing for XR	12
53-471	Game Design, Prototyping and Production	15
53-472	Advanced Game Studio	9
53-558	Reality Computing Studio	12
60-333	IDeATe: Character Rigging for Production	10
60-419	Advanced ETB: Experimental Game Design	10

Additional courses as available. Please refer to the IDeATe website for the list of Game Design courses for the currnent and upcoming semesters.

Double-Counting

Students may double-count up to two of their Game Design minor courses toward requirements for other majors or minors.

Minor in Health Care Policy and Management

Sponsored by:
Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:
Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 27 units from the following:		
79-330	Medicine and Society	9
90-836	Health Systems	6
90-721	Healthcare Management	6
90-861	Health Policy	6

Elective Courses

Complete a minimum of 18 units from these two sections:

Heinz College Courses		
90-831	Advanced Financial Management of Health Care	6
94-705	Health Economics	12
90-832	Health Law	6
90-833	Population Health	6
90-818	Health Care Quality & Performance Improvement	6
90-834	Health Care Geographical Information Systems	12
Other courses as approved		

Humanities and Social Sciences Courses (9 units each)		
80-245	Medical Ethics	9
76-494	Healthcare Communications	9
88-365	Behavioral Economics and Public Policy	9
67-476	Innovation in Information Systems: Health Care	9
42-444	Medical Devices	9
Other courses as approved		

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

Health Management/Administration Focus		Units
90-831	Advanced Financial Management of Health Care	6
90-832	Health Law	6
90-818	Health Care Quality & Performance Improvement	6
80-245	Medical Ethics	9
76-494	Healthcare Communications	9

Health Policy Focus		Units
94-705	Health Economics	12
90-832	Health Law	6
90-833	Population Health	6
88-365/90-882	Behavioral Economics and Public Policy	9
Other courses as approved		

Health Analytisc & IT Focus		Units
90-834	Health Care Geographical Information Systems	12
67-476	Innovation in Information Systems: Health Care	9
42-444	Medical Devices	9
Other courses as approved		

Bachelor of Science in Music and Technology

The Bachelor of Science in Music and Technology is offered jointly by the School of Music, the School of Computer Science, and the College of Engineering.

This program consists of a set of courses that span both music and technology, as well as a capstone composition/design/performance project. Courses in all three areas of study are stipulated in the music and technology undergraduate curriculum and provide for students coming from any of the three areas. In other words, regardless of a student’s entry point — an interest in computer science, electrical engineering, or music — the coursework prescribed will allow the student to gain the requisite knowledge and experience in all three areas. Students will work closely with advisors and will be guided in both course selection and capstone projects.

Curriculum

Minimum units required for B.S. in Music and Technology 380

General Requirements 85 units

Seminar

57-570	Sound and Music Computing Seminar (8 semesters for a total of 8 units)	1

University

99-101	Computing @ Carnegie Mellon	3
76-101	Interpretation and Argument	9
79-104	Global Histories	9

Humanities

xx-xxx	Cognition, Choice and Behavior course	9
xx-xxx	English, History, Modern Languages, Philosophy, or Psychology course	9

Mathematics

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10

Science

33-114	Physics of Musical Sound	9
33-106	Physics I for Engineering Students	12

Electives 33 units

Music Core 87 units

57-152	Harmony I	9
57-153	Harmony II	9
57-408	Form and Analysis	6
57-151	Counterpoint in Theory and Application	6
57-258	20th-21st Century Techniques	6
57-257	Orchestration I	6
57-xxx	Music Support Course	6
57-189	Introduction to Repertoire and Listening for Musicians	3
57-190	Repertoire and Listening for Musicians I	3
57-289	Repertoire and Listening for Musicians II	3
57-290	Repertoire and Listening for Musicians III	3
57-181	Solfege I	3
57-182	Solfege II	3
57-183	Solfege III	3
57-184	Solfege IV	3
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-173	Survey of Western Music History	9

Music and Technology Core 120 units

15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	10
15-322	Introduction to Computer Music	9
18-100	Introduction to Electrical and Computer Engineering	12
18-202	Mathematical Foundations of Electrical Engineering	12
18-290	Signals and Systems	12
57-101	Introduction to Music Technology	6
57-347	Electronic and Computer Music	6
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9
57-571	Music and Technology Project	12
57-572	Music and Technology Project	12

Concentration

Students complete either the Music Concentration or the Technical Concentration:

Music Concentration **60 units**

57-5xx	Studio (4 semesters)	36
57-4xx	Major Ensemble (4 semesters)	24

Technical Concentration **57 or 55 units**

21-127	Concepts of Mathematics	10
15/18-213	Introduction to Computer Systems	12

AND EITHER:

18-220	Electronic Devices and Analog Circuits	12
18-240	Structure and Design of Digital Systems	12
15-2xx/18-3xx or above	Electives in ECE or CS	12

OR:

15-128	Freshman Immigration Course	1
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-323	Computer Music Systems and Information Processing	9
15-2xx/18-3xx or above	Electives in ECE or CS	12

Bachelor of Science in Neuroscience

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

www.cmu.edu/neuro

Neuroscience is an interdisciplinary field in which scientists from many backgrounds apply the tools of biology, cognitive science, psychology, chemistry, mathematics, statistics, computer science, and engineering to develop a comprehensive understanding of brain function at the level of molecules, neurons, brain circuits, cognitive brain modules, and behavior. Research in neuroscience across these disciplines has grown substantially in the past two decades, and a solid understanding of the physiological basis of many aspects of brain function both in health and disease has come along with this growth in research. Along with this comes an increasing need for students to begin careers in neuroscience and to be prepared to work on the problems in neuroscience and to bring new answers to the public and to patients. In order to be successful in developing new treatments and answering outstanding questions in the field, neuroscientists need to be conversant in many different levels of inquiry from neurobiology to cognitive neuroscience to computational neuroscience.

The Dietrich College of Humanities & Social Sciences and the Mellon College of Science have joined forces to establish an exciting interdisciplinary program leading to a Bachelor of Science in Neuroscience. The goal of this degree program is to provide an intensive interdisciplinary education to enable outstanding students to become leaders in identifying and solving tomorrow's Neuroscience problems using a variety of methods. The program's interdisciplinary curriculum is designed for students to gain a fundamental understanding of brain function on many different levels and to begin to specialize within the broad field of Neuroscience. Students in Mellon College of Science or Dietrich College may have a primary major in Neuroscience in any of the three concentrations. Students from other colleges may have a second major in Neuroscience in any of the three concentrations, subject to double-counting restrictions.

A degree in neuroscience provides excellent preparation for medical school or other graduate programs in the health professions. These students are aided by the Carnegie Mellon Health Professions Program (HPP), an advisory and resource service for all Carnegie Mellon students who are considering careers in the health care field. (See the HPP (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateoptions/#healthprofessionsprogram) section in this catalog or www.cmu.edu/hpp for more information.)

Students wishing to pursue the Neuroscience major through Dietrich College should contact Dr. Lori Holt (loriholt@cmu.edu). Students wishing to pursue the Neuroscience major through the Mellon College of Science should contact the Biological Sciences Undergraduate Programs Office (bio-ungrad@andrew.cmu.edu). Students wishing to pursue an additional major in either the Neurobiology or Computational Neuroscience concentrations should contact the Biological Sciences Undergraduate Programs Office (bio-ungrad@andrew.cmu.edu). Students wishing to pursue an additional major in the Cognitive Neuroscience concentration should contact Dr. Lori Holt (loriholt@cmu.edu).

Students who pursue this major will:

- Gain a broad understanding of Neuroscience at many different levels of analysis, including: cellular biology of the brain, brain systems, cognitive brain function, and computational brain modeling
- Gain an understanding of the sciences underlying Neuroscience, including: Biology, Chemistry, Computer Science, Cognition and Psychology, and other emerging areas
- Develop a comprehensive understanding of brain function in health and disease

- Be familiar with neuroanatomy & neurophysiology and their implications for nervous system function
- Be prepared for advanced study in neurobiology, cognitive neuroscience, and/or neural computation
- Be able to collaborate with Neuroscientists across a wide range of systems and levels of analysis
- Prepare for careers in Neuroscience related companies, Neuroscience research, and/or medicine
- Be prepared for specialization within subfields of Neuroscience given their concentration selection

Requirements for a B.S. in Neuroscience

All students must complete the following:

1. General Science Requirements (see section A)
2. Core Neuroscience Courses (see section B)
3. Requirements for one concentration (see sections C, D, or E)*
4. 18 additional relevant course units in their home concentration or other neuroscience areas (some examples listed in sections C, D, E, & F). At least 9 of these units must be at the 300-level or above.
5. Their home college's General Education requirements
6. Free elective units to come to a total of 360 total course units

* **Double-counting restrictions and additional majors & minors**
- Students may not major in two concentrations.
- Students using Neuroscience as an additional major or who have an additional major or minor to Neuroscience may only double-count at most 3 courses between this an their other major or minor (this restriction does not apply to prerequisites, General Education Requirements, or the General Science Requirements – section A).
- Other majors and minors may have more stringent double-counting restrictions, please consult with your neuroscience advisors and with the advising staff for the relevant host department for the other majors/minors.

A. General Science Requirements

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
03-201	Undergraduate Colloquium for Sophomores	1
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-207	Techniques in Quantitative Analysis [1]	9-12
or 09-221	Laboratory I: Introduction to Chemical Analysis	
or 03-124	Modern Biology Laboratory	
09-217	Organic Chemistry I [1]	9
or 33-122	Physics II for Biological Sciences and Chemistry Students	
33-121	Physics I for Science Students	12
15-110	Principles of Computing [2]	10-12
or 15-112	Fundamentals of Programming and Computer Science	
or 02-201	Programming for Scientists	
36-200	Reasoning with Data [2]	9
or 36-247	Statistics for Lab Sciences	
or 36-217	Probability Theory and Random Processes	
or 36-225	Introduction to Probability Theory	
		108-113

1 Neurobiology concentration students are required to complete 09-217 & 09-207 or 09-221.

2 Computational Neuroscience concentration students are required to complete 21-122, 15-112, & 36-217

B. Core Neuroscience Courses

		Units
85-219	Biological Foundations of Behavior	9
or 03-161	Molecules to Mind	
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
15-386	Neural Computation [3]	9
or 85-419	Introduction to Parallel Distributed Processing	
or 02-319	Genomics and Epigenetics of the Brain	
or 86-375	Computational Perception	
		45

3 Computational Neuroscience concentration students are required to complete 15-386.

C. Neurobiology Concentration

Didactic Core: Students must complete all of the following*		Units
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
		18

* Neurobiology concentration students must complete 09-217 & 09-207 or 09-221 in their General Science Requirements (section A, above)

Required laboratory, data analysis, & methodological courses		Units
03-343	Experimental Techniques in Molecular Biology	12
03-346	Experimental Neuroscience	12
or 03-345	Experimental Cell and Developmental Biology	
		24

Electives in Neurobiology (minimum of 18 additional units)**		Units
03-133	Neurobiology of Disease	9
03-250	Introduction to Computational Biology	12
03-350	Developmental Biology	9
03-364	Developmental Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
03-366	Biochemistry of the Brain	9
03-439	Introduction to Biophysics	9
03-442	Molecular Biology	9
09-218	Organic Chemistry II	9
09-208	Techniques for Organic Synthesis and Analysis	9
or 09-222	Laboratory II: Organic Synthesis and Analysis	
42-202	Physiology	9
42-203	Biomedical Engineering Laboratory NOTE: VERY Limited Seating Available for 42-203	9

** At least 9 of these units must be 300 level or above

D. Cognitive Neuroscience Concentration

Didactic Core. Students must complete all of the following		Units
85-102	Introduction to Psychology	9
36-309	Experimental Design for Behavioral & Social Sciences	9
		18

Required laboratory, data analysis, & methodological courses		Units
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
		18

Electives in Cognitive Neuroscience (minimum of 27 additional hours)**		Units
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-261	Abnormal Psychology	9
85-356	Music and Mind: The Cognitive Neuroscience of Sound	9
85-370	Perception	9
85-390	Human Memory	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-408	Visual Cognition	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing *	9
85-424	Hemispheric Specialization: Why, How and What?	9

85-426	Learning in Humans and Machines	9
85-429	Cognitive Brain Imaging	9
85-442	Health Psychology	9
85-501	Stress, Coping and Well-Being	9

* If not used as a core course

** At least 18 of these hours must be 300 level or above

E. Computational Neuroscience Concentration

Didactic Core. Students must complete all of the following*		Units
21-127	Concepts of Mathematics	10
15-122	Principles of Imperative Computation	10
or 15-150	Principles of Functional Programming	
21-241	Matrices and Linear Transformations	10
or 21-240	Matrix Algebra with Applications	
		30

* Computational Neuroscience concentration students must complete 21-122, 15-112, and 36-217 in their General Science Requirements (section A, above) and 15-386 in their Core Neuroscience Courses (section B, above). Students must complete a minimum of 60 units in this concentration. Students should select their required laboratory and elective courses to complete a minimum of 31 units (Four 9 unit courses or a lesser number of 9 and 12 unit courses could be combined to complete this requirement).

Required laboratory, data analysis, and methodological courses (18-24 total units)		Units
42-631	Neural Data Analysis	9
or 86-631	Neural Data Analysis	
42-632	Neural Signal Processing	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
15-883	Computational Models of Neural Systems	12

Electives in Computational Neuroscience (minimum of 9 units)		Units
03-512	Computational Methods for Biological Modeling and Simulation	9
or 02-512	Computational Methods for Biological Modeling and Simulation	
10-401	Introduction to Machine Learning (Undergrad)	12
or 10-601	Introduction to Machine Learning (Master's)	
15-381	Artificial Intelligence: Representation and Problem Solving	9
15-387	Computational Perception	9
15-451	Algorithm Design and Analysis	12
15-453	Formal Languages, Automata, and Computability	9
15-494	Cognitive Robotics: The Future of Robot Toys	12
15-883	Computational Models of Neural Systems	12
16-299	Introduction to Feedback Control Systems	12
16-311	Introduction to Robotics	12
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-259	Calculus in Three Dimensions	9
21-272	Introduction to Partial Differential Equations	9
21-341	Linear Algebra	9
36-208	Regression Analysis	9
36-226	Introduction to Statistical Inference	9
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-462	Special Topics: Data Mining	9
42/86-631	Neural Data Analysis	9
42-632	Neural Signal Processing	12

F. Additional Neuroscience Electives

Students are required to take a minimum of 18 additional relevant course units in their home concentration or other neuroscience areas. Some examples are listed in sections C, D, & E above as well as in the list below. At least 9 of these units must be at the 300-level or above.

NOTE: this list is not restrictive. Concentration advisors can approve additional elective courses that contribute to the student's neuroscience education, subject to additional approval by the major steering committee.

Examples of Additional Electives relevant to major*		
33-122	Physics II for Biological Sciences and Chemistry Students unless used for Science Core (section A)	9
76-385	Introduction to Discourse Analysis	9
80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-220	Philosophy of Science	9
80-254	Analytic Philosophy	9
80-270	Philosophy of Mind	9
80-280	Linguistic Analysis	9
80-314	Causal Discovery, Statistics, and Machine Learning	9
88-355	Social Brains: Neural Bases of Social Perception and Cognition	9

* Up to 9 units of applicable undergraduate research course work (e.g. 03-445 or 85-507/85-508) can count as a neuroscience elective (not towards a concentration). A maximum of 27 additional units can be counted as a free electives.

Free Electives (depending on concentration & college)	**51-61**
TOTAL hours to degree	**360**

B.S. in Psychology & Biological Sciences

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/#hampssgeneraleducationprogram160) and MCS (http://coursecatalog.web.cmu.edu/melloncollegeofscience) are found on their respective Catalog pages.

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	General Biology Elective [1]	9
03-3xx	Advanced Biology Elective [1]	18
Total Biology units		78

[1] Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Mathematics, Statistics, Physics and Computer Science		Units
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10
or 21-122	Integration and Approximation	
36-247	Statistics for Lab Sciences	9
or 36-200	Reasoning with Data	
36-309	Experimental Design for Behavioral & Social Sciences	9

or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	
33-121	Physics I for Science Students [2]	12
or 33-141	Physics I for Engineering Students	
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
or 02-201	Programming for Scientists	
99-101	Computing @ Carnegie Mellon	3
Total Science units		63-65

[2] MCS students must also complete 33-122 Physics II for Biological Sciences and Chemistry Students.

Chemistry		Units
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
or 09-219	Modern Organic Chemistry	
09-218	Organic Chemistry II	9
or 09-220	Modern Organic Chemistry II	
09-207	Techniques in Quantitative Analysis	9-12
or 09-221	Laboratory I: Introduction to Chemical Analysis	
09-208	Techniques for Organic Synthesis and Analysis	9-12
or 09-222	Laboratory II: Organic Synthesis and Analysis	
Total Chemistry units		56-62

Psychology Courses		Units
85-102	Introduction to Psychology	9
85-219	Biological Foundations of Behavior	9
85-2xx	Survey Psychology Courses *	18
85-310	Research Methods in Cognitive Psychology	9
or 85-340	Research Methods in Social Psychology	
or 85-320	Research Methods in Developmental Psychology	
or 85-314	Cognitive Neuroscience Research Methods	
or 85-330	Analytic Research Methods	
85-3xx	Advanced Psychology Electives	18
Total Psychology units		63

* Excluding 85-261 Abnormal Psychology

Additional Advanced Elective 9 units

(Choose one of the following courses)		
85-3xx	Advanced Psychology Elective	9
or		
03-3xx	Advanced Biology Elective	9

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)		
03-344	Experimental Biochemistry	12
03-345	Experimental Cell and Developmental Biology	12
03-346	Experimental Neuroscience	12
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-340	Research Methods in Social Psychology	9

Elective Units	Units
Free Electives	33-36
MCS Nontechnical Breadth or DC General Education requirements	36-48
Total Elective units	69-84

Minimum number of units required for degree: 360

BXA Intercollege Degree Programs

M. Stephanie Murray, Director
Location: Posner 348B
www.cmu.edu/interdisciplinary

Mission Statement

The BXA Intercollege Degree Programs are designed for students who want to turn talent and passion into viable professions for the future through a challenging academic curriculum. BXA students pursue their goals with the help of multifaceted advising, innovative pedagogical strategies and a focus on the impact arts have on technology and vice versa.

The goal of the Bachelor of Computer Science and Arts (BCSA), the Bachelor of Humanities and Arts (BHA), the Bachelor of Science and Arts (BSA) and the additional major in Engineering and Arts (EA), housed under the BXA Intercollege Degree Programs, is to allow a select group of students who demonstrate interest and accomplishment in the fine arts and computer science, engineering, humanities, social sciences or natural sciences to explore beyond the traditional academic major, or integrate more than one field of study across disciplines. These programs foster the creativity of students who explore innovative approaches to the academic environments of two colleges. By merging the components in the arts and computer science, engineering, natural sciences or humanities into an interdisciplinary/multidisciplinary study, a unique, complex product is born. BXA students produce new information, challenging questions and innovative theory. BXA students are models of independence, motivation and well-rounded scholarship as humanists, scientists and artists at the same time.

In the context of the Carnegie Mellon University environment, the BXA Intercollege Degree Programs hold a special role. BXA provides access to five strong colleges that offer specialized training with expert faculty and researchers. The BXA Programs challenge students to utilize those resources as they explore and develop their own approach to interdisciplinary studies in the fine arts and computer science, engineering, humanities and social sciences, or the natural and mathematical sciences.

BXA students balance courses in their CFA concentration with courses in their academic concentration, as well as BXA-specific courses. These BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques. The curricula in the concentration areas provide students with a solid disciplinary foundation upon which they can draw for interdisciplinary projects.

A BXA intercollege degree prepares students for graduate study and careers in an enormous variety of fields, including traditional graduate training in the arts as well as academic areas, positions in arts and education non-profits such as museums and foundations, and technical positions with media and technology companies.

Program Objectives

The skills developed by BXA students span the creative, the technical, the academic and the practical. The objective of the BXA Intercollege Degree Programs is to prepare graduates for careers in which they will draw on their creative and academic skills to create, educate, communicate and innovate across disciplines.

Students who complete the BXA curriculum will graduate with the following skills:

- Foundational knowledge and technical expertise in the CFA concentration area and the DC/E/MCS/SCS concentration area
- Ability to describe the connections between these concentrations and how the student integrates them
- Ability to communicate ideas textually, visually and orally
- Knowledge of how the concentration disciplines intersect with history, society and culture from local and global perspectives
- Ability to use cognitive, behavioral and ethical dimensions within the concentration disciplines to make decisions on individual and social levels
- Experience in engaging in art research to produce new knowledge both within the CFA concentration and the DC/E/MCS/SCS concentration
- Experience in designing, researching and completing a large-scale, object-based project that integrates both areas of concentration

Bachelor of Computer Science and Arts Degree Program

Carnegie Mellon University recognizes that there are students who are naturally gifted in both the fine arts and computer science. In order to accommodate students who want to pursue an education simultaneously in these areas, we offer a degree that combines the strengths of the College of Fine Arts (CFA) and the School of Computer Science (SCS). The intercollege degree, called the Bachelor of Computer Science and Arts (BCSA), is a rigorous program that offers a unique group of qualified students the opportunity to develop their talents and interests in an area of the fine arts and computer science.

The BCSA curriculum is divided into three parts: 1) BCSA General Education coursework, 2) CFA concentration coursework, and 3) SCS concentration coursework.

The BCSA Degree Program is governed by faculty and administrators from both colleges and led by the director of the BXA Intercollege Degree Programs. The director and associate director of the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and SCS. Students receive extensive advising support. Each student has two additional academic advisors: an advisor in the admitting school of CFA for their fine arts concentration and an advisor in SCS for their computer science concentration. This network of advisors guides each student through their curriculum.

BCSA Curriculum

	Units
I. BCSA General Education	**121**
II. SCS Concentration	**111**
III. CFA Concentration	**108**
IV. Free Electives	**40**
Total BCSA Degree Requirements	**380**

BCSA General Education

(15 courses, 122 units minimum)

- Writing (1 course, 9 units, 76-101 required)
- Mathematics (2 courses, 19 units minimum, 21-122 and either 21-259 or 21-241 required), Probability (1 course, 9 units minimum)
- Science & Engineering (2 courses, 18 units minimum)
- Economic, Political, & Social Institutions OR Cognition, Choice & Behavior (1 course, 9 units minimum)
- Two additional courses from Dietrich or CFA (2 course, 18 units minimum)
- University Requirement (1 course, 3 units, 99-101 required)
- BXA Required Courses (5 courses, 36 units minimum, 52-190 or 52-291, 52-391, 52-392, 52-401, 52-402)

Writing (1 course, 9 units)

Broadly considered, language is a tool used to communicate, as well as a way to organize non-visual and non-mathematical thinking. This requirement focuses on the social nature of language and the ways in which writing constitutes thinking.

76-101	Interpretation and Argument	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106 & 76-107 & 76-108	Writing about Literature, Art and Culture and Writing about Data and Writing about Public Problems	

All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html

Mathematics & Probability (3 courses, 28 units minimum)

Choose two mathematics courses (19 units minimum):

21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	9
or 21-241	Matrices and Linear Transformations	

Choose one probability course (9 units minimum):

15-259	Probability and Computing	12
21-325	Probability	9
36-218	Probability Theory for Computer Scientists	9

Science & Engineering (2 courses, 18 units minimum)

Choose two science courses from differing departments or one science and one engineering course from the following list:

02-223	Personalized Medicine: Understanding Your Own Genome	9
02-261	Quantitative Cell and Molecular Biology Laboratory	9
03-121	Modern Biology	9
03-125	Evolution	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
06-100	Introduction to Chemical Engineering	12
09-105	Introduction to Modern Chemistry I	10
09-217	Organic Chemistry I	9
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
12-201	Geology	9
18-100	Introduction to Electrical and Computer Engineering	12
24-101	Fundamentals of Mechanical Engineering	12
27-100	Engineering the Materials of the Future	12
33-104	Experimental Physics	9
33-114	Physics of Musical Sound	9
33-120	Science and Science Fiction	9
33-121	Physics I for Science Students	12
33-151	Matter and Interactions I	12
42-101	Introduction to Biomedical Engineering	12
85-219	Biological Foundations of Behavior	9

Economic, Political & Social Institutions OR Cognition, Choice & Behavior (1 course from either category, complete 9 units minimum)

Economic, Political & Social Institutions

This requirement explores the processes by which institutions organize individual preferences and actions into collective outcomes.

19-101	Introduction to Engineering and Public Policy	12
70-332	Business, Society and Ethics	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics *	9
79-245	Capitalism and Individualism in American Culture	9
79-320	Women, Politics, and Protest	9
79-331	Body Politics: Women and Health in America	9
79-341	The Cold War in Documents and Film	9
79-383	The History of Capitalism	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-335	Social and Political Philosophy	9
84-104	Decision Processes in American Political Institutions	9
84-275	Comparative Politics	9
84-322	Nonviolent Conflict and Revolution	9
84-326	Theories of International Relations	9
84-362	Diplomacy and Statecraft	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-389	Terrorism and Insurgency	9

Cognition, Choice, and Behavior

This requirement explores the process of thinking, decision making, and behavior in the context of the individual.

70-311	Organizational Behavior *	9
80-130	Introduction to Ethics	9
80-150	Nature of Reason	9
80-180	Nature of Language	9
80-221	Philosophy of Social Science	9
80-242	Conflict and Dispute Resolution	9
80-270	Philosophy of Mind	9
80-271	Philosophy and Psychology	9
85-102	Introduction to Psychology	9
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artifical Intelligence	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9
85-261	Abnormal Psychology	9
88-120	Reason, Passion and Cognition	9

* Indicates co-requisites and/or prerequisites required.

Complete Two additional courses from Dietrich or CFA (2 courses, complete 18 units minimum)

These courses must be non-technical/non-studio. Each CFA concentration has recommended courses for this category; consult with your BXA advisor to determine the best courses to fulfill this requirement.

University Requirement (1 course, 3 units)

This is a mini-course, pass/no pass, to be completed in the first semester or online in the summer prior to the first semester.

99-101	Computing @ Carnegie Mellon	3

BXA Required Courses (5 courses, 36 units minimum)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer	9
or 52-291	BXA Seminar II: Transferring Knowledge	
52-391	BXA Junior Portfolio	0
52-392	BXA Seminar III: Deconstructing Disciplines	9
52-401	BXA Seminar IV: Capstone Project Research	9
52-402	BXA Seminar V: Capstone Project Production	9

School of Computer Science Concentration

Computer Science Concentration (111 units minimum)

Prerequisite

15-112	Fundamentals of Programming and Computer Science	12

Computer Science Core Requirements (5 courses, 56 units)

15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
15-210	Parallel and Sequential Data Structures and Algorithms	12

15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Concepts of Mathematics (1 course, 10 units)

21-127	Concepts of Mathematics (co-requisite for 15-122; prerequisite for 15-150)	10

Applications Courses or CS Electives (5 courses, 45 units minimum)

Choose a minimum of five courses from SCS beyond the core requirements, 200-level or higher, not including 02-201, 02-223, 02-250, 02-261, 15-351, 16-223, 17-200, 17-333, 17-562. Listed below are suggested choices for these electives. Consult with the CS advisor if interested in courses not listed.

05-391	Designing Human Centered Software	12
05-418	Design Educational Games	12
10-335	Art and Machine Learning	12
11-291	Applied Computational Intelligence Lab	9
11-344	Machine Learning in Practice	12
11-411	Natural Language Processing	12
15-322	Introduction to Computer Music	9
15-323	Computer Music Systems and Information Processing	9
15-365	Experimental Animation	12
15-381	Artificial Intelligence: Representation and Problem Solving	9
15-388	Practical Data Science	9
15-415	Database Applications	12
15-451	Algorithm Design and Analysis	12
15-458	Discrete Differential Geometry	12
15-462	Computer Graphics	12
15-463	Computational Photography	12
15-464	Technical Animation	12
15-465	Animation Art and Technology	12
15-466	Computer Game Programming	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-264	Humanoids	12
16-362	Mobile Robot Algorithms Laboratory	12
16-374	IDeATe: Art of Robotic Special Effects	12
16-384	Robot Kinematics and Dynamics	12
16-385	Computer Vision	12
16-423	Designing Computer Vision Apps	12
16-455	IDeATe: Human-Machine Virtuosity	12
16-465	Game Engine Programming	10
16-467	Human Robot Interaction	12
17-214	Principles of Software Construction: Objects, Design, and Concurrency	12
17-313	Foundations of Software Engineering	12
17-356	Software Engineering for Startups	12
17-437	Web Application Development	12

College of Fine Arts Concentration

(number of courses vary, 108 units minimum)

BCSA students choose one of the following concentrations:

- Architecture (108 units)
- Art (108 units)
- Design (108 units)
- Drama (108 units)
- Music (108 units)

Architecture Concentration (108 units minimum)

Architecture Required Courses (7 courses, 52 units minimum)

48-100	Architecture Design Studio: Foundation I -Fall, Freshman year	10-15
or 48-095	Spatial Concepts for Non-Majors	
62-122	Digital Media I -Fall, Freshman year	6
62-125	Drawing I -Fall, Freshman year	6
62-123	Digital Media II -Spring, Freshman year	6
62-126	Drawing II -Spring, Freshman year	6
48-240	Historical Survey of World Architecture and Urbanism I -Spring, Freshman year	9
48-241	Modern Architecture -Fall, Sophomore year	9

Architecture Electives (56 units minimum)

A minimum of **56** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office.

Art Concentration (108 units minimum)

Concept Studios (2 courses, 20 units)

Complete two courses:

60-101	Concept Studio: The Self and the Human Being	10
60-201	Concept Studio: Space and Time	10
60-202	Concept Studio: Systems and Processes	10
60-280	Introduction to Contextual Practice	10

Media Studios (3 courses, 30 units minimum)

Complete three courses. 3D mini courses count as half a course:

60-150	2D Media Studio: Drawing	10
60-160	2D Media Studio: Imaging	10
60-131	3D Media Studio I (mini-1)	5
60-132	3D Media Studio I (mini-2)	5
60-133	3D Media Studio II (mini-3)	5
60-134	3D Media Studio II (mini-4)	5
60-250	2D Media Studio: Painting	10
60-251	2D Media Studio: Print Media	10
60-110	Electronic Media Studio: Introduction to the Moving Image	10
60-210	Electronic Media Studio: Introduction to Interactivity	10-12
or 60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	

Advanced Studios (4 courses, 40 units)

Complete four courses. Courses may be offered in the fall and/or spring. Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired.

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) *		10
Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) *		10
Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) *		10
Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) *		10
60-499	Studio Independent Study (one only)	10

* Courses offered intermittently; speak with a BXA advisor to determine course availability.

Critical Studies (2 courses, 18 units)

60-205	Critical Theory in Art III -Fall	9
60-206	Critical Theory in Art IV -Spring	9

Note: Critical Theory I & II are strongly recommended.

Review Requirement (complete 2 required reviews, 0 units)

A review is required at the end of the sophomore and senior years. Pass/no pass only.

60-200	Sophomore Review -Spring	0
60-400	Senior Review -Fall	0

Design CONCENTRATION (108 UNITS MINIMUM)

Design Required Courses (13 courses, 95 units)

51-101	Studio: Survey of Design (Fall, Freshman year)	10
51-121	Visualizing (Fall, Freshman year)	10
51-171	Placing (Fall, Freshman year)	10
51-102	Design Lab (Spring, Freshman year)	10
51-122	Collaborative Visualizing (Spring, Freshman year)	10
51-172	Systems (Spring, Freshman year)	9
Choose Two Studios (Fall, Sophomore year):		4.5+4.5
51-225	Communications Studio I: Understanding Form & Context	4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	
Choose Two Corresponding Labs (Fall, Sophomore year):		4.5+4.5
51-227	Prototyping Lab I: Communications	4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	
51-271	How People Work (Fall, Sophomore year)	9
51-371	Futures I (Fall, Junior year or later)	4.5
51-373	Futures II (Fall, Junior year or later)	4.5

Design Electives (13 units)

A minimum of **13** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration (108 units minimum)

Options available in the following areas: 1) Design, 2) Directing, 3) Dramaturgy, 4) Production Technology and Management

Note: There is no BHA Acting or Musical Theatre option.

Required Courses for All Concentration Options (5 courses, 20 units)

54-175-54-176	Conservatory Hour-Conservatory Hour (1 unit each)	2
54-177	Foundations of Drama I	6
54-281	Foundations of Drama II (prerequisite: 54-177)	6
54-381	Special Topics in Drama: History, Literature and Criticism	6

Work with Drama Faculty Option Coordinator to Approve Concentration Option (**88** units minimum):

Design Required Courses (2 courses, 26 units)

54-151-54-152	Stagecraft-Stagecraft (13 units + 13 units)	26

A minimum of **62** additional Design units must be approved by the Design faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Directing Required Courses (10 courses, 52 units)

54-121-54-122	Directing I: Sources-Directing I: Sources	18
54-221-54-222	Directing II: Fundamentals-Directing II: Fundamentals	18
54-159-54-159	Production Practicum-Production Practicum (two times, 12 units total)	12
54-517	Director's Colloquium (four times, 4 units total)	1

A minimum of **36** additional Directing units must be approved by the Directing faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (9 courses, 53 units minimum)

54-109	Dramaturgy 1: Approaches to Text	9
54-184	Dramaturgy 2: Introduction to Production Dramaturgy	9
54-121	Directing I: Sources	9
54-159-54-159	Production Practicum-Production Practicum (two times, 12 units total)	12
54-200-54-200	Dramaturgy Forum-Dramaturgy Forum -Fall (minimum of two; every semester it is offered while enrolled)	2
54-xxx	Dramaturgy 3, 4, 5 or 6 (minimum of two; all four if enrolled as BXA for six semesters or more)	18

A minimum of **29** additional Dramaturgy units must be approved by the Dramaturgy faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Production Technology and Management Required Courses (2 courses, 26 units)

54-151-54-152	Stagecraft-Stagecraft (13 units + 13 units)	26

A minimum of **62** additional PTM units must be approved by the PTM faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Music Concentration (108 units minimum)

Options available in the following areas: 1) Music Performance (instrumental, piano, organ, voice), 2) Composition 3) Musicology, 4) Audio Recording & Production 5) Sound Theory & Practice

Required Course for All Concentration Options (1 course, 9 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	

Work with Music Advisor to Approve Concentration Option (**99** units minimum):

Music Performance and Composition Required Courses (12 courses, 76 units)

57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Musicology Required Courses (8 courses, 45 units)

57-283	Music History I (co-requisite: 57-190)	9
57-284	Music History II (co-requisite: 57-289)	9
57-285	Music History III (co-requisite: 57-290)	9
57-189	Introduction to Repertoire and Listening for Musicians	3
57-190	Repertoire and Listening for Musicians I	3
57-289	Repertoire and Listening for Musicians II	3
57-290	Repertoire and Listening for Musicians III	3
57-611	Independent Study in History	6

Choose **36** units from:

57-209	The Beatles	9
57-306	World Music	9

57-404	String Quartet: A Social History	9
57-405	Concerto: Virtuosity and Contrast	9
57-409	Puccini's Operas	9
57-427	Advanced Seminar in Film Musicology	9
57-476	How Music Works: An Affective History	6
57-477	Music of the Spirit	6
57-478	Survey of Historical Recording	6
57-480	History of Black American Music	6
57-485	History of the Symphony	9

A minimum of **18** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Audio Recording & Production Required Courses (7 courses, 40 units)

57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Choose **59** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-275	History of Sound Design	3
54-666	Production Audio	6
57-344	Experimental Sound Synthesis	9
57-421	The Exploded Ensemble	6
57-425	Expanded Music Performance	9
57-427	Advanced Seminar in Film Musicology	9
57-478	Survey of Historical Recording	6
57-622	Independent Study in Sound Recording Production	3
60-131	3D Media Studio I	5
60-210	Electronic Media Studio: Introduction to Interactivity	10

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Sound Theory & Practice Required Courses (7 courses, 47 units)

57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
18-090	Twisted Signals: Multimedia Processing for the Arts	10
57-911	Music Since 1945	9
57-616	Independent Study in Sound Studies	9

Choose **52** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music (pre-requisite: 15-112)	9
15-323	Computer Music Systems and Information Processing (pre-requisite: 15-122)	9
33-114	Physics of Musical Sound	9
57-337	Sound Recording	6
57-343	Interdisciplinary Studies in Listening, Culture, and Technology	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music (pre-requisite: 57-101 or 57-171)	6
57-421	The Exploded Ensemble	6
57-425	Expanded Music Performance	9
57-438	Multitrack Recording	9
57-478	Survey of Historical Recording	6
57-829	Contemporary Soundscapes	9
60-131	3D Media Studio I	5
60-210	Electronic Media Studio: Introduction to Interactivity	10

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 4 courses, 39 units minimum)

Take any Carnegie Mellon course. A maximum of 9 units of physical education and/or military science may be counted toward this requirement. Physical education and military science courses will not be calculated in a student's QPA.

Bachelor of Humanities and Arts Degree Program

Carnegie Mellon University offers an intercollege degree that combines the strengths of the College of Fine Arts (CFA) and the College of Dietrich College of Humanities and Social Sciences (DC). The intercollege degree, called the Bachelor of Humanities and Arts (BHA), offers depth of study in both the fine arts and the humanities, social and behavioral sciences. The BHA Degree Program enables a student to receive broader exposure to the humanities and liberal arts than is generally possible through a Bachelor of Fine Arts degree in CFA, while obtaining deeper and more substantial training in the fine arts than is generally possible through a Bachelor of Arts or Bachelor of Science degree in DC. Students receive extensive training in one or more of the fine arts disciplines as well as related advanced training in areas such as writing, social sciences, behavioral sciences or cultural studies. The program also provides enough flexibility to allow students to explore other areas of interest. The most important aspect of the BHA Program is for students to blend their interests and to explore the connections between their chosen disciplines.

The BHA curriculum is divided into three parts: 1) BHA General Education coursework, 2) CFA concentration coursework, and 3) DC concentration coursework.

The BHA Degree Program is governed by faculty and administrators from both colleges and led by the director of the BXA Intercollege Degree Programs. The director and associate director of the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and DC. Students receive extensive advising support. Each student has two additional academic advisors: an advisor in the admitting school of CFA for their fine arts concentration and an advisor in DC for their humanities/social sciences concentration. This network of advisors guides each student through their curriculum.

BHA Curriculum

	Units
I. BHA General Education	**111**
II. DC Concentration	**81**

III. CFA Concentration	**108**
IV. Free Electives	**78**
Total BHA Degree Requirements	**378**

BHA General Education

(14 courses, 111 units minimum)

- Communicating: Language and Interpretations (3 courses, 27 units minimum, 76-101 required, two approved modern language courses required)
- Reflecting: Societies and Cultures (1 course, 9 units, 79-104 required)
- Modeling: Mathematics and Experiments (1 course, 9 units minimum)
- Deciding: Social Sciences and Values (3 courses, 27 units minimum, 36-200 required)
- University Requirement (1 course, 3 units, 99-101 required)
- BXA Required Courses (5 courses, 36 units minimum, 52-190 or 52-291, 52-391, 52-392, 52-401, 52-402)

Communicating: Language and Interpretations (3 courses, 27 units minimum)

Courses in this category give special attention to the study of language as interpretation, expression and argument within and across multiple discourses. Students examine language for its internal logics and structures.

76-101	Interpretation and Argument	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106 & 76-107 & 76-108	Writing about Literature, Art and Culture and Writing about Data and Writing about Public Problems	
All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html		
82-xxx	Modern Languages	18
Complete two courses taught in a language offered by the Modern Language Department. A wide selection of courses are offered in Arabic, Chinese Studies, European Studies, French and Francophone Studies, German Studies, Hispanic Studies, Italian, Japanese Studies, Russian Studies, and Spanish. Students must complete two courses in the same language. Languages taught at other institutions are also acceptable (with advisor approval).		

Reflecting: Societies and Cultures (1 course, 9 units)

This category emphasizes the study of history, society, and culture from local and global perspectives.

79-104	Global Histories	9

Course topics can be found on the Department of History website (http://www.history.cmu.edu/undergraduate/fall.html).

Modeling: Mathematics and Experiments (1 course, 9 units minimum)

Courses in this category stress the interplay of mathematical (formal) theories and experimental work. Some courses investigate the internal structure of theories, whereas others use them as models for producing real-world knowledge. Such models may be drawn from a variety of disciplines including the natural sciences, but also, for example, psychology and computer science. The interactions between theorizing and experimenting (observing) can be understood within an intellectual framework that invites comparative assessment. Select one course from the following course options:

Mathematics

21-111	Differential Calculus	10
21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	10
80-110	Nature of Mathematical Reasoning	9
80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9

Natural Science

03-121	Modern Biology	9
03-125	Evolution	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
03-161	Molecules to Mind	9
09-103	Atoms, Molecules and Chemical Change	9
09-105	Introduction to Modern Chemistry I	10
12-201	Geology	9
33-104	Experimental Physics	9
33-114	Physics of Musical Sound	9
33-115	Physics for Future Presidents	9
33-124	Introduction to Astronomy	9

Other Courses

05-413	Human Factors	9
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
33-120	Science and Science Fiction	9
80-220	Philosophy of Science	9
80-226	Revolutions in Science	9
80-312	Mathematical Revolutions	9
80-327	Philosophy of Neuroscience	9
85-370	Perception	9
88-275	Bubbles: Data Science for Human Minds	9
99-236	Introduction to Environmental Ideas	9

Deciding: Social Sciences and Values (3 courses, 27 units minimum)

The theme of this category is the exploration of cognitive, behavioral and ethical dimensions of decision-making on both the individual and social level. Making decisions requires a broad understanding of human rationality and social interaction. Some courses examine the critical collection and analysis of data for achieving such an understanding, whereas others emphasize the historical development of policies and values, which form the matrix for decision-making.

36-200	Reasoning with Data -REQUIRED	9
05-292	IDeATe: Learning in Museums	12
73-102	Principles of Microeconomics	9
80-130	Introduction to Ethics	9
80-136	Social Structure, Public Policy & Ethics	9
80-208	Critical Thinking	9
80-221	Philosophy of Social Science	9
80-242	Conflict and Dispute Resolution	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-270	Philosophy of Mind	9
80-271	Philosophy and Psychology	9
80-305	Choices, Decisions, and Games	9
80-330	Ethical Theory	9
80-348	Health, Human Rights, and International Development	9
80-405	Game Theory	9
80-447	Global Justice	9
84-104	Decision Processes in American Political Institutions	9
84-315	Contemporary Debates in Human Rights	9
85-102	Introduction to Psychology	9
85-211	Cognitive Psychology	9
85-219	Biological Foundations of Behavior	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9

85-261	Abnormal Psychology	9
88-120	Reason, Passion and Cognition	9

University Requirement (1 course, 3 units)

This is a mini-course, pass/no pass, to be completed in the first semester or online prior to the first semester.

99-101	Computing @ Carnegie Mellon	3

BXA Required Courses (5 courses, 36 units minimum)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer	9
or 52-291	BXA Seminar II: Transferring Knowledge	
52-391	BXA Junior Portfolio	0
52-392	BXA Seminar III: Deconstructing Disciplines	9
52-401	BXA Seminar IV: Capstone Project Research	9
52-402	BXA Seminar V: Capstone Project Production	9

Dietrich College of Humanities and Social Sciences Concentration

(9 courses, 81 units minimum)

BHA students declare an 81-unit DC concentration based on existing DC programs, through consultation with their BXA advisor and the DC concentration advisors. A completed DC Concentration Declaration form must be approved by the concentration advisor and submitted to the BXA office, by the end of the student's sophomore year.

Curriculum for several BHA DC concentration options are outlined below, though this list is not exhaustive of all concentrations possible in DC.

BHA students who are admitted as freshmen are undeclared until they have met with a concentration advisor and have submitted their signed Declaration form. BHA students who are admitted through internal transfer must have chosen a DC concentration at the time of their application (which serves as declaration). All BHA students wishing to change their DC concentration at any time following the initial declaration must meet with the advisor of their intended concentration area to complete a new Declaration form, which will be reviewed during the internal transfer application period.

Anthropology Concentration (81 units minimum)

The BHA concentration in Anthropology offers students training in ethnographic methods and in theoretical understandings of culture. Students examine the evolution, depth, and complexities of ethnography, and explore notions of "culture" in diverse settings, over time and across space. In today's world, students are increasingly aware of the importance of developing a sophisticated approach to culture and its articulation with changes in the domains of the arts, technology, economics, and politics. The BHA concentration in Anthropology provides students with the tools to link artistic practices to various aspects of globalization. It is highly recommended that Anthropology students study abroad in some capacity. There are three required courses for the concentration: 79-201 Introduction to Anthropology and 79-400 Global Studies Research Seminar, and one Methods course which may be satisfied by rotating options each semester. Students also choose 6 regional/topical courses (51 units). Demonstrating intermediate to advanced level proficiency in a language other than English is also crucial component of the concentration in Anthropology; all students are required to take at least two upper level (intermediate or above) language courses to satisfy this language pre-requisite requirement (which is in addition to required concentration courses).

Language Proficiency Requirement

Demonstrating intermediate to advanced level proficiency in a language other than English is a crucial component of the concentration in Anthropology. Normally this requirement can be satisfied by successfully completing a course conducted in the second language at the 300-level or above for French, German, Italian, or Spanish, or the fourth semester (Intermediate II) level or above for Arabic, Chinese, Japanese, or Russian. Comparable proficiency for other languages can be considered. Additional advanced cultural, historical, and literary study in the second language is strongly recommended. If needed these courses may be counted toward the BHA General Education Communicating: Language and Interpretations category.

Anthropology Required Introductory and Capstone Courses (2 courses, 21 units)

Students must earn a final grade of "C" or better for these courses to count toward the concentration.

79-201	Introduction to Anthropology	9
79-400	Global Studies Research Seminar	12

Required Anthropological Methods Course (1 course, 9 units)

Students must take one course in ethnographic, archaeological, or other anthropological methods selecting from the list below. Other courses may fulfill these requirements, with permission of the BHA Anthropology faculty advisor.

79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

Anthropological Perspectives (6 courses, 51 units minimum)

Students gain knowledge of specialized theoretical and regional topics by choosing 51 units (typically six courses) selecting from the list below.

57-306	World Music	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-224	Mayan America	9
79-235	Caribbean Cultures	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-275	Introduction to Global Studies	9
79-276	Beyond the Border	6
79-278	How (NOT) to Change the World	9
79-286	Archaeology: Understanding the Ancient World	6
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-314	The Politics and Culture of Memory	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-317	Art, Anthropology, and Empire	9
79-333	Sex, Gender & Anthropology	9
79-334	Climate Change and Climate Justice: Global Perspectives	6
79-342	Introduction to Science and Technology Studies	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-377	Food, Culture, and Power: A History of Eating	9

Note: Courses that count toward this category may be taken at another university, and the units transferred to the BHA concentration under the guidance of the BHA Anthropology faculty advisor.

Behavioral Economics, Policy & Organizations Concentration (81 units minimum)

Students in BEPO—the first and only major of its kind—will be uniquely trained in the integration of Economics and Psychology and will have a solid grounding in quantitative methods. The core includes courses in economics, psychology, behavioral economics, and quantitative methods. SDS offers the largest selection of behavioral economics courses anywhere in the world. Applied projects in courses will teach students how to collect original data, design field and laboratory experiments, analyze data, and develop interventions to improve economic outcomes and decisions. Students will be well equipped to enter a wide range of professions and graduate degree programs.

Quantitative Methods (3 courses, 27 units)

36-202	Statistics & Data Science Methods	9
88-251	Empirical Research Methods	9
88-252	Causal Inference in the Field	9

Economics Courses (2 courses, 18 units)

73-102	Principles of Microeconomics	9
73-160	Foundations of Microeconomics: Applications and Theory	9
or 73-230	Intermediate Microeconomics	

Psychology Courses (2 courses, 18 units)

88-120	Reason, Passion and Cognition (freshman or sophomore year)	9
88-302	Behavioral Decision Making	9

Behavioral Economics Courses (2 courses, 18 units)

88-360	Behavioral Economics	9
88-367	Behavioral Economics in the Wild	9

Cognitive Neuroscience Concentration (81 units minimum)

Cognitive neuroscience is a science concerned with discovering biological bases of psychological functions. It addresses questions of how behavior is produced by neural circuits of the brain and also how those neural circuits are in turn influenced by behavioral experiences. Students with a concentration in Cognitive Neuroscience are expected to learn about existing findings within the field and also to become proficient in how to conduct and analyze scientific investigations directed toward understanding the biological basis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analyses, and writing reports.

Introductory and Survey Coursework (4 courses, 36 units)

03-121	Modern Biology	9
03-363	Systems Neuroscience	9
85-219	Biological Foundations of Behavior	9
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	

Research Methods Training (2 courses, 18 units)

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	
85-314	Cognitive Neuroscience Research Methods *	9

* 85-310 Research Methods in Cognitive Psychology may be substituted if necessary.

Distribution Requirements (3 courses, 27 units)

Complete three courses with at least one from each category below.

Approaches to Cognitive Neuroscience:

15-386	Neural Computation	9
15-883	Computational Models of Neural Systems	12
36-746	Statistical Methods for Neuroscience and Psychology	12
85-345	Meaning in Mind and Brain	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-429	Cognitive Brain Imaging	9

Cognitive Neuroscience Electives:

03-133	Neurobiology of Disease	9
03-362	Cellular Neuroscience	9
03-364	Developmental Neuroscience	9
85-356	Music and Mind: The Cognitive Neuroscience of Sound	9
85-370	Perception	9
85-385	Auditory Perception: Sense of Sound	9
85-390	Human Memory	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-435	Neural and Cognitive Models of Adaptive Decisions	9
85-442	Health Psychology	9
85-501	Stress, Coping and Well-Being	9

Cognitive Science Concentration (81 units minimum)

The field of cognitive science has grown out of increasingly active interaction among psychology, linguistics, artificial intelligence, philosophy, and neuroscience. All of these fields share the goal of understanding intelligence. By combining these diverse perspectives, students of cognitive science are able to understand cognition at a deep level. Because this concentration is administered by the Psychology Department, it focuses on human cognition and the experimental study of the human mind as illuminated by the techniques of the above disciplines.

Pre-requisite Courses

15-112	Fundamentals of Programming and Computer Science	12
21-120	Differential and Integral Calculus	10-20
or 21-111 & 21-112	Differential Calculus and Integral Calculus	
21-127	Concepts of Mathematics	10

Statistics Course (1 course, 9 units)

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	

Computational/Cognitive Modeling Core (3 courses, 29 units minimum)

Complete two of the following courses:

15-122	Principles of Imperative Computation	10
15-150	Principles of Functional Programming	10
15-251	Great Ideas in Theoretical Computer Science	12

Plus one of the following courses:

85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-435	Neural and Cognitive Models of Adaptive Decisions	9

Cognitive Psychology Core (4 courses, 36 units)

85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	
85-310	Research Methods in Cognitive Psychology	9

Plus two of the following (one of which must be 85-3xx or 85-4xx):

85-219	Biological Foundations of Behavior	9
85-359	Introduction to Music Cognition Research	9
85-370	Perception	9
85-390	Human Memory	9
85-395	Applications of Cognitive Science	9
85-408	Visual Cognition	9
85-414	Cognitive Neuropsychology	9
85-421	Language and Thought	9
80-310	Formal Logic	9
80-314	Causal Discovery, Statistics, and Machine Learning	9
80-315	Modal Logic	9
80-381	Meaning in Language	9
80-383	Language in Use	9

Cognitive Science Elective (1 course, 9 units)

Choose one elective in consultation with your Cognitive Science Advisor.

Creative Writing Concentration (81 units minimum)

In the Creative Writing concentration, BHA students develop their talents in writing fiction, poetry, and other imaginative forms. While studying with faculty members who are practicing poets and prose writers, students read widely in literature, explore the resources of their imaginations, sharpen their critical and verbal skills, and develop a professional attitude toward their writing. The Creative Writing program is based on a conservatory model, made up of faculty and students who have an intense commitment to their work.

Students in the Creative Writing concentration are required to take two of the introductory Survey of Forms courses, ideally in their sophomore year. Choices include Poetry (76-265), Fiction (76-260), Screenwriting (76-269), and Nonfiction (76-261). In order to proceed into the upper level courses in the major (and in each of the genres), students must do well in these introductory courses (receive a grade of A or B). After completing the Survey of Forms courses, students take four workshops in fiction, poetry, screenwriting, or nonfiction. At least two of the workshops must be taken in a single genre. In the writing workshops, students develop their critical and verbal abilities through close writing and analysis of poems, stories, and other literary forms. Their work is critiqued and evaluated by peers and the faculty.

Survey of Forms Courses (2 courses, 18 units)

76-222	Creative Writing Matters -Fall, Freshman year (co-requisite: 76-101)	9
76-260	Survey of Forms: Fiction	9
76-261	Survey of Forms: Creative Nonfiction	9
76-265	Survey of Forms: Poetry	9
76-269	Survey of Forms: Screenwriting	9

Note: A student must receive a grade of A or B in the Survey of Forms class in a specific genre in order to be eligible to enroll in a workshop of that genre. A student who receives a grade of C in a Survey of Forms course may enroll in a related workshop only with the permission of the workshop professor. A student who receives a D or R in Survey of Forms may not take a workshop in that genre.

Creative Writing Workshops (4 courses, 36 units)

Complete four Creative Writing workshops, at least two in a single genre. Workshops in all genres may be taken more than once for credit.

76-365	Beginning Poetry Workshop	9
76-366	Essay Writing Workshop	9
76-460	Beginning Fiction Workshop	9
76-462	Advanced Fiction Workshop	9
76-464	Creative Nonfiction Workshop: Magazines and Journals	9
76-465	Advanced Poetry Workshop	9
76-469	Screenwriting Workshop: Screenwriting/ Television Writing	9
76-4xx	Elective Workshops (various forms)	9

English Electives (3 courses, 27 units)

Complete three courses from the English Department's offerings. Reading in Forms classes are recommended, as is 76-306 Editing and Publishing. Please consult the list of courses published each semester by the Department for current offerings. Students should discuss curriculum choices with the Creative Writing advisor to determine the best electives for their focus in Creative Writing.

Decision Science Concentration (81 units minimum)

Decision Science is grounded in theories and methods drawn from psychology, economics, philosophy, statistics, and management science. Courses in the BHA concentration in Decision Science cover the three aspects of decision science: (a) normative analysis, creating formal models of rational choice; (b) descriptive research, studying how cognitive, emotional, social, and institutional factors affect judgment and choice, and (c) prescriptive interventions, seeking to improve judgment and decision making. In addition to gaining a broad education in the principles of judgment and decision making, students with a concentration in Decision Science gain broadly applicable skills in research design and analysis. They also have the chance to think about and discuss decision making in many different areas.

Disciplinary Perspectives (5 courses, 48 units)

73-102	Principles of Microeconomics	9
85-102	Introduction to Psychology	9
88-120	Reason, Passion and Cognition (freshman or sophomore year)	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9

Research Methods (2 courses, 18 units)

36-202	Statistics & Data Science Methods	9
88-251	Empirical Research Methods	9

Electives (2 courses, 18 units)

Complete at least 18 units from the following categories of courses. The selected courses may be from one category or from any combination of categories. Note that not all elective courses are offered every year. At least one of these courses (9 units) must be a Department of Social and Decision Sciences course (88-xxx).

Biological and Behavioral Aspects of Decision Making:

85-350	Psychology of Prejudice	9
85-352	Evolutionary Psychology	9
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-442	Health Psychology	9
85-444	Relationships	9
85-446	Psychology of Gender	9
88-230	Human Intelligence and Human Stupidity	9
88-342	The Neuroscience of Decision Making	9
88-355	Social Brains: Neural Bases of Social Perception and Cognition	9
88-360	Behavioral Economics	9
88-365	Behavioral Economics and Public Policy	9
88-380	Dynamic Decisions	9

Managerial and Organizational Aspects of Decision Making:

70-311	Organizational Behavior	9
70-381	Marketing I	9
70-460	Mathematical Models for Consulting	9
88-150	Managing Decisions	9
88-221	Analytical Foundations of Public Policy	9
88-406	Behavioral Economics in Organizations	9
88-418	Domestic Negotiation	9
88-419	International Negotiation	9
88-444	Public Policy and Regulation	9
88-451/452	Policy Analysis Senior Project	12

Philosophical and Ethical Perspectives on Decision Making:

70-332	Business, Society and Ethics	9
80-208	Critical Thinking	9
80-221	Philosophy of Social Science	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-249	AI, Society, and Humanity	9
80-271	Philosophy and Psychology	9
80-305	Choices, Decisions, and Games	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9
88-275	Bubbles: Data Science for Human Minds	9
88-409	Behavioral Economics Perspectives on Ethical Issues	9

Economic and Statistical Methods for Decision Science:

70-374	Data Mining & Business Analytics	9
70-455	Modern Data Management	9
70-460	Mathematical Models for Consulting	9
73-265	Economics and Data Science	9
73-347	Game Theory for Economists	9
80-405	Game Theory	9

88-255	Strategic Decision Making: Cooperation and Competition in Social Interactions	9
88-300	Programming and Data Analysis for Social Scientists	9
88-360	Behavioral Economics	9
88-367	Behavioral Economics in the Wild	9

Decision Science and Public Policy:

84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-369	Decision Science for International Relations	9
88-221	Analytical Foundations of Public Policy	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-405	Risk Perception and Communication	9
88-444	Public Policy and Regulation	9
88-451/452	Policy Analysis Senior Project	12

Research Methods for Decision Science:

36-303	Sampling, Survey and Society	9
70-460	Mathematical Models for Consulting	9
85-310	Research Methods in Cognitive Psychology	9
88-252	Causal Inference in the Field	9
88-402	Modeling Complex Social Systems	9
88-435	Decision Science and Policy	9

Economics Concentration (81 units minimum)

The BHA concentration in Economics provides a solid understanding of economic theory and quantitative economic analysis. The core disciplinary sequences in economic theory and quantitative analysis are combined with calculus and data analysis to provide students with knowledge and skills that allow for creative problem-solving.

Mathematics Pre-requisites

These courses are not counted as part of your DC Concentration. It may be used to satisfy general education or free elective requirements.

21-120	Differential and Integral Calculus	10
21-256	Multivariate Analysis	9

Economic Theory Requirements (4 courses, 36 units)

73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

Quantitative Analysis Requirements (2 courses, 18 units)

These courses require 36-200 Reasoning with Data as a pre-requisite; 36-200 fulfills a general education Deciding requirement, as well.

73-265	Economics and Data Science	9
73-274	Econometrics I	9

Advanced Economics Electives (2 courses, 18 units)

Students must take two advanced elective courses. Advanced elective courses are those numbered 73-300 through 73-495, as well as courses designated by the program offered by other departments/programs. Additionally, students may work with their economics advisor to structure alternative sets of courses to meet these requirements based on their particular interests, subject to course availability.

Senior Work (1 course, 9 units)

73-497	Senior Project	9

Note: Students who have already taken 73-100 Principles of Economics should take 73-230 Intermediate Microeconomics and 73-240 Intermediate Macroeconomics for their Economic Theory Requirements. They will then take 27 units of Advanced Economics Electives.

Environmental & Sustainability Studies Concentration (81 units minimum)

The BHA concentration in Environmental & Sustainability Studies (ESS) focuses on human-environment interactions from a multitude of disciplinary perspectives. The curriculum draws on the expertise of faculty across several Carnegie Mellon colleges in order to provide students with the interdisciplinary background and skills necessary to understand environmental problems and the means to mitigate them. The curriculum is designed to help students apply social and scientific perspectives to environmental problems; to distinguish among scientific methods for evaluating environmental problems; to identify and assess sources of environmental data; and to identify environmental justice issues within the context of proposed policy solutions.

Environmental Core Course (1 courses, 9 units)

99-236	Introduction to Environmental Ideas	9

Scientific Foundation Course (1 courses, 9 units)

Take one of the following courses:

03-128	Biology for Life Special Topics (Fall 2019, Section A only)	9
09-105	Introduction to Modern Chemistry I	10
09-103	Atoms, Molecules and Chemical Change	9
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
33-115	Physics for Future Presidents	9
12-201	Geology	9

Environmental Electives (7 courses, 63 units)

Students must take seven elective courses addressing aspects of environment and sustainability chosen from the list below. Other courses may fulfill these requirements, with permission of the ESS concentration advisor. At least five Environmental Elective courses must come from Dietrich College departments.

73-427	Sustainability, Energy, and Environmental Economcs	9
76-319	Environmental Rhetoric	9
79-278	How (NOT) to Change the World	9
79-280	Coffee and Capitalism	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-289	Animal Planet: An Environmental History of People and Animals	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-334	Climate Change and Climate Justice: Global Perspectives	6
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9
80-244	Environmental Ethics	9
80-348	Health, Human Rights, and International Development	9
09-108	The Illusion and Magic of Food	6
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
12-201	Geology	9
51-377	Design Center: Sensing Environments	9
62-315	IDeATe: Shaping the Built Environment: Experiments in Geometry and Matter	Var.
70-376	Energy Systems	9

Ethics, History, & Public Policy Concentration (81 units minimum)

The BHA concentration in Ethics, History, & Public Policy (EHPP) provides students with a rigorous, interdisciplinary humanistic and social-scientific education. The concentration in EHPP encourages the development of a broad technical skill set that will benefit students in whatever career they ultimately choose to pursue. Students with a concentration in EHPP learn how to analyze and construct arguments; to evaluate evidentiary statements; to persuade people to agree with their particular claims; to conduct research under time and resource constraints; and to craft policies that address real world problems in a way that is sensitive both to history and competing sets of values. Comprised of courses in the departments of History, Philosophy, Economics, and Decision Science, the BHA concentration in EHPP encourages specialization, internship experiences, and research in a wide range of policy areas.

Foundations of Public Policy Requirement (1 course, 9 units)

Choose one 9-unit course from the list below.

73-102	Principles of Microeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-110	Foundations of Political Economy	9

History Core (3 courses, 27 units)

Choose one 9-unit course from each category below. (Students must earn a final grade of "C" or better for these courses to count toward the concentration).

Policy History:

79-300	Guns in American History: Culture, Violence, and Politics	9

U.S. History:

79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-249	20th & 21st Century U.S. History	9
79-320	Women, Politics, and Protest	9

Non-U.S. History:

Non-US Survey		
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-237	Comparative Slavery	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-307	Religion and Politics in the Middle East	9

Philosophy Core (3 courses, 27 units)

Choose one course from three of the four categories below. No more than 9 units at the 100-level may be counted toward this requirement.

Ethics:

80-130	Introduction to Ethics	9
80-330	Ethical Theory	9

Political Philosophy:

80-135	Introduction to Political Philosophy	9
80-335	Social and Political Philosophy	9

Foundations of Social Science:

80-221	Philosophy of Social Science	9
80-321	Causation, Law, and Social Policy	9
80-324	Philosophy of Economics	9

Applied Philosophy:

80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

Elective Courses (2 courses, 18 units)

Choose any two courses from any of the following categories.

Engineering and Public Policy:

19-424	Energy and the Environment	9

Business:

70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-332	Business, Society and Ethics	9
70-364	Business Law	9
70-365	International Trade and International Law	9
70-430	International Management	9

Economics:

73-352	Public Economics	9
73-359	Benefit-Cost Analysis	9
73-365	Firms, Market Structures, and Strategy	9
73-372	International Money and Finance	9
73-408	Law and Economics	9
73-476	American Economic History	9

English:

76-492	Rhetoric of Public Policy	9

History:

79-206	Crime and Punishment in Early Modern Europe	9
79-228	The Civil Rights Movement and the World	9
79-233	The United States and the Middle East since 1945	9
79-234	Technology and Society	9
79-242	African American History: Reconstruction to the Present	9
79-247	African Americans, Imprisonment, and the Carceral State	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-298	Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal	6
79-299	From Newton to the Nuclear Bomb: History of Science, 1750-1950	9
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-305	Moneyball Nation: Data in American Life	9
79-310	Modern U. S. Business History: 1870 to the Present	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-320	Women, Politics, and Protest	9
79-322	Stalin and the Great Terror	9
79-325	U.S. Gay and Lesbian History	6
79-330	Medicine and Society	9
79-331	Body Politics: Women and Health in America	9
79-336	Oil & Water: Middle East Perspectives	6
79-338	History of Education in America	9
79-339	Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)	6
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6

79-342	Introduction to Science and Technology Studies	9
79-343	Education, Democracy, and Civil Rights	9
79-349	United States and the Holocaust	6
79-370	Disasters in American History (2):Epidemics & Fires	6
79-371	African American Urban History	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-397	Environmental Crises and the City	6

Philosophy:

80-256	Modern Moral Philosophy	9
80-305	Choices, Decisions, and Games	9
80-405	Game Theory	9

Institute for Politics and Strategy:

84-310	International Political Economy	9
84-380	Grand Strategy in the United States	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6

Social and Decision Sciences:

88-223	Decision Analysis	12
88-281	Topics in Law: 1st Amendment	9
88-444	Public Policy and Regulation	9

Note: Other elective courses may be approved at the discretion of the EHPP faculty advisor. A list of these courses must be filed in the BXA office.

Film & Visual Media Studies (81 units minimum)

The BHA concentration in Film & Visual Media Studies trains students through a combination of coursework in visual media, film history and analysis, screenwriting, and production of film and other visual media. This concentration offers a comprehensive education in film and visual media, from theoretical framing and historical-cultural contextualization to training skills in both creating and analyzing film, and developing a complex blend of creative, professional, and technical competencies. CMU's Department of English is an ideal home for the Film & Visual Media Studies concentration due to the department’s combination of creative writers, film and media studies scholars, film makers, digital humanities, and visual communication researchers.

Introductory Courses (2 courses, 18 units)

76-239	Introduction to Film Studies	9
76-259	Introduction to Film History	9

Production Course (1 course, 9 units)

76-292	Film Production	9

Screenwriting Course (1 course, 9 units)

76-269	Survey of Forms: Screenwriting	9

Topics in Film & Visual Media Studies (2 courses, 18 units)

76-312	Crime and Justice in American Film	9
76-338	The American Cinema	9
76-339	Topics in Film and Media: Hollywood vs. the World (Can be taken more than once.)	9
76-353	Transnational Feminisms: Fiction and Film	9
76-367	Fact Into Film: Translating History into Cinema	9
76-377	Shakespeare and Film	9
76-438	The Wire: Crime, Realism, and Long-Form TV	9
76-439	Seminar in Film and Media Studies: Class, Race, & Gender in Film	9
76-448	Shakespeare on Film	9
76-449	Race and Media	9
79-214	Paris in Revolt: History, Literature, Film	6
79-225	West African History in Film	9
79-306	Fact into Film: Translating History into Cinema	9
79-308	Crime and Justice in American Film	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-326	German History through Film	9
79-339	Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)	6
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6
79-341	The Cold War in Documents and Film	9
82-215	Arab Culture Through Film & Literature	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-284	Multicultural Pittsburgh: A Creative Media Exploration of Cmmnty, Lang & Identit	9
82-296	A Century of Russian Film	9
82-355	Tpcs in Hispanic Std: Beyond the Film Screen: The Hispanic World Through Film	9

Courses in Film Production, Screenwriting, Digital Media, Literature & Culture, and/or Film & Visual Media Studies (3 courses, 27 units)

Students may take an additional three Dietrich College courses for a minimum of 27 units of courses offered in the categories listed above. Because there are dozens of options available, including many of the courses listed above, please consult with the Department of English academic advisor for guidance.

German Studies Concentration (81 units minimum)

A BHA concentration in German Studies promotes not just language proficiency but also an understanding of German culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level, or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Intermediate level proficiency in German. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores.

Core Courses in German (3 courses, 27 units)

82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-323	Germany, Austria and Switzerland in the 20th Century	9
82-327	The Emergence of the German Speaking World	9

Note: A 400-level course may be substituted with the major advisor's approval.

Core Courses in Modern Languages (2 courses, 12 units)

Complete one 9 unit course plus the Senior Seminar (3 units).

82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
82-580	Senior Seminar in Modern Languages	3

Note: In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in German Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

German Studies and Interdisciplinary Electives (5 courses, 42 units minimum)

Complete four courses from German Electives and one course from Interdisciplinary Electives, or a minimum of three courses from German Electives and two courses from Interdisciplinary Electives in consultation with the German advisor.

German Electives:

82-420	The Crucible of Modernity:Vienna 1900	9
82-425	Topics in German Literature and Culture	9
or 82-426	Topics in German Literature and Culture	
82-427	Nazi and Resistance Culture	9
82-428	History of German Film	9
82-505	Undergraduate Internship	Var.
82-521	Special Topics: German Studies	Var.
or 82-522	Special Topics: German Studies	

Interdisciplinary Electives:

This list is compiled from possibilities such as but not limited to the following. Students should consult OLR and the advisor for the most up to date interdisciplinary electives appropriate for the German Studies curriculum. Courses may be suggested to the advisor for approval as a substitute. Note that not all courses are offered each semester.

Architecture		
48-338	European Cities in the XIX Century: Planning, Architecture, Preservation	9
48-340	Modern Architecture and Theory 1900-1945	9
48-350	Postwar Modern Architecture and Theory	9
English		
76-239	Introduction to Film Studies	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6
76-483	Corpus Analysis in Rhetoric	9
History		
79-205	20th Century Europe	9
79-256	Sex, Guns, and Rock 'n Roll: Youth Rebellion in 1960s & 1970s Europe	6
79-349	United States and the Holocaust	6
Modern Languages		
82-227	Germany & the European Union	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-427	Nazi and Resistance Culture	9
82-428	History of German Film	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
Music		
57-306	World Music	9
Philosophy		
80-180	Nature of Language	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-256	Modern Moral Philosophy	9
80-275	Metaphysics	9
80-280	Linguistic Analysis	9
80-281	Language and Thought	9
80-380	Philosophy of Language	9
Psychology		
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

Global Studies Concentration (81 units minimum)

The BHA concentration in Global Studies is designed for students interested in humanistic approaches to understanding past and present processes of globalization. Participating faculty in the departments of History, Modern Languages, and English conduct research in Africa, Asia, Europe, Latin America, the Middle East, and the Pacific. The rigorous yet flexible Global Studies curriculum combines anthropology, history, literary and cultural studies, and advanced language training in order to help students make sense of complex interactions among global processes, regional and local cultures, and societal structures. BHA concentration students in Global Studies develop a broad understanding of their prospects and responsibilities as citizens of the world confronting challenging contemporary problems.

There are two required courses for the concentration: Introduction to Global Studies (79-275) and Global Studies Research Seminar (79-400). Students also choose among several courses focused on theory, research methods, transnational histories, and regional/national histories and cultures.

In addition to coursework at Carnegie Mellon, BHA students with a concentration in Global Studies are encouraged to incorporate a semester of study abroad into their course of study in order to immerse themselves in society different from their own with unfamiliar cultural practices, language, and history.

Students should consult frequently with the BHA advisor, the Global Studies academic program manager, and the faculty director who will help students to craft a coherent course of study on specific topics and/or regions that may lead to the capstone research project (79-400 Global Studies Research Seminar), the BXA capstone project (52-401 and 52-402) or a Dietrich College senior honors thesis (https://www.cmu.edu/dietrich/students/undergraduate/programs/senior-honors). The faculty director and the academic program manager will also work with students to connect their academic interests and their participation in student organizations and/or organizations based in Pittsburgh with transnational reach.

Global Studies Introductory and Capstone Courses (2 courses, 21 units)

Students must earn a final grade of "C" or better for these courses to count toward the concentration.

79-275	Introduction to Global Studies	9
79-400	Global Studies Research Seminar	12

Language Proficiency Requirement

Demonstrating intermediate to advanced level proficiency in a language other than English is a crucial component of the concentration in Global Studies. Normally this requirement can be satisfied by successfully completing a course conducted in the second language at the 300-level or above for French, German, Italian, or Spanish, or the fourth semester (Intermediate II) level or above for Arabic, Chinese, Japanese, or Russian. Comparable proficiency for other languages can be considered. Additional advanced cultural, historical, and literary study in the second language is strongly recommended. If needed these courses may be counted toward the BHA General Education Communicating: Language and Interpretations category. Additional courses in a language other than English may also be counted as Global Studies transnational, global, regional courses or Global Studies electives as appropriate.

Theoretical and Topical Core Courses (2 courses, 18 units)

To gain a solid foundation in the theories, methods, and analytical topics underpinning the concentration in Global Studies, students select 18 units (typically two courses) from the core courses listed below. Students must earn a final grade of "C" or better in these courses to fulfill the theoretical and topical core course requirement.

79-201	Introduction to Anthropology	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-278	How (NOT) to Change the World	9
79-280	Coffee and Capitalism	9
79-289	Animal Planet: An Environmental History of People and Animals	9
79-314	The Politics and Culture of Memory	9
79-315	Thirsty Planet: The Politics of Water in Global Perspective	9
79-317	Art, Anthropology, and Empire	9
79-318	Sustainable Social Change: History and Practice	9
79-377	Food, Culture, and Power: A History of Eating	9
79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-383	The History of Capitalism	9

Transnational, Global, and Regional Courses (3 courses, 27 units)

To gain insight into how complex transnational and global processes shape and are affected by local, national, and regional dynamics, students will select 27 units (typically three courses) from any subcategories below.

Transnational and Global Courses:

76-353	Transnational Feminisms: Fiction and Film	9
76-384	Race, Nation, and the Enemy	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
79-224	Mayan America	9
79-233	The United States and the Middle East since 1945	9
79-237	Comparative Slavery	9
79-276	Beyond the Border	6
79-280	Coffee and Capitalism	9
79-282	Europe and the World Since 1800	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-333	Sex, Gender & Anthropology	9
79-350	Early Christianity	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-385	Out of Africa: The Making of the African Diaspora	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
82-283	Language Diversity & Cultural Identity	9
82-304	The Francophone World	9
82-345	Introduction to Hispanic Literary & Cultural Studies	9
84-322	Nonviolent Conflict and Revolution	9
84-326	Theories of International Relations	9
84-370	Global Nuclear Politics	9
84-389	Terrorism and Insurgency	9

Regional Courses:

Africa

79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-291	Globalization in East African History	6
79-386	Entrepreneurs in Africa, Past, Present and Future	9

Eastern and Southern Asia and the Pacific

79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-264	Tibet and China: History and Propaganda	6
88-411	Rise of the Asian Economies	9

Europe

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-208	Witchcraft and Witch-Hunting	9
79-268	World War I: The Twentieth Century's First Catastrophe	9
79-270	Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present	6
79-323	Family, Gender, and Sexuality in European History, 500-1800	9
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-415	Topics in French and Francophone Studies	9
82-441	Studies in Peninsular Literature and Culture	9

The Middle East

79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-307	Religion and Politics in the Middle East	9
79-336	Oil & Water: Middle East Perspectives	6
79-398	Documenting the 1967 Arab-Israeli War	9
84-323	War and Peace in the Contemporary Middle East	9

The Americas

79-223	Mexico: From the Aztec Empire to the Drug War	9
79-235	Caribbean Cultures	9
82-245	New Directions in Hispanic Studies	9
82-343	Latin America Language and Culture	9
82-451	Studies in Latin American Literature and Culture	9
82-455	Topics in Hispanic Studies	9
82-456	Topics in Hispanic Studies	9
84-308	Political Economy of Latin America	9

Electives (2 courses, 15 units minimum)

Students are required to take an additional 15 units (typically two courses) of electives, selected from one or both of the subcategories below. "Theoretical and Topical Core Courses" and "Transnational, Global, and Regional Courses" listed above that are not used to fulfill those requirements may be counted as electives in addition to the courses listed below.

Global Studies offers students the opportunity to gain credit for a 9 unit elective while gaining first-hand experience interning with Pittsburgh-based organizations that work across borders. 79-506 Global Studies Internship is offered every semester and students should register for the course after consulting with the academic advisor and faculty director. The faculty director will assist students with matching their interests to local organizations and identifying an on-site supervisor available to collaborate in the ongoing and final evaluation of the student's work.

Thematic Courses:

57-306	World Music	9
70-365	International Trade and International Law	9
76-241	Introduction to Gender Studies	9
76-386	Language & Culture	9
76-449	Race and Media	9
76-450	Law, Culture, and the Humanities	9
76-468	Space and Mobilities	9
79-228	The Civil Rights Movement and the World	9
79-281	Introduction to Religion	9
79-286	Archaeology: Understanding the Ancient World	6
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-316	Photography, the First 100 Years, 1839-1939	9
79-324	#MeToo: Naming and Resisting Gender Violence	6
79-330	Medicine and Society	9
79-343	Education, Democracy, and Civil Rights	9
79-349	United States and the Holocaust	6
79-397	Environmental Crises and the City	6
80-244	Environmental Ethics	9
80-335	Social and Political Philosophy	9
82-215	Arab Culture Through Film & Literature	9
82-541	Special Topics: Hispanic Studies	Var.
84-275	Comparative Politics	9
84-310	International Political Economy	9
84-318	Politics of Developing Nations	9
84-362	Diplomacy and Statecraft	9

Nation-based Courses:

79-214	Paris in Revolt: History, Literature, Film	6
79-216	Genghis Khan and the Mongol Empire	3
79-256	Sex, Guns, and Rock 'n Roll: Youth Rebellion in 1960s & 1970s Europe	6
79-257	Germany and the Second World War	9
79-258	French History: From the Revolution to De Gaulle	9
79-259	France During World War II	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9

79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-269	Russian History: From Socialism to Capitalism	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-320	Women, Politics, and Protest	9
79-322	Stalin and the Great Terror	9
79-326	German History through Film	9
79-331	Body Politics: Women and Health in America	9
79-392	America at War: From Vietnam to Afghanistan	9
82-253	Korean Culture Through Film	9
82-254	World of Korea, Then and Now	9
82-273	Introduction to Japanese Language and Culture	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-294	Topics in Russian Language and Culture	9
82-303	Introduction to French Culture	9
82-305	French in its Social Contexts	9
82-333	Introduction to Chinese Language and Culture	Var.
82-342	Spain: Language and Culture	9
82-344	U.S. Latinos: Language and Culture	9
82-361	Italian Language and Culture I	9
82-420	The Crucible of Modernity:Vienna 1900	9
82-425	Topics in German Literature and Culture	9
82-427	Nazi and Resistance Culture	9
82-428	History of German Film	9
82-433	Topics in Contemporary Culture of China	9
82-434	Studies in Chinese Traditions	9
82-440	Studies in Chinese Literature & Culture	9
82-473	Topics in Japanese Studies	9

Global Systems & Management (81 units minimum)

The BHA concentration in Global Systems & Management (GSM) is intended for students wishing to develop skills essential for participating in emerging opportunities in global business systems, systems development, product development and global project management. GSM exposes students to contemporary issues and practices facing organizations, managers and individuals working on a global scale across political, cultural and temporal boundaries. GSM presents an opportunity for students to learn about being part of an organization that works globally with its employees, business partners, customers and supply chains.

Students will learn about global project management, outsourcing and cross-cultural communications from theoretical and practical viewpoints. An organized elective structure enables students to tailor the concentration to reflect their specific interests.

Required Information Systems Course (1 course, 9 units)

Students must earn a final grade of "C" or better for these courses to count toward the concentration.

67-329	Contemporary Themes in Global Systems	9

Required Communications Courses (2 courses, 18 units)

Students must take two courses from the list below. Other courses may fulfill these requirements, with permission of the BHA GSM advisor.

05-341	Organizational Communication	9
70-321	Negotiation and Conflict Resolution	9
70-340	Business Communications	9
70/85/88-341	Team Dynamics and Leadership	9
70-342	Managing Across Cultures	9
70-350	Acting for Business	9
70-483	Advertising and Marketing Communications	9
73-341	Within the Firm: Managing through Incentives	9
76-270	Writing for the Professions	9
76-318	Communicating in the Global Marketplace	9
76-386/786	Language & Culture	9
76-428	Visual Verbal Communication	9
85-375	Crosscultural Psychology	9
88-419	International Negotiation	9

Global Systems Management Electives (6 courses, 54 units)

Students distribute their electives between the two categories listed below. Students must complete a minimum of 18 units in each category.

Humans, Heritage and Culture:

82-215	Arab Culture Through Film & Literature	9
82-238	Topics in Chinese Culture	9
82-253	Korean Culture Through Film	9
82-254	World of Korea, Then and Now	9
82-273	Introduction to Japanese Language and Culture	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-303	Introduction to French Culture	9
82-304	The Francophone World	9
82-305	French in its Social Contexts	9
82-311	Advanced Arabic I	9
82-312	Advanced Arabic II	9
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-323	Germany, Austria and Switzerland in the 20th Century	9
82-333	Introduction to Chinese Language and Culture	Var.
82-342	Spain: Language and Culture	9
82-343	Latin America Language and Culture	9
82-345	Introduction to Hispanic Literary & Cultural Studies	9
82-361	Italian Language and Culture I	9
82-362	Italian Language and Culture II	9
82-399	Special Topics: Russian in Context	9
82-400	Russian Studies Topics	6
82-415/416	Topics in French and Francophone Studies	9
82-425	Topics in German Literature and Culture	9
82-433	Topics in Contemporary Culture of China	9
82-441	Studies in Peninsular Literature and Culture	9
82-450	Advanced Research in Hispanic Language & Culture	9
82-456	Topics in Hispanic Studies	9
82-473/474	Topics in Japanese Studies	9
84-275	Comparative Politics	9
84-312	Gender and Development in Sub-Saharan Africa	6
84-315	Contemporary Debates in Human Rights	9
84-389	Terrorism and Insurgency	9

Note: History Department courses numbered 79-200 or above covering international/regional studies that are outside of U.S. history may also count in this category, with prior approval of the GSM advisor.

International Management:

19-411	Global Competitiveness: Firms, Nations and Technological Change	9
70-342	Managing Across Cultures	9
70-364	Business Law	9
70-365	International Trade and International Law	9
70-430	International Management	9
70-480	International Marketing	9
73-341	Within the Firm: Managing through Incentives	9
73-372	International Money and Finance	9
84-310	International Political Economy	9
84-311	International Development: Theory and Praxis	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-320	Domestic Politics and International Affairs	9
84-321	Autocrats and Democrats	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-362	Diplomacy and Statecraft	9

84-363	Comparative Legal Systems	9
84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-405	The Future of Warfare	9
84-414	International and Subnational Security	9
88-411	Rise of the Asian Economies	9
88-418	Domestic Negotiation	9

International Relations and Politics Concentration (81 units minimum)

Offered through the Institute for Politics and Strategy (IPS), the International Relations and Politics (IRP) BHA concentration analyzes the role of politics at the national, regional, international, and transnational levels; examines political and institutional arrangements within and among these levels; and investigates the grand strategy of nation-states.

Statesmen, scholars, and policy makers often define grand strategy as the combination of diplomatic, economic, military, and political factors used by leaders to defend their respective nation-states. The IRP concentration investigates the way in which leaders and citizens construct grand strategy and national security policy more generally; the impact of domestic and international forces on states' security and economic policies; and the significance of alliances, coalitions, and international institutions for world politics. Although the study of grand strategy and political institutions is the flagship initiative of the concentration, students are also able to study the effects of culture, economics, and society on the international system through a rich set of elective courses.

Thinking systematically about international and domestic politics is the core objective of the IRP concentration. The concentration is rooted in the discipline of political science but also utilizes the interdisciplinary strengths of decision science, economics, and political history. Thus, students pursuing this concentration will use the analytic tools of game theory, economic and statistical analysis, qualitative analysis, rational choice theory, and theories of behavioral decision making as they study alliances, coalitions, institutions, and political strategy.

The name of the concentration signifies that those studying IRP learn about international relations and domestic politics from the standpoint of the discipline of political science. Also, the concentration taps into and contributes to CMU's strengths in other social sciences that combine analytical and empirical methods. IRP includes an innovative initiative that incorporates decision science in international relations. It enables students to apply the burgeoning science of judgment and decision making to understanding political actors' strategies and foibles, the strengths and weaknesses of formal methods of policy analysis (e.g., cost, risk, benefit, analysis), and the factors shaping public responses to politics and policies.

Recognizing the influence of language and culture on politics, students are required to complete the intermediate (200) level, or its equivalent, in a modern language other than English. Advanced-level study is strongly encouraged.

Open to all Carnegie Mellon undergraduates, the Carnegie Mellon University Washington Semester Program (CMU/WSP) allows students to study public policy and intern in Washington for one semester. Courses taken through CMU/WSP will count toward the elective sequence in politics and public policy for the IRP concentration.

IRP students interested in developing their research skills are encouraged to apply for a research position with the Center for International Relations and Politics or work directly with a member of the IPS faculty. Students are also encouraged to join student organizations focused on domestic or international politics. Becoming involved in the Institute for Politics and Strategy, as well as attending lectures and events sponsored by the Center for International Relations and Politics will provide additional opportunities for students. Students are also encouraged to submit their work for publication in the CIRP Journal (https://www.cmu.edu/ir/cirp-journal), an online and print publication that analyzes current problems facing the United States and the international system.

Pre-requisite

84-110	Foundations of Political Economy	9
or 73-102	Principles of Microeconomics	

Core Courses (6 courses, 54 units)

84-104	Decision Processes in American Political Institutions	9
84-265	Political Science Research Methods	9
84-275	Comparative Politics	9
84-326	Theories of International Relations	9
84-369	Decision Science for International Relations	9
84-450	Policy Forum	6
36-202	Statistics & Data Science Methods	9

Language Requirement

BHA IRP students are required to complete the intermediate (200) level or the equivalent in a modern language other than English. The language requirement may be satisfied by the BHA General Education Modern Languages requirement if the 200-level is reached. Advanced level study is strongly encouraged.

Electives (3 courses, 21 units minimum)

International Relations and Politics BHA students will either:

Option 1

Take 21 units (three courses) from the elective lists below. At least two courses must be from the Institute for Politics and Strategy (84-xxx).

Grand Strategy and Political Institutions		
66-221	Topics of Law: Introduction to Intellectual Property Law	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-298	Mobile Phones & Social Media in Development & Human Rights: A Critical Appraisal	6
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
80-135	Introduction to Political Philosophy	9
80-321	Causation, Law, and Social Policy	9
80-335	Social and Political Philosophy	9
84-250	Writing for Political Science and Policy	9
84-309	Political Behavior	9
84-319	U.S. Foreign Policy and Interventions in World Affairs	9
84-320	Domestic Politics and International Affairs	9
84-321	Autocrats and Democrats	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	6
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-363	Comparative Legal Systems	9
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-366	The American Presidency	9
84-370	Global Nuclear Politics	9
84-372	Space and National Security	9
84-373	Emerging Technologies and the Law	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-387	Technology and Policy of Cyber War	9
84-388	Concepts of War and Cyber War	6
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	6
84-402	Judicial Politics and Behavior	6
84-405	The Future of Warfare	9
84-414	International and Subnational Security	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

Economics and Society		
19-452	EPP Projects	12
70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-430	International Management	9
73-103	Principles of Macroeconomics	9
73-328	Health Economics	12
73-332	Political Economy	9
79-386	Entrepreneurs in Africa, Past, Present and Future	9

80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-249	AI, Society, and Humanity	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
84-308	Political Economy of Latin America	9
84-310	International Political Economy	9
84-311	International Development: Theory and Praxis	9
84-312	Gender and Development in Sub-Saharan Africa	6
84-313	International Organizations and Law	9
84-315	Contemporary Debates in Human Rights	9
84-318	Politics of Developing Nations	9
88-411	Rise of the Asian Economies	9

International Cultures

76-318	Communicating in the Global Marketplace	9
76-386	Language & Culture	9
79-205	20th Century Europe	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-224	Mayan America	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-233	The United States and the Middle East since 1945	9
79-257	Germany and the Second World War	9
79-259	France During World War II	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	6
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-275	Introduction to Global Studies	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-291	Globalization in East African History	6
79-307	Religion and Politics in the Middle East	9
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-314	The Politics and Culture of Memory	9
79-318	Sustainable Social Change: History and Practice	9
79-320	Women, Politics, and Protest	9
79-338	History of Education in America	9
79-342	Introduction to Science and Technology Studies	9
79-343	Education, Democracy, and Civil Rights	9
79-377	Food, Culture, and Power: A History of Eating	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-385	Out of Africa: The Making of the African Diaspora	9
79-398	Documenting the 1967 Arab-Israeli War	9
85-375	Crosscultural Psychology	9
300 or 400- level language course		

Option 2

Complete their electives via the Carnegie Mellon University Washington Semester Program (CMU/WSP) Politics and Public Policy elective sequence.

The Washington Semester Program (CMU/WSP) Politics and Public Policy Elective Sequence includes:

84-450-84-450	Policy Forum-Policy Forum (This course will count as the Policy Forum Core Course Requirement)	12
84-360	CMU/WSP Internship Seminar	12
84-3xx	CMU/WSP Elective Seminars (Take 24 units from the elective list below)	24

CMU/WSP Politics and Public Policy Elective Seminars

84-330	The Shading of Democracy: The Influence of Race on American Politics	6
84-331	Money, Media, and the Power of Data in Decisionmaking	6
84-332	Effects of US Policy on Businesses: Perspectives of Asian Americans	6
84-333	Power and Levers for Change in Washington, DC	12
84-334	Presidential Power in a Constitutional System	6
84-336	Implementing Public Policy: From Good Idea To Reality	12
84-337	Biomedical Science Research, Policy, and Governance	6
84-340	Making Change: How Organized Interests Work in Washington	12
84-343	Language and Power: How to Understand and Use Political Speech	6
84-346	Legal Issues in Public Administration	6
84-348	Advocacy, Policy and Practice	6

Japanese Studies Concentration (81 units minimum)

A BHA concentration in Japanese Studies promotes not just language proficiency but also an understanding of Japanese culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level, or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Low-intermediate level proficiency in Japanese. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level) or exemption based on internal placement test scores.

Core Courses in Japanese (4 courses, 39 units)

82-272	Intermediate Japanese II *	12
82-273	Introduction to Japanese Language and Culture	9
82-371	Advanced Japanese I	9
82-372	Advanced Japanese II	9

* Students who place out of 82-272 Intermediate Japanese II must take 12 units chosen from the Japanese Studies and Interdisciplinary Electives category below.

Core Courses in Modern Languages (2 courses, 12 units)

Complete one 9 unit course plus the Senior Seminar (3 units).

82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
82-580	Senior Seminar in Modern Languages	3

Japanese Studies and Interdisciplinary Electives (4 courses, 30 units minimum)

Complete three courses from Japanese Electives and one course from Interdisciplinary Electives, or a minimum of two courses from Japanese Electives and two courses from Interdisciplinary Electives in consultation with the Japanese advisor. One course from Interdisciplinary Electives must be chosen from the History department courses, orwith permission of the advisor students are encouraged to complete at least one Japanese history course at the University of Pittsburgh, one in Japan when they study abroad, or in a summer program at any other university.

Japanese Electives

82-373	Structure of the Japanese Language	9
82-374	Technical Japanese	9
82-473/474	Topics in Japanese Studies (Students may repeat with new topics.)	9
82-505	Undergraduate Internship	Var.
82-571/572	Special Topics in Japanese Studies	Var.

Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their advisor for the most up to date interdisciplinary electives appropriate for the Japanese Studies curriculum. Courses may be suggested to the advisor for approval as a substitute.

English		
76-239	Introduction to Film Studies	9
76-386	Language & Culture	9
76-387	Writing in the Disciplines	6
History		
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-275	Introduction to Global Studies	9
Modern Languages		
82-234	Topics in Chinese History	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-280	Learning About Language Learning	9
82-281	Tutoring for Community Outreach	Var.
82-282	Community Service Learning	Var.
82-283	Language Diversity & Cultural Identity	9
82-373	Structure of the Japanese Language	9
82-374	Technical Japanese	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Understanding Second Language Fluency	9
82-480	Social and Cognitive Aspects of Bilingualism	9
Music		
57-306	World Music	9
Philosophy		
80-180	Nature of Language	9
80-280	Linguistic Analysis	9
80-380	Philosophy of Language	9
Psychology		
85-375	Crosscultural Psychology	9
85-421	Language and Thought	9

Linguistics Concentration (81 units minimum)

The BHA concentration in Linguistics combines courses from the departments of English, Modern Languages, Philosophy and Psychology and the Language Technologies Institute. Linguistics is the study of human language, and it encompasses a broad spectrum of research questions, approaches and methodologies. Some linguists are concerned with the cognitive aspects of language learning, production and comprehension; some are concerned with language as a social and cultural phenomenon; others engage in the analysis of linguistic form and meaning, some from a functional and others from a formal perspective. There are also computational approaches to linguistics with both applied and theoretical goals.

Introductory Course (1 course, 9 units)

80-180	Nature of Language	9

Linguistics Core (2 courses, 18 units)

Take one course each in two of the following three areas.

Sounds:

80-282	Phonetics and Phonology I	9

Structure:

80-280	Linguistic Analysis	9
80-285	Natural Language Syntax	9

Meaning:

80-381	Meaning in Language	9
80-383	Language in Use	9

Extended Core (3 courses, 27 units)

Choose three courses from Extended Core or additional courses from the Linguistics Core above.

80-283	It Matters How You Say It	9
80-284	Invented Languages	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: Transcription and Analysis	9
80-382	Phonetics and Phonology II	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9

Elective Courses (3 courses, 27 units)

Take three additional electives. These can be additional courses from the Core or Extended Core courses listed above, the electives list below, or any other course which must be approved by the Director as a linguistics elective. Listed below are the additional electives taught on a regular basis. Additional appropriate courses are offered irregularly or on a one-off basis. The Director will provide students with a list of possible electives each semester, and will assist students in selecting electives that are consistent with their goals and interests. A list of these courses must be filed in the BXA office.

Philosophy:

80-380	Philosophy of Language	9
80-484	Language and Thought	9

English:

76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-385	Introduction to Discourse Analysis	9
76-386	Language & Culture	9
76-389	Rhetorical Grammar	9

Modern Languages:

82-283	Language Diversity & Cultural Identity	9
82-305	French in its Social Contexts	9
82-373	Structure of the Japanese Language	9
82-383	Second Language Acquisition: Theories and Research	9
82-585	Topics in Second Language Acquisition	9

Psychology:

85-354	Infant Language Development	9
85-421	Language and Thought	9

Language Technologies Institute:

11-411	Natural Language Processing	12
11-423	ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.	12
11-492	Speech Processing	12
11-661	Language and Statistics	12
11-722	Grammar Formalisms	12

Philosophy Concentration (81 units minimum)

The BHA Concentration in in Philosophy provides students with a broad humanities education and sharpens their analytical skills. We encourage, but do not require, students to choose a thematic concentration through their electives. Sample curricula emphasizing Pre-Law, Metaphysics and Epistemology, Ethics and Social Philosophy, and Philosophy of Mind are suggested below. However, alternative emphases can be proposed and approved by the Director.

In any of the areas listed, substitutions of courses that cohere with a student’s interest may be allowed with approval from the Advisor.

Introduction to Philosophy (1 course, 9 units)

80-100	Introduction to Philosophy	9

Area 1: Values and Normative Theory (1 course, 9 units)

80-130	Introduction to Ethics	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-248	Engineering Ethics	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
80-430	Ethics and Medical Research	9
80-447	Global Justice	9

Area 2: Philosophy of Mind/Language/Metaphysics (1 course, 9 units)

80-180	Nature of Language	9
80-270	Philosophy of Mind	9
80-271	Philosophy and Psychology	9
80-276	Philosophy of Religion	9
80-280	Linguistic Analysis	9
80-281	Language and Thought	9
80-282	Phonetics and Phonology I	9
80-283	It Matters How You Say It	9
80-284	Invented Languages	9
80-327	Philosophy of Neuroscience	9
80-371	Philosophy of Perception	9
80-380	Philosophy of Language	9
80-381	Meaning in Language	9
80-382	Phonetics and Phonology II	9
80-383	Language in Use	9
80-384	Linguistics of Turkic Languages	9
80-580	Seminar on the Philosophy of Language	9

Area 3: Logic/Philosophy of Mathematics (1 course, 9 units)

80-110	Nature of Mathematical Reasoning	9
80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
80-312	Mathematical Revolutions	9
80-315	Modal Logic	9
80-411	Proof Theory	9
80-413	Category Theory	9
80-513	Seminar on Philosophy of Mathematics	9
80-514	Categorical Logic	9

Area 4: Epistemology/Metaphysics (1 course, 9 units)

80-150	Nature of Reason	9
80-201	Knowledge and Justified Belief	9
80-208	Critical Thinking	9
80-214	Computing, AI, and Philosophy	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-222	Measurement and Methodology	9
80-223	Causality and Probability	9
80-226	Revolutions in Science	9
80-305	Choices, Decisions, and Games	9
80-321	Causation, Law, and Social Policy	9
80-322	Philosophy of Physics	9
80-323	Philosophy of Biology	9
80-324	Philosophy of Economics	9
80-327	Philosophy of Neuroscience	9
80-405	Game Theory	9
80-515	Seminar on the Foundations of Statistics	9
80-516	Causality and Learning	Var.
80-520	Seminar on Philosophy Science	9
80-521	Seminar on Formal Epistemology	Var.

Area 5: History of Philosophy (1 course, 9 units)

80-150	Nature of Reason	9
80-226	Revolutions in Science	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-252	Kant	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism	9
80-256	Modern Moral Philosophy	9
80-257	Nietzsche	9
80-261	Experience, Reason, and Truth	9
80-362	Russell	9
80-363	19th Century Foundations of Science	9

Area 6: Electives (3 courses, 27 units)

Three other philosophy courses, or appropriate courses from other departments, with the permission of the Director.

Professional Writing Concentration (81 units minimum)

Professional Writing combines liberal and professional education with a strong foundation in rhetorical studies. The concentration in Professional Writing has a strong career orientation and is specifically designed to prepare students for successful careers as writers and communications specialists in a range of fields: publishing, government, journalism, the non-profit sector, education, public and media relations, corporate communications, advocacy writing, and the arts. The concentration is designed to develop articulate and reflective communications professionals with both the skills needed to enter and negotiate current work contexts (including writing for the web and other digital media) and the analytic and problem-solving skills needed to understand and keep pace with cultural and technological change.

Prerequisite English Elective

Students with a concentration in Professional Writing must complete one perquisite course from the English Department's offerings, which focuses on the relationships between texts and their cultural and historical contexts. The course must be at or above the 200 level. 76-270 Writing for the Professions, 76-272 Language in Design, and 76-271 Introduction to Professional and Technical Writing may not count as English electives. Appropriate courses are advertised every semester in the English department's "What Counts for What" publication.

Foundation Courses (5 courses, 39 units)

76-26x	Survey of Forms (Nonfiction, Fiction, Poetry, or Screenwriting)	9
76-271	Introduction to Professional and Technical Writing	9
76-300	Professional Seminar	3
76-373	Argument	9
76-390	Style	9

Rhetoric/Language Studies Course (1 course, 9 units)

Students with a concentration in Professional Writing complete one course from designated Rhetoric courses offered and advertised each semester by the English Department. Rhetoric courses focus on understanding the role of language and language practices in both personal and professional contexts. Courses emphasize the relationships between texts and their contexts and pay particular attention to textual features, meaning, processes of reading and writing, and the ways in which language practices vary over time and across situations and cultures. The courses also equip students with explicit techniques for analyzing, understanding, and exploring language practices. The Rhetoric/Language Studies courses may also be taken as part of the concentration requirements for three additional, Advanced Writing/Rhetoric courses and include but are not limited to the following list.

76-319	Environmental Rhetoric	9
76-351	Rhetorical Invention	9
76-355	Leadership, Dialogue, and Change	9
76-386	Language & Culture	9

76-388	Coding for Humanists	9
76-396	Non-Profit Message Creation	9
76-415	Mediated Power and Propaganda	9
76-419	Media in a Digital Age	9
76-428	Visual Verbal Communication	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-484	Discourse Analysis	9
76-491	Rhetorical Analysis	9

Advanced Writing/Rhetoric Courses (3 courses, 27 units minimum)

Students with a concentration in Professional Writing complete three Advanced Writing/Rhetoric courses at the 300- or 400-level. Options for these courses include all of the Rhetoric/Language Studies courses listed above plus the writing-focused courses listed below. Additional courses that fulfill these requirements are advertised on a semester-by-semester basis. For help in choosing which of the possible options are most appropriate for various professional goals – journalism, writing for new media, editing and publishing, public relations/corporate communications, or science and technical writing – consult your English Department advisor. All students with a concentration in PW, regardless of their career focus, are encouraged to take 76-391 Document & Information Design and 76-487 Web Design to extend their skills in writing for print to include information design for digital media. Both courses focus on the role of the writer in these specializations and provide lab instruction in the relevant software and related computer skills.

76-301	Internship	Var.
76-302	Global Communication Center Practicum	6
76-319	Environmental Rhetoric	9
76-351	Rhetorical Invention	9
76-355	Leadership, Dialogue, and Change	9
76-372	News Writing	9
76-375	Magazine Writing	9
76-386	Language & Culture	9
76-389	Rhetorical Grammar	9
76-391	Document & Information Design	12
76-396	Non-Profit Message Creation	9
76-425	Science in the Public Sphere	9
76-428	Visual Verbal Communication	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-484	Discourse Analysis	9
76-487	Web Design	12
76-491	Rhetorical Analysis	9

English Elective (1 course, 6 units minimum)

Students with a concentration in Professional Writing complete one additional course from the English Department's offerings. This course should be one that focuses on the relationships between texts and their cultural and historical contexts. Courses in literature, cultural studies, rhetoric, and media studies that meet this requirement are advertised on a semester-by-semester basis. The English Elective may be any course offered by the Department with the exception of 76-270 Writing for the Professions and 76-272 Language in Design, both of which are designed for non-majors and overlap with 76-271 Introduction to Professional and Technical Writing.

Psychology Concentration (81 units minimum)

Psychology is a science that embraces both biological and social sciences. It is a science concerned with establishing principles and laws regarding the ways in which people think, feel, and behave through the scientific study of human behavior. Students with a concentration in Psychology are expected not only to learn about findings already established by psychologists, but also to become proficient in the investigation and analysis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analyses, and writing reports.

Breadth Courses (4 courses, 36 units)

To gain familiarity with the breadth of the field of Psychology, students take 85-102 Introduction to Psychology and three survey courses.

Required Intro Course:

85-102	Introduction to Psychology	9

Survey Courses:

85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artifical Intelligence	
85-219	Biological Foundations of Behavior	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9

Research Methods and Statistics (2 courses, 18 units)

Students complete one course in Research Methods (9 units). The corresponding survey course is a prerequisite for this course.

85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

The following Statistics course is a prerequisite for all the Research Methods courses. This Statistics course counts toward the Psychology concentration.

36-309	Experimental Design for Behavioral & Social Sciences -Fall	9
or 85-309	Experimental Design for Behavioral & Social Sciences - Psychology	

Advanced Courses (3 courses, 27 units)

Complete any three advanced courses or seminars in Psychology numbered higher than 85-341 (excepting 85-480, 85-482, 85-484, 85-505, 85-506, 85-507, 85-508).

Social & Political History Concentration (81 units minimum)

The BHA concentration in Social & Political History focuses on new ways to understand the past and new ways to use what we know, as well as on connections between past and present and on how historical knowledge facilitates understanding of social, cultural, and policy change. The History concentration emphasizes empirical methods and conceptual analysis, as well as specific research skills relevant to many types of jobs and further professional training. The History concentration combines a structured sequence of courses, training in research methods, theoretical concepts, and analytical writing skills, plus a considerable array of electives.

The BHA concentration in Social & Political History emphasizes broad-based, cumulative knowledge and interpretive skills in the study of the past. Offerings at the 200- and 300-level are designed to allow maximum flexibility in meeting requirements and maximum choice in focusing on particular themes, places, or eras. Upper-level courses aim to give students majoring in History more time together in smaller classes and more experience working with primary and secondary sources. The senior capstone seminar, Advanced Studies in History, provides training and experience in conducting original research and in interpretive, analytical writing—skills that prepare graduates for professional careers as well as for graduate or law school.

Required History Courses (2 courses, 21 units)

Students must earn a final grade of "C" or better for these courses to count toward the concentration.

79-200	Introduction to Historical Research & Writing - Sophomore or Junior year	9
79-420	Historical Research Seminar -Fall, Senior year	12

Required Survey Courses (2 courses, 18 units)

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	Social and Political Change in 20th Century Central and Eastern Europe	9
79-205	20th Century Europe	9
79-206	Crime and Punishment in Early Modern Europe	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9

79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-233	The United States and the Middle East since 1945	9
79-235	Caribbean Cultures	9
79-240	Development of American Culture	9
79-241	African American History: Africa to the Civil War	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-249	20th & 21st Century U.S. History	9
79-258	French History: From the Revolution to De Gaulle	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-269	Russian History: From Socialism to Capitalism	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-307	Religion and Politics in the Middle East	9
79-320	Women, Politics, and Protest	9

Social & Political History Elective Courses (5 courses, 42 units minimum)

A minimum of 42 additional History units must be approved with the History advisor. Any History courses not fulfilling another major requirement may be chosen as an elective.

79-257	Germany and the Second World War	9
79-268	World War I: The Twentieth Century's First Catastrophe	9
79-276	Beyond the Border	6
79-278	How (NOT) to Change the World	9
79-280	Coffee and Capitalism	9
79-299	From Newton to the Nuclear Bomb: History of Science, 1750-1950	9
79-300	Guns in American History: Culture, Violence, and Politics	9
79-302	Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems	6
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-305	Moneyball Nation: Data in American Life	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-314	The Politics and Culture of Memory	9
79-316	Photography, the First 100 Years, 1839-1939	9
79-317	Art, Anthropology, and Empire	9
79-318	Sustainable Social Change: History and Practice	9
79-322	Stalin and the Great Terror	9
79-323	Family, Gender, and Sexuality in European History, 500-1800	9
79-331	Body Politics: Women and Health in America	9
79-338	History of Education in America	9
79-339	Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)	6
79-345	Roots of Rock & Roll	9
79-346	American Political Humor	9
79-350	Early Christianity	9
79-352	Christianity Divided: The Protestant and Catholic Reformations, 1450-1650	9
79-359	Truth, Lies, and Propaganda: A Historical Inquiry	9
79-363	The Rise of Modern Golf, 1860 to the Present	6
79-371	African American Urban History	9
79-372	Cities, Technology, and the Environment	6
79-377	Food, Culture, and Power: A History of Eating	9
79-381	Energy and Empire: How Fossil Fuels Changed the World	9
79-385	Out of Africa: The Making of the African Diaspora	9
79-395	The Arts in Pittsburgh	9
79-396	Music and Society in 19th and 20th Century Europe and the U.S.	9

Students may satisfy the elective requirements in SPH with up to 27 units of the following courses offered by other departments in Dietrich College:

73-476	American Economic History	9
76-230	Literature & Culture in the 19th Century: Environmentalisms	9
76-239	Introduction to Film Studies	9
76-295	Topics in Russian Language & Culture: 20th Century Russian Masterpieces	9
76-449	Race and Media	9
80-135	Introduction to Political Philosophy	9
80-226	Revolutions in Science	9
80-335	Social and Political Philosophy	9
82-208	Topics in European Studies	9
82-245	New Directions in Hispanic Studies	9
82-247	The Hispanic World: History, Culture and Globalization	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-327	The Emergence of the German Speaking World	9
82-420	The Crucible of Modernity:Vienna 1900	9
82-427	Nazi and Resistance Culture	9
84-275	Comparative Politics	9
84-308	Political Economy of Latin America	9
84-322	Nonviolent Conflict and Revolution	9
84-324	The Future of Democracy	6
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-364	Comparative Presidential Behavior: Leadership, Personality, and Decision Making	9
84-366	The American Presidency	9
84-380	Grand Strategy in the United States	9
84-386	The Privatization of Force	9
84-389	Terrorism and Insurgency	9
85-380	In Search of Mind: The History of Psychology	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

Statistics Concentration (81 UNITS MINIMUM)

In the BHA concentration in Statistics, students develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, students with a BHA concentration in Statistics gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration.

Mathematics Pre-requisites

These courses are not counted as part of your DC Concentration. They may be used to satisfy general education or free elective requirements.

21-120	Differential and Integral Calculus	10
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	
or 21-242	Matrix Theory	

Note: 21-240, 21-241, 21-242 must be completed before taking 36-401 Modern Regression. 21-241 and 21-242 are intended only for students with a very strong mathematical background.

Statistics Pre-requisite

This course is not counted as part of your DC Concentration. It fulfills the BHA General Education Statistics Requirement.

36-200	Reasoning with Data	9

Statistics Core (6 courses, 54 units)

36-202	Statistics & Data Science Methods	9
or 36-290	Introduction to Statistical Research Methodology	
36-225	Introduction to Probability Theory	9

36-226	Introduction to Statistical Inference	9
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Special Topics and Electives (3 courses, 27 units)

Students must take a total of three courses from Special Topics (numbered 36-46x) and Statistics Electives listed below. Students will consult with the Statistics advisor to select the Special Topics and Electives courses that best fit for their areas of interest.

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-490	Undergraduate Research	9
36-46x	Special Topics (topics and offerings vary)	9
36-497	Corporate Capstone Project	9

Statistics & Machine Learning (81 UNITS MINIMUM)

In the BHA concentration in Statistics & Machine Learning, develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, students with a BHA concentration in Statistics & Machine Learning gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. This program is geared towards students interested in statistical computation, data science, or “Big Data” problems.

Mathematics and Computer Science Pre-requisites

These five courses are not counted as part of your DC Concentration. They may be used to satisfy general education or free elective requirements.

21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	10
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	
or 21-242	Matrix Theory	
15-112	Fundamentals of Programming and Computer Science	12

Note: 21-240, 21-241, 21-242 must be completed before taking 36-401 Modern Regression. 21-241 and 21-242 are intended only for students with a very strong mathematical background.

Statistics Core (5 courses, 45 units)

36-225	Introduction to Probability Theory	9
36-226	Introduction to Statistical Inference	9
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Data Analysis Electives (1 course, 9 units)

Students must take one course from the Statistics Electives listed below. Students will consult with the Statistics advisor to select the Special Topics and Electives courses that best fit for their areas of interest.

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-46x	Special Topics (topics and offerings vary)	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Machine Learning Core (2 courses, 22 units)

15-122	Principles of Imperative Computation	10
10-301	Introduction to Machine Learning	12

Machine Learning Elective (1 course, 9 units minimum)

Students must take one course from the ML Electives listed below. Students will consult with the Statistics & Machine Learning advisor to choose an elective that best fits their area of interest. This course may have additional pre-requisites. Keep in mind this is not an exhaustive list and other applicable courses can be reviewed to be approved as an ML elective – please speak with your Statistics & Machine Learning advisor about this.

10-405	Machine Learning with Large Datasets (Undergraduate)	12
or 10-605	Machine Learning with Large Datasets	
10-703	Deep Reinforcement Learning & Control	12
10-707	Topics in Deep Learning	12
11-411	Natural Language Processing	12
11-441	Machine Learning for Text Mining	9
11-661	Language and Statistics	12
or 11-761	Language and Statistics	
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
15-387	Computational Perception	9
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
or 16-720	Computer Vision	

Technical Writing Concentration (81 units minimum)

The concentration in Technical Writing is specifically designed to prepare students for successful careers involving scientific, technical, and computer-related communication, including writing and designing for digital media. Technical communicators develop and design web sites, explain science and technology to the public, develop print and multimedia materials, develop information management systems, design and deliver corporate training, and develop support systems for consumer products ranging from software for word processing or personal finances to complex data management systems. The Technical Writing concentration includes with a common core of foundation courses in print and on-line communication as well as a set of prerequisites in math, statistics, and computer programming.

Students with a TW concentration take two Theory/Specialization courses specific to either the Technical Communication or the Scientific and Medical Communication track. In addition, students in the SMC track take two courses in the natural sciences or engineering relevant to their areas of interest, while TC students take two electives in management, technology, and social issues.

Prerequisite Courses

21-111	Differential Calculus	10
or 21-112	Integral Calculus	
or 21-120	Differential and Integral Calculus	
or 21-127	Concepts of Mathematics	
15-110	Principles of Computing (recommended for SMC-track students)	10
or 15-112	Fundamentals of Programming and Computer Science	
(recommended for TC-track students)		

Technical Writing Core Courses (6 courses, 54 units)

76-26x	Survey of Forms (Nonfiction, Fiction, Poetry, or Screenwriting)	9
76-271	Introduction to Professional and Technical Writing	9
76-300	Professional Seminar	3
76-390	Style	9
76-391	Document & Information Design	12
76-487	Web Design	12

Theory/Specialization Courses (2 courses, 18 units minimum)

Complete two courses to deepen your area of specialty in Technical Communication (TC) or Scientific and Medical Communication (SMC). One course must be chosen from among courses designated as Recommended Options. Check with the English department each semester for additional options.

Recommended Options:

76-319	Environmental Rhetoric	9
76-361	Corpus Rhetorical Analysis	9
76-388	Coding for Humanists	9
76-395	Science Writing	9
76-425	Science in the Public Sphere	9

76-428	Visual Verbal Communication	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-491	Rhetorical Analysis	9
76-494	Healthcare Communications	9

Additional Options include but are not limited to the following:

76-301	Internship	Var.
76-302	Global Communication Center Practicum	6
76-318	Communicating in the Global Marketplace	9
76-319	Environmental Rhetoric	9
76-325	Intertextuality	9
76-351	Rhetorical Invention	9
76-355	Leadership, Dialogue, and Change	9
76-359	User Experience Methods for Documents	9
76-360	Literary Journalism Workshop	9
76-361	Corpus Rhetorical Analysis	9
76-372	News Writing	9
76-375	Magazine Writing	9
76-378	Literacy: Educational Theory and Community Practice	9
76-386	Language & Culture	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-391	Document & Information Design	12
76-395	Science Writing	9
76-396	Non-Profit Message Creation	9
76-419	Media in a Digital Age	9
76-420	The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process	9
76-425	Science in the Public Sphere	9
76-428	Visual Verbal Communication	9
76-472	Topics in Journalism: Storytelling in a Digital Age	9
76-474	Software Documentation	9
76-475	Law, Performance, and Identity	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-484	Discourse Analysis	9
76-487	Web Design	12
76-491	Rhetorical Analysis	9
39-605	Engineering Design Projects	12

Electives (1 course, 9 units)

Students with a TW concentration take one course outside of English to deepen their area of specialty in their track. Typically, students in the SMC track select courses in the natural sciences, psychology, and social and decision sciences, or (for example) healthcare-related courses in the Heinz School. Students in the TC track typically select courses from engineering, design, HCI, computer science, math or statistics. Students should work with their faculty advisor to select courses that are meaningful for their track.

College of Fine Arts Concentration

(number of courses vary, 108 units minimum)

BHA students choose one of the following concentrations:

- Architecture (108 units)
- Art (108 units)
- Design (108 units)
- Drama (108 units)
- Music (108 units)

ARCHITECTURE CONCENTRATION (108 UNITS MINIMUM)

Architecture Required Courses (7 courses, 52 units minimum)

48-100	Architecture Design Studio: Foundation I -Fall, Freshman year	10-15
or 48-095	Spatial Concepts for Non-Majors	
62-122	Digital Media I -Fall, Freshman year	6
62-125	Drawing I -Fall, Freshman year	6
62-123	Digital Media II -Spring, Freshman year	6
62-126	Drawing II -Spring, Freshman year	6
48-240	Historical Survey of World Architecture and Urbanism I -Spring, Freshman year	9
48-241	Modern Architecture -Fall, Sophomore year	9

Architecture Electives (56 units minimum)

A minimum of **56** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office.

ART CONCENTRATION (108 UNITS MINIMUM)

Concept Studios (2 courses, 20 units)

Complete two courses:

60-101	Concept Studio: The Self and the Human Being	10
60-201	Concept Studio: Space and Time	10
60-202	Concept Studio: Systems and Processes	10
60-280	Introduction to Contextual Practice	10

Media Studios (3 courses, 30 units minimum)

Complete three courses. 3D mini courses count as half a course:

60-150	2D Media Studio: Drawing	10
60-160	2D Media Studio: Imaging	10
60-131	3D Media Studio I (mini-1)	5
60-132	3D Media Studio I (mini-2)	5
60-133	3D Media Studio II (mini-3)	5
60-134	3D Media Studio II (mini-4)	5
60-250	2D Media Studio: Painting	10
60-251	2D Media Studio: Print Media	10
60-110	Electronic Media Studio: Introduction to the Moving Image	10
60-210	Electronic Media Studio: Introduction to Interactivity	10-12
or 60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	

Advanced Studios (4 courses, 40 units)

Complete four courses. Courses may be offered in the fall and/or spring. Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired.

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) *		10
Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) *		10
Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) *		10
Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) *		10
60-499	Studio Independent Study (one only)	10

* Courses offered intermittently; speak with a BXA advisor to determine course availability.

Critical Studies (2 courses, 18 units)

60-205	Critical Theory in Art III -Fall	9
60-206	Critical Theory in Art IV -Spring	9

Note: Critical Theory I & II are strongly recommended.

Review Requirement (complete 2 required reviews, 0 units)

A review is required at the end of the sophomore and senior years. Pass/no pass only.

60-200	Sophomore Review -Spring	0
60-400	Senior Review -Fall	0

DESIGN CONCENTRATION (108 UNITS MINIMUM)

Design Required Courses (13 courses, 95 units)

51-101	Studio: Survey of Design (Fall, Freshman year)	10
51-121	Visualizing (Fall, Freshman year)	10
51-171	Placing (Fall, Freshman year)	10
51-102	Design Lab (Spring, Freshman year)	10
51-122	Collaborative Visualizing (Spring, Freshman year)	10
51-172	Systems (Spring, Freshman year)	9
Choose Two Studios (Fall, Sophomore year):		4.5+4.5
51-225	Communications Studio I: Understanding Form & Context	4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	
Choose Two Corresponding Labs (Fall, Sophomore year):		4.5+4.5
51-227	Prototyping Lab I: Communications	4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	
51-271	How People Work (Fall, Sophomore year)	9
51-371	Futures I (Fall, Junior year or later)	4.5
51-373	Futures II (Fall, Junior year or later)	4.5

Design Electives (13 units)

A minimum of **13** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

DRAMA CONCENTRATION (108 UNITS MINIMUM)

Options available in the following areas: 1) Design, 2) Directing, 3) Dramaturgy, 4) Production Technology and Management

Note: There is no BHA Acting or Musical Theatre option.

Required Courses for All Concentration Options (5 courses, 20 units)

54-175-54-176	Conservatory Hour-Conservatory Hour (1 unit each)	2
54-177	Foundations of Drama I	6
54-281	Foundations of Drama II (prerequisite: 54-177)	6
54-381	Special Topics in Drama: History, Literature and Criticism	6

Work with Drama Faculty Option Coordinator to Approve Concentration Option (**88** units minimum):

Design Required Courses (2 courses, 26 units)

54-151-54-152	Stagecraft-Stagecraft (13 units + 13 units)	26

A minimum of **62** additional Design units must be approved by the Design faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Directing Required Courses (10 courses, 52 units)

54-121-54-122	Directing I: Sources-Directing I: Sources	18
54-221-54-222	Directing II: Fundamentals-Directing II: Fundamentals	18
54-159-54-159	Production Practicum-Production Practicum (two times, 12 units total)	12
54-517	Director's Colloquium (four times, 4 units total)	1

A minimum of **36** additional Directing units must be approved by the Directing faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (9 courses, 53 units minimum)

54-109	Dramaturgy 1: Approaches to Text	9
54-184	Dramaturgy 2: Introduction to Production Dramaturgy	9
54-121	Directing I: Sources	9
54-159-54-159	Production Practicum-Production Practicum (two times, 12 units total)	12
54-200-54-200	Dramaturgy Forum-Dramaturgy Forum -Fall (minimum of two; every semester it is offered while enrolled)	2
54-xxx	Dramaturgy 3, 4, 5 or 6 (minimum of two; all four if enrolled as BXA for six semesters or more)	18

A minimum of **29** additional Dramaturgy units must be approved by the Dramaturgy faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Production Technology and Management Required Courses (2 courses, 26 units)

54-151-54-152	Stagecraft-Stagecraft (13 units + 13 units)	26

A minimum of **62** additional PTM units must be approved by the PTM faculty option coordinator. A list of these selected courses must be filed in the BXA office.

MUSIC CONCENTRATION (108 UNITS MINIMUM)

Options available in the following areas: 1) Music Performance (instrumental, piano, organ, voice), 2) Composition 3) Musicology, 4) Audio Recording & Production 5) Sound Theory & Practice

Required Course for All Concentration Options (1 course, 9 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	

Work with Music Advisor to Approve Concentration Option (**99** units minimum):

Music Performance and Composition Required Courses (12 courses, 76 units)

57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Musicology Required Courses (8 courses, 45 units)

57-283	Music History I (co-requisite: 57-190)	9
57-284	Music History II (co-requisite: 57-289)	9
57-285	Music History III (co-requisite: 57-290)	9
57-189	Introduction to Repertoire and Listening for Musicians	3
57-190	Repertoire and Listening for Musicians I	3
57-289	Repertoire and Listening for Musicians II	3

57-290	Repertoire and Listening for Musicians III	3
57-611	Independent Study in History	6

Choose **36** units from:

57-209	The Beatles	9
57-306	World Music	9
57-404	String Quartet: A Social History	9
57-405	Concerto: Virtuosity and Contrast	9
57-409	Puccini's Operas	9
57-427	Advanced Seminar in Film Musicology	9
57-476	How Music Works: An Affective History	6
57-477	Music of the Spirit	6
57-478	Survey of Historical Recording	6
57-480	History of Black American Music	6
57-485	History of the Symphony	9

A minimum of **18** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Audio Recording & Production Required Courses (7 courses, 40 units)

57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Choose **59** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-275	History of Sound Design	3
54-666	Production Audio	6
57-344	Experimental Sound Synthesis	9
57-421	The Exploded Ensemble	6
57-425	Expanded Music Performance	9
57-427	Advanced Seminar in Film Musicology	9
57-478	Survey of Historical Recording	6
57-622	Independent Study in Sound Recording Production	3
60-131	3D Media Studio I	5
60-210	Electronic Media Studio: Introduction to Interactivity	10

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Sound Theory & Practice Required Courses (7 courses, 47 units)

57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
18-090	Twisted Signals: Multimedia Processing for the Arts	10
57-911	Music Since 1945	9
57-616	Independent Study in Sound Studies	9

Choose **52** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music (pre-requisite: 15-112)	9
15-323	Computer Music Systems and Information Processing (pre-requisite: 15-122)	9
33-114	Physics of Musical Sound	9
57-337	Sound Recording	6
57-343	Interdisciplinary Studies in Listening, Culture, and Technology	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music (pre-requisite: 57-101 or 57-171)	6
57-421	The Exploded Ensemble	6
57-425	Expanded Music Performance	9
57-438	Multitrack Recording	9
57-478	Survey of Historical Recording	6
57-829	Contemporary Soundscapes	9
60-131	3D Media Studio I	5
60-210	Electronic Media Studio: Introduction to Interactivity	10

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 9 courses, 78 units)

Take any Carnegie Mellon course. Many BHA students use their electives to broaden or deepen their concentrations. A maximum of 9 units of physical education and/or military science may be counted toward this requirement. Physical education and military science courses will not be calculated in a student's QPA.

Bachelor of Science and Arts Degree Program

Carnegie Mellon University recognizes that there are students who are naturally gifted in both the fine arts and the natural sciences or mathematics. In order to accommodate students who want to pursue an education simultaneously in these areas, we offer a degree that combines the strengths of the College of Fine Arts (CFA) and the Mellon College of Science (MCS). The intercollege degree, called the Bachelor of Science and Arts (BSA), is a rigorous program that offers a unique group of qualified students the opportunity to develop their talents and interests in an area of the fine arts and an area of the natural sciences or mathematics.

The BSA curriculum is divided into three parts: 1) BSA General Education coursework, 2) CFA concentration coursework, and 3) MCS concentration coursework.

The BSA Degree Program is governed by faculty and administrators from both colleges and led by the director of the BXA Intercollege Degree Programs. The director and associate director of the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and MCS. Students receive extensive advising support. Each student has two additional academic advisors: an advisor in the admitting school of CFA for their fine arts concentration and an advisor in MCS for their natural sciences/mathematics concentration. This network of advisors guides each student through their curriculum.

BSA Curriculum

	Units
I. BSA General Education	**129**
II. MCS Concentration	**114-134**
III. CFA Concentration	**108**
IV. Free Electives	**9-29**
Total BSA Degree Requirements	**380**

BSA General Education

(18 courses, 129 units minimum)

- Mathematics (2 courses, 20 units, 21-120 and 21-122 or 21-124 required)
- Science (3 courses, 31 units, 03-121, 09-105, and 33-111 or 33-151 required)
- First-year Courses (2 courses, 12 units, 76-101 and 99-101 required)
- ENGAGE (3 courses, 3 units)
- Cultural/Global Understanding (1 course, 9 units)
- Humanities and Social Sciences (2 courses, 18 units)
- BXA Required Courses (5 courses, 36 units minimum, 52-190 or 52-291, 52-391, 52-392, 52-401, 52-402)

Technical Breadth Requirements (5 courses, 51 units)

As a 21st Century practicing scientist or mathematician, our graduates will work with others from a variety of technical backgrounds. Therefore, all of our students will be broadly trained within the technical fields of science and math. Students will fulfill this training by completing five (5) introductory technical courses in the Mellon College of Science at Carnegie Mellon University.

A student must take the five (5) courses listed below. AP/IB/Cambridge credit may be used to fulfill some of these requirements, but STEM electives must be taken at CMU or at another university for transfer credit to reach the total of five (5) Technical Breadth courses. A list of STEM electives can be found in the MCS general education requirements (p.).

Mathematics (2 courses, 20 units)

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	

Science (3 courses, 31 units)

03-121	Modern Biology	9
09-105	Introduction to Modern Chemistry I	10
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	

Nontechnical Breadth Requirements (8 courses, 42 units)

MCS aspires for all of our undergraduates to leave our campus with a strong sense of personal integrity, social responsibility, ethics, working with diverse others, global engagement, and personal health and well-being. The following non-technical breadth requirements will require students to develop a personalized plan for their course selection and meta-curricular participation to maximize their CMU experience. Our graduates will be well trained to be life-long and life-wide learners that will lead the scientific community and the world at large.

All candidates for BSA degree must complete the following non-technical breadth requirements:

First-year Courses (2 courses, 12 units)

76-101	Interpretation and Argument	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106 & 76-107 & 76-108	Writing about Literature, Art and Culture and Writing about Data and Writing about Public Problems	
All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html		
99-101	Computing @ Carnegie Mellon	3

ENGAGE (3 courses, 3 units)

The ENGAGE courses are self-directed learning opportunities (using the MyCORE online platform) designed to enhance students' engagement with wellness and community service. Choose three courses from the list below:

38-110	ENGAGE in Service	1
38-230	ENGAGE in Wellness: Looking Inward	1
38-330	ENGAGE in Wellness: Looking Outward	1
38-430	ENGAGE in Wellness: Looking Forward	1

Cultural/Global Understanding (1 course, 9 units)

Cultural or global understanding course(s) may be taken at any time. Nine (9) or more units from the following group of courses will fulfill this requirement. Any student who finds an appropriate Carnegie Mellon course not on the list below that might fulfill this requirement should contact their academic advisor to review the course description to determine if it can be substituted. Cultural and global understanding courses that are taken while studying abroad can be used to fulfill this category. In addition, transfer courses will also be considered for this category. However, this course requirement cannot be satisfied with AP/IB/Cambridge exam credit.

57-173	Survey of Western Music History	9
57-209	The Beatles	9
57-306	World Music	9
70-342	Managing Across Cultures	9
76-221	Books You Should Have Read by Now: 16th & 17th C. Pop Culture	9
76-227	Comedy	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
76-386	Language & Culture	9
79-104	Global Histories	9
79-201	Introduction to Anthropology	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-205	20th Century Europe	9
79-210	Identity, Nationhood, and State	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	Origins of the Arab-Israeli Conflict, 1880-1948	9
79-230	Arab-Israeli Conflict Since 1948	9
79-232	Arabian Peninsula Environmental History	9
79-233	The United States and the Middle East since 1945	9
79-235	Caribbean Cultures	9
79-240	Development of American Culture	9
79-241	African American History: Africa to the Civil War	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-265	Russian History: From the First to the Last Tsar	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9

79-275	Introduction to Global Studies	9
79-307	Religion and Politics in the Middle East	9
79-345	Roots of Rock & Roll	9
79-350	Early Christianity	9
79-377	Food, Culture, and Power: A History of Eating	9
80-100	Introduction to Philosophy	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism	9
80-276	Philosophy of Religion	9
82-xxx	Any course from Modern Languages	

Humanities and Social Sciences (2 courses, 18 units)

To fulfill this requirement, students must complete a minimum of two (2) nontechnical courses totaling at least 18 units in the Tepper School of Business and/or the Dietrich College of Humanities and Social Sciences. Courses counted toward the Cultural/Global Understanding requirement, and 76-101, do not count toward this requirement.

Check our web site for courses from DC, CFA, and Tepper that may NOT be used (http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html) to satisfy this requirement because they are too technical in nature, plus a list of courses in other colleges (including SCS, CIT, Tepper, and Heinz College) that do satisfy (http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html) this requirement.

BXA Required Courses (5 courses, 36 units minimum)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer	9
or 52-291	BXA Seminar II: Transferring Knowledge	
52-391	BXA Junior Portfolio	0
52-392	BXA Seminar III: Deconstructing Disciplines	9
52-401	BXA Seminar IV: Capstone Project Research	9
52-402	BXA Seminar V: Capstone Project Production	9

Mellon College of Science Concentration

(number of courses vary, 114-134 units)

BSA students declare one of the following concentrations, through consultation with their BXA advisor and the MCS concentration advisors. A completed MCS Concentration Declaration form must be approved by the concentration advisor and submitted to the BXA office, by the end of the student's first year.

- Biological Sciences (114 units)
- Chemistry (121 units)
- Mathematical Sciences (123 units)
- Neurobiology (114 units)
- Physics (134 units)

BSA students who are admitted as freshmen are undeclared until they have met with a concentration advisor and have submitted their signed Declaration form. BSA students who are admitted through internal transfer must have chosen an MCS concentration at the time of their application (which serves as declaration). All BSA students wishing to change their MCS concentration at any time following the initial declaration must meet with the advisor of their intended concentration area to complete a new Declaration form, which will be reviewed during the internal transfer application period.

Biological Sciences Concentration (114 units minimum)

Biological Sciences Required Courses (11 courses, 96 units minimum)

03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics (co-requisite: 03-343)	9
03-231	Honors Biochemistry - Spring, Sophomore year	9
03-320	Cell Biology - Fall, Junior year	9
03-343	Experimental Techniques in Molecular Biology - Fall, Junior year	12
09-106	Modern Chemistry II	10
09-207	Techniques in Quantitative Analysis	9
09-208	Techniques for Organic Synthesis and Analysis	9
or 03-344	Experimental Biochemistry	
or 03-345	Experimental Cell and Developmental Biology	
or 03-346	Experimental Neuroscience	
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
33-122	Physics II for Biological Sciences and Chemistry Students	9

Biological Sciences Electives (2 courses, 18 units)

One course must be an advanced elective selected from 03-3xx or higher, excluding 03-445.

Chemistry Concentration (121 units minimum)

Chemistry Required Courses (14 courses, 103 units)

09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-214	Physical Chemistry	9
or 09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	
or 09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-204	Professional Communication Skills in Chemistry	3
09-201-09-202	Undergraduate Seminar I - Undergraduate Seminar II: Safety and Environmental Issues for Chemists - Undergraduate Seminar III	3
09-402	Undergraduate Seminar VI	3
33-122	Physics II for Biological Sciences and Chemistry Students	9

Note: Students who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an "A" grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Advanced Chemistry Electives (2 courses, 18 units)

May be any upper level chemistry course, 09-3xx or higher, or Biochemistry I, 03-231 or 03-232, with the exception of 09-435 Independent Study, which can be used only by permission of the Director of Undergraduate Studies.

Mathematical Sciences Concentration (123 units minimum)

Mathematical Sciences Required Courses (9 courses, 87 units minimum)

(Reasonable substitutions within the core program will be allowed.)

15-110	Principles of Computing	10
21-127	Concepts of Mathematics	10
or 21-128	Mathematical Concepts and Proofs	
21-228	Discrete Mathematics	9
21-241	Matrices and Linear Transformations	10
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	9
or 21-268	Multidimensional Calculus	
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-355	Principles of Real Analysis I	9

21-373	Algebraic Structures	9
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	

Mathematical Sciences Electives (2 courses, 18 units)

Students with a Music concentration should take 21-272 Introduction to Partial Differential Equations.

Mathematical Sciences, Statistics, or Computer Science Electives (2 courses, 18 units)

May be computer science course above the 100-level, mathematical science courses beyond the calculus sequence, and statistics courses at the level of 36-225 or higher.

Neurobiology Concentration (114 units minimum)

Neurobiology Required Courses (12 courses, 96 units)

03-161	Molecules to Mind	9
or 85-219	Biological Foundations of Behavior	
03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics - Fall, Sophomore year	9
03-231	Honors Biochemistry - Spring, Sophomore year	9
03-320	Cell Biology - Fall, Junior year	9
03-342	Introduction to Biological Laboratory Practices - Fall, Junior year	1
03-343	Experimental Techniques in Molecular Biology - Fall, Junior year	12
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
09-217	Organic Chemistry I	9
33-122	Physics II for Biological Sciences and Chemistry Students	9
85-211	Cognitive Psychology	9

Neurobiology Electives (2 courses, 18 units)

One course must be an advanced elective selected from 03-3xx or higher.

Physics Concentration (134 units minimum)

Physics Required Courses (16 courses, 116 units)

21-259	Calculus in Three Dimensions	9
33-104	Experimental Physics	9
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-201	Physics Sophomore Colloquium I -Fall	2
33-202	Physics Sophomore Colloquium II -Spring	2
33-211	Physics III: Modern Essentials	10
33-228	Electronics I	10
33-231	Physical Analysis	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
33-301	Physics Upperclass Colloquium I -Fall	1
33-302	Physics Upperclass Colloquium II -Spring	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-340	Modern Physics Laboratory	10
33-341	Thermal Physics I	10

Physics Electives (2 courses, 18 units)

Two courses to be pre-approved by the Physics Department.

33-xxx	Two Physics Electives	18

Note: 33-114 Physics of Musical Sound (9 units) is highly recommended for students with a Music concentration.

College of Fine Arts Concentration

(number of courses vary, 108 units minimum)

BSA students choose one of the following concentrations:

- Architecture (108 units)
- Art (108 units)
- Design (108 units)
- Drama (108 units)
- Music (108 units)

ARCHITECTURE CONCENTRATION (108 UNITS MINIMUM)

Architecture Required Courses (7 courses, 52 units minimum)

48-100	Architecture Design Studio: Foundation I -Fall, Freshman year	10-15
or 48-095	Spatial Concepts for Non-Majors	
62-122	Digital Media I -Fall, Freshman year	6
62-125	Drawing I -Fall, Freshman year	6
62-123	Digital Media II -Spring, Freshman year	6
62-126	Drawing II -Spring, Freshman year	6
48-240	Historical Survey of World Architecture and Urbanism I -Spring, Freshman year	9
48-241	Modern Architecture -Fall, Sophomore year	9

Architecture Electives (56 units minimum)

A minimum of **56** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office.

ART CONCENTRATION (108 UNITS MINIMUM)

Concept Studios (2 courses, 20 units)

Complete two courses:

60-101	Concept Studio: The Self and the Human Being	10
60-201	Concept Studio: Space and Time	10
60-202	Concept Studio: Systems and Processes	10
60-280	Introduction to Contextual Practice	10

Media Studios (3 courses, 30 units minimum)

Complete three courses. 3D mini courses count as half a course:

60-150	2D Media Studio: Drawing	10
60-160	2D Media Studio: Imaging	10
60-131	3D Media Studio I (mini-1)	5
60-132	3D Media Studio I (mini-2)	5
60-133	3D Media Studio II (mini-3)	5
60-134	3D Media Studio II (mini-4)	5
60-250	2D Media Studio: Painting	10
60-251	2D Media Studio: Print Media	10
60-110	Electronic Media Studio: Introduction to the Moving Image	10
60-210	Electronic Media Studio: Introduction to Interactivity	10-12
or 60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	

Advanced Studios (4 courses, 40 units)

Complete four courses. Courses may be offered in the fall and/or spring. Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired.

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) *		10

Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) *		10
Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) *		10
Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) *		10
60-499	Studio Independent Study (one only)	10

* Courses offered intermittently; speak with a BXA advisor to determine course availability.

Critical Studies (2 courses, 18 units)

60-205	Critical Theory in Art III -Fall	9
60-206	Critical Theory in Art IV -Spring	9

Note: Critical Theory I & II are strongly recommended.

Review Requirement (complete 2 required reviews, 0 units)

A review is required at the end of the sophomore and senior years. Pass/no pass only.

60-200	Sophomore Review -Spring	0
60-400	Senior Review -Fall	0

DESIGN CONCENTRATION (108 UNITS MINIMUM)

Design Required Courses (13 courses, 95 units)

51-101	Studio: Survey of Design (Fall, Freshman year)	10
51-121	Visualizing (Fall, Freshman year)	10
51-171	Placing (Fall, Freshman year)	10
51-102	Design Lab (Spring, Freshman year)	10
51-122	Collaborative Visualizing (Spring, Freshman year)	10
51-172	Systems (Spring, Freshman year)	9
Choose Two Studios (Fall, Sophomore year):		4.5+4.5
51-225	Communications Studio I: Understanding Form & Context	4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	
Choose Two Corresponding Labs (Fall, Sophomore year):		4.5+4.5
51-227	Prototyping Lab I: Communications	4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	
51-271	How People Work (Fall, Sophomore year)	9
51-371	Futures I (Fall, Junior year or later)	4.5
51-373	Futures II (Fall, Junior year or later)	4.5

Design Electives (13 units)

A minimum of **13** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

DRAMA CONCENTRATION (108 UNITS MINIMUM)

Options available in the following areas: 1) Design, 2) Directing, 3) Dramaturgy, 4) Production Technology and Management

Note: There is no BHA Acting or Musical Theatre option.

Required Courses for All Concentration Options (5 courses, 20 units)

54-175-54-176	Conservatory Hour-Conservatory Hour (1 unit each)	2
54-177	Foundations of Drama I	6
54-281	Foundations of Drama II (prerequisite: 54-177)	6
54-381	Special Topics in Drama: History, Literature and Criticism	6

Work with Drama Faculty Option Coordinator to Approve Concentration Option (**88** units minimum):

Design Required Courses (2 courses, 26 units)

54-151-54-152	Stagecraft-Stagecraft (13 units + 13 units)	26

A minimum of **62** additional Design units must be approved by the Design faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Directing Required Courses (10 courses, 52 units)

54-121-54-122	Directing I: Sources-Directing I: Sources	18
54-221-54-222	Directing II: Fundamentals-Directing II: Fundamentals	18
54-159-54-159	Production Practicum-Production Practicum (two times, 12 units total)	12
54-517	Director's Colloquium (four times, 4 units total)	1

A minimum of **36** additional Directing units must be approved by the Directing faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (9 courses, 53 units minimum)

54-109	Dramaturgy 1: Approaches to Text	9
54-184	Dramaturgy 2: Introduction to Production Dramaturgy	9
54-121	Directing I: Sources	9
54-159-54-159	Production Practicum-Production Practicum (two times, 12 units total)	12
54-200-54-200	Dramaturgy Forum-Dramaturgy Forum -Fall (minimum of two; every semester it is offered while enrolled)	2
54-xxx	Dramaturgy 3, 4, 5 or 6 (minimum of two; all four if enrolled as BXA for six semesters or more)	18

A minimum of **29** additional Dramaturgy units must be approved by the Dramaturgy faculty option coordinator. A list of these selected courses must be filed in the BXA office.

Production Technology and Management Required Courses (2 courses, 26 units)

54-151-54-152	Stagecraft-Stagecraft (13 units + 13 units)	26

A minimum of **62** additional PTM units must be approved by the PTM faculty option coordinator. A list of these selected courses must be filed in the BXA office.

MUSIC CONCENTRATION (108 UNITS MINIMUM)

Options available in the following areas: 1) Music Performance (instrumental, piano, organ, voice), 2) Composition 3) Musicology, 4) Audio Recording & Production 5) Sound Theory & Practice

Required Course for All Concentration Options (1 course, 9 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	

Work with Music Advisor to Approve Concentration Option (**99** units minimum):

Music Performance and Composition Required Courses (12 courses, 76 units)

57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1

57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Musicology Required Courses (8 courses, 45 units)

57-283	Music History I (co-requisite: 57-190)	9
57-284	Music History II (co-requisite: 57-289)	9
57-285	Music History III (co-requisite: 57-290)	9
57-189	Introduction to Repertoire and Listening for Musicians	3
57-190	Repertoire and Listening for Musicians I	3
57-289	Repertoire and Listening for Musicians II	3
57-290	Repertoire and Listening for Musicians III	3
57-611	Independent Study in History	6

Choose **36** units from:

57-209	The Beatles	9
57-306	World Music	9
57-404	String Quartet: A Social History	9
57-405	Concerto: Virtuosity and Contrast	9
57-409	Puccini's Operas	9
57-427	Advanced Seminar in Film Musicology	9
57-476	How Music Works: An Affective History	6
57-477	Music of the Spirit	6
57-478	Survey of Historical Recording	6
57-480	History of Black American Music	6
57-485	History of the Symphony	9

A minimum of **18** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Audio Recording & Production Required Courses (7 courses, 40 units)

57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Choose **59** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-275	History of Sound Design	3
54-666	Production Audio	6
57-344	Experimental Sound Synthesis	9
57-421	The Exploded Ensemble	6
57-425	Expanded Music Performance	9
57-427	Advanced Seminar in Film Musicology	9
57-478	Survey of Historical Recording	6
57-622	Independent Study in Sound Recording Production	3
60-131	3D Media Studio I	5
60-210	Electronic Media Studio: Introduction to Interactivity	10

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Sound Theory & Practice Required Courses (7 courses, 47 units)

57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
18-090	Twisted Signals: Multimedia Processing for the Arts	10
57-911	Music Since 1945	9
57-616	Independent Study in Sound Studies	9

Choose **52** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music (pre-requisite: 15-112)	9
15-323	Computer Music Systems and Information Processing (pre-requisite: 15-122)	9
33-114	Physics of Musical Sound	9
57-337	Sound Recording	6
57-343	Interdisciplinary Studies in Listening, Culture, and Technology	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music (pre-requisite: 57-101 or 57-171)	6
57-421	The Exploded Ensemble	6
57-425	Expanded Music Performance	9
57-438	Multitrack Recording	9
57-478	Survey of Historical Recording	6
57-829	Contemporary Soundscapes	9
60-131	3D Media Studio I	5
60-210	Electronic Media Studio: Introduction to Interactivity	10

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 1-3 courses, 9-29 units)

Take any Carnegie Mellon course. A maximum of 9 units of physical education and/or military science may be counted toward this requirement. Physical education and military science courses will not be calculated in a student's QPA.

Engineering and Arts Additional Major

Carnegie Mellon recognizes that there are STEM-minded students who want the opportunity to formally incorporate their fine arts talents with their current study in engineering. In order to accommodate students who wish to pursue an education in both areas, while retaining the full engineering curriculum and licensure, we offer an additional major that combines the strengths of the College of Fine Arts (CFA) and the College of Engineering (E). The Engineering and Arts (EA) additional major is an interdisciplinary program that offers a unique group of qualified Engineering students the foundation to develop their skills and interests in an area of the fine arts and engineering.

The EA curriculum has two main components: BXA requirements and fine arts concentration requirements. Each student's course of study is structured so it can be completed alongside their primary engineering major.

The EA Additional Major Program is governed by faculty and administrators from both colleges and led by the director of the BXA Intercollege Degree Programs. Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the advisors and liaisons between CFA and Engineering. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts, and their primary advisor in Engineering to guide their full major in engineering.

EA Curriculum

	Units
I. BXA Requirements	**36**
II. CFA Concentration	**108**
Total EA Additional Major Requirements	**144**

BXA Requirements

BXA Required Courses (5 courses, 36 units minimum)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer	9
or 52-291	BXA Seminar II: Transferring Knowledge	
52-391	BXA Junior Portfolio	0
52-392	BXA Seminar III: Deconstructing Disciplines	9
52-401	BXA Seminar IV: Capstone Project Research	9
52-402	BXA Seminar V: Capstone Project Production	9

College of Fine Arts Concentration

Art Concentration (108 units minimum)

Concept Studios (2 courses, 20 units)

Complete two courses:

60-101	Concept Studio: The Self and the Human Being	10
60-201	Concept Studio: Space and Time	10
60-202	Concept Studio: Systems and Processes	10
60-280	Introduction to Contextual Practice	10

Media Studios (3 courses, 30 units Minimum)

Complete three courses. 3D mini courses count as half a course:

60-150	2D Media Studio: Drawing	10
60-160	2D Media Studio: Imaging	10
60-131	3D Media Studio I (mini-1)	5
60-132	3D Media Studio I (mini-2)	5
60-133	3D Media Studio II (mini-3)	5
60-134	3D Media Studio II (mini-4)	5
60-250	2D Media Studio: Painting	10
60-251	2D Media Studio: Print Media	10
60-110	Electronic Media Studio: Introduction to the Moving Image	10
60-210	Electronic Media Studio: Introduction to Interactivity	10-12
or 60-212	Electronic Media Studio: Interactivity and Computation for Creative Practice	

Advanced Studios (4 courses, 40 units)

Complete four courses. Courses may be offered in the fall and/or spring. Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired.

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
60-410 - 60-429	Advanced Electronic and Time-Based Work (ETB)	10
60-430 - 60-447	Advanced Sculpture, Installation and Site-Work (SIS)	10
60-448 - 60-449	Advanced Contextual Practice (CP)	10
60-450 - 60-498	Advanced Drawing, Painting, Print Media and Photography (DP3)	10
60-499	Studio Independent Study (one only)	10

Critical Studies (2 courses, 18 units)

60-205	Critical Theory in Art III -Fall	9
60-206	Critical Theory in Art IV -Spring	9

Note: Critical Theory I & II are strongly recommended.

Review Requirement (Complete 2 Required Reviews, 0 units)

A review is required at the end of the sophomore and senior years. Pass/no pass only.

60-200	Sophomore Review -Spring	0
60-400	Senior Review -Fall	0

Academic Policies

Professional and Community Standards

As a condition of enrollment BXA, and as a student in the College of Fine Arts, we expect you to positively contribute to the community in order to fully engage in the intellectual life at CFA. Classrooms, studios, rehearsal and performance spaces, exhibition venues and off-campus curricular destinations are safe spaces for expression and self-identification. Students are expected to treat everyone with respect, regardless of race, country of origin, gender identity and expression, sexual orientation, disability, physical appearance, age, religion, political affiliation or marital status. Lack of respect and harassment includes offensive comments related to any protected personal characteristic, deliberate intimidation, sustained disruption of speech, inappropriate physical contact and unwelcome sexual attention. Violations of this agreement are subject to a response to be determined by the BXA Director and CFA Associate Deans.

Academic Standards and Actions

Academic standards are established to ensure a student is progressing well in their desired CMU degree. Deviation from these standards will prompt an academic action, which notifies both the student and their advisors so appropriate responses can be considered.

At the end of every semester, the academic performance of each BXA student is evaluated based on the established academic standards listed below. As the College of Fine Arts is the unifying body among the BXA degrees, the BXA Director presents recommendations for academic actions to the College of Fine Arts Academic Advisory Council (CFA-AAC) for a final review and council vote in accordance with CFA-AAC protocol. Once the actions are approved, the student will receive written notice of the action. Copies of all communications will also be sent to their BXA, CFA and academic college advisors.

Academic Standards

BXA students are expected to maintain a cumulative QPA of 2.0 or higher and to make satisfactory progress toward their academic degree. Meeting one or more of the following conditions in the semester will result in an academic action. Note that meeting a singular criterion more than once within the current semester is equivalent to meeting 2 or more criteria:

- Semester QPA below 2.0
- Cumulative QPA below 2.0
- Grade of D or R in a required concentration course*
- Grade of R in a general education course

- Completing fewer than 27 factorable units toward intended degree in a semester (free electives do not count toward total)

*as defined by each degree option.

Academic Actions

All academic actions are cumulative and sequential. Should a student resume good standing and later meet the criteria for another academic action, they will continue where they previously left off. All academic actions also transfer between colleges. BXA students who enter the program through internal transfer on action, will continue on the equivalent action.

After an action of probation, the student's BXA advisor will initiate an intervention team. This team will include the student's BXA college liaison and all three of their associated advisors (BXA, CFA and academic college advisors) to strategize a path to success and discuss available resources.

Students on an academic action are not allowed to overload classes, cross-register for classes or participate in study abroad during the semesters the action is in effect.

First Academic Action:

Warning: Warning will be administered if a student meets 1 criterion for an academic action within the current semester.
Probation: Probation will be administered if a student meets 2 or more criteria for an academic action.

Second Academic Action:

Probation: Probation will be administered if a student was previously on a "Warning" and now meets 1 or more criteria for an academic action within the current semester.
Final Probation: Final Probation will be administered if a student was previously on a "Probation" and now meets only 1 criterion for an academic action within the current semester.
Suspension: Suspension will be administered if a student was previously on a "Probation" and now meets 2 or more criteria for an academic action or meets an individual criterion multiple times within the current semester.

Third Academic Action:

Final Probation: Final Probation will be administered if a student was previously on a "Probation" and now meets 1 or more criteria for an academic action within the current semester.
Suspension: Suspension will be administered if a student was previously on a "Final Probation" and now meets only 1 criterion for an academic action within the current semester.
Drop: Drop will be administered if a student was previously on Final Probation and now meets 2 or more criteria for an academic action within the given semester. -OR- If a student was previously on a "Suspension" and now meets 1 or more of the criteria for an academic action within the current semester. (If the student has failed to secure admittance to a different program by this time, the student will also be dropped from the university.)

Fourth Academic Action:

Suspension: Suspension will be administered if a student was previously on a "Final Probation" and now meets 1 or more of the criteria for an academic action within the current semester.
Drop: Drop will be administered if a student was previously on a "Suspension" and now meets 1 or more of the criteria for an academic action within the current semester. (If the student has failed to secure admittance to a different program by this time, the student will also be dropped from the university.)

Fifth Academic Action:

Drop: Drop will be administered if a student was previously on a "Suspension" and now meets 1 or more of the criteria for an academic action within the current semester. (If the student has failed to secure admittance to a different program by this time, the student will also be dropped from the university.)

Appeal of Academic Action

Students have the right to appeal academic actions. If a student believes an academic action is inconsistent with BXA policies or merits additional review, a student should submit a formal written appeal, as specified in the initial academic action letter, to the assistant/associate deans listed below, with a copy to the deans of both CFA and their academic college. Appeals should include all relevant materials to substantiate their case and support their concerns.

A student may appeal to the relevant assistant/associate deans within seven days from the date of their academic action letter. All appeals should be in written form, under three pages in length (not including appendices) and authored by the student.

BCSA Appeals should be addressed to:
Kristen Letts Kovak, Senior Associate Dean for Academics, College of Fine Arts
Guy Belloch, Associate Dean for Undergraduate Education, Computer Science Department

BHA Appeals should be addressed to:
Kristen Letts Kovak, Senior Associate Dean for Academics, College of Fine Arts
Ana Maria Ulloa-Shields, Assistant Dean and Director, Dietrich College Academic Advisory Center

BSA Appeals should be addressed to:
Kristen Letts Kovak, Senior Associate Dean for Academics, College of Fine Arts
Maggie Braun, Associate Dean for Undergraduate Affairs, Mellon College of Science

If, after carrying out the steps of the process described above, the student believes that the matter has not been adequately resolved, or if no decision has been rendered by the appropriate date, the student may appeal at the university level. To appeal at the university level, the student must present copies of all previously submitted documents and a formal letter of appeal to the provost. The provost or another designated university officer will respond in writing with a final resolution, including the basis for it, within thirty (30) days when possible.

Disabilities

Students with a learning disability or a physical disability are encouraged to email access@andrew.cmu.edu. The circumstances will remain confidential to the extent desired. The university has a formal procedure for documenting disabilities, notifying advisors and faculty, and making arrangements to utilize university resources in support of expressed needs, but will take no action until contacted by the student. The BXA academic advisors will work with the student to coordinate assistance. Please note that requests for accommodations are not retroactive; you must ask that accommodation requests be put in place before you anticipate needing them.

Grading Policies

University grading policies may vary depending on the particular school/department. Please consult the Undergraduate Academic Regulations (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateacademicregulations).

Intercollege Deans' List

Students who earn 36 graded units (no "pass/no pass" grades) with a grade point average of 3.5 or higher, no "incompletes" and "no grades" qualify for BCSA, BHA or BSA Deans' List. The BXA Intercollege Deans' List Honors are posted online each semester.

Intercollege Honors

BXA students who successfully complete a BXA Capstone Project under the guidance of a faculty member will graduate with BCSA, BHA, BSA or EA Intercollege Honors if all of the following conditions are met:

- grade of "A" achieved in 62-401 and 62-402
- overall QPA of 3.25 or higher
- research results presented at Meeting of the Minds Undergraduate Research Symposium

As a citizen of two colleges, a BXA student also has the opportunity to graduate with CFA College Honors, DC College Honors, E College Honors and MCS College Honors. These particular honors are defined by each college. BXA students will receive honors color cords during the BXA/CFA Commencement Honors Ceremony and EA additional major students at the College of Engineering Commencement Honors Ceremony.

University Honors

Students who graduate with an overall QPA of 3.5 or higher will graduate with University Honors. Students will receive an honors medallion during the BXA/CFA Commencement Honors Ceremony.

Internal Transfer/Additional Major Process

For current Carnegie Mellon students who wish to apply to a BXA program, an internal transfer and additional major (EA) application process takes place in both the fall and spring semester. Applications are available online and in the BXA office and are reviewed by a committee of BCSA, BHA, BSA and EA advisors in October and in March. However, certain concentrations consider applications only once a year; please consult with a BXA advisor for guidance on scheduling your application.

All students applying for internal transfer should meet with their current advisor, a BXA advisor, and an advisor in their target area, as well as take preliminary coursework in their target area before applying. For all concentrations, there are required courses that must be taken before an application will be considered; please consult with a BXA advisor for guidance on scheduling these courses.

Current BXA students who wish to change their BXA program (e.g. BHA to BCSA) or change their CFA concentration (e.g BHA architecture to BHA art) or delineated options within CFA concentrations (e.g. music performance to music composition) must apply for that change through the internal transfer process. Current BHA and BSA students who wish to change their academic college concentration after declaring (e.g. BHA creative writing to BHA psychology, BSA physics to BSA mathematical sciences) must submit a new DC/MCS Concentration Declaration form for approval of that change, which will be reviewed at the internal transfer committee meeting each semester. Current BXA students seeking internal transfer out of BXA into another college program must apply and meet entry requirements to that program.

Study Abroad

Studying abroad is encouraged to broaden BXA students' interdisciplinary experiences through traditional and non-traditional study abroad, from coursework and artistic studios to for-credit internships, volunteer service and research opportunities.

Courses taken while studying abroad may count toward your BXA concentration requirements, your general education requirements or your free electives. Studying abroad should not delay your graduation, as long as you work with your study abroad advisor and your BXA advisor to plan the most appropriate courses.

The timing and length of program are important considerations while planning. Due to required BXA coursework, students should avoid studying abroad in their last three semesters (junior spring, senior fall/spring). Spending an entire year abroad is not typically possible for BXA students without intending to take an additional semester at Carnegie Mellon. Many students study abroad during the spring of their sophomore year or the fall semester of their junior year, as well during the summer, and over winter and spring breaks. Talk to your BXA academic advisor early in your academic career to identify the best time for study abroad.

When studying abroad, students are still enrolled at Carnegie Mellon. A student never takes a leave of absence to study abroad. Prior to studying abroad, all students must attend a required pre-departure orientation offered by the Office of International Education (OIE).

Students must also complete a Study Abroad Transfer Credit (SATC) form prior to departure for study abroad, which must be signed after completion by the BXA advisor. The SATC will guarantee transfer credit for courses taken abroad, and is filled out by the corresponding departments to the coursework being transferred. Unlike regular transfer credit, there is no limit to the number of courses transferable from study abroad, but there may exist stricter limits on the use of coursework to fulfill concentration or general education requirements.

Students will receive credit for courses for which they receive a grade of "C" or better. However, grades received abroad do not count toward a student's Carnegie Mellon University QPA.

Transfer Credit

Once a BXA student enrolls at Carnegie Mellon University as a degree candidate, they may transfer a maximum of five courses from another institution (excepting official study abroad programs through the CMU Office of International Education) for credit towards their BXA degree. This applies to courses taken at other institutions in the United States, as well as courses taken internationally in the student's home country.

Individual departments may impose stricter limits regarding the number or type of courses students propose to take elsewhere to fulfill requirements. Some departments may not accept transfer credit from online courses.

Students must have prior approval to transfer courses from their BXA advisor, as well as concentration advisors, to use coursework towards requirements. To receive permission, students must complete the BXA Transfer Credit Request form and provide course information (syllabi) to the corresponding department for evaluation of appropriate credit. When the course is finished, official transcripts must be sent to Carnegie Mellon University before credit will be recorded.

Transfer courses must be taken for a letter grade and students must earn a C (2.00) or above (B or above at a community college). Transfer credit is not factored into a student's CMU QPA.

The following courses must be taken at CMU and cannot be transferred in:

- First-Year Writing Requirement Course (76101, 76102, 76106/7/8)
- 79-104: Global Histories
- 36-200: Statistical Reasoning (AP credit only)
- 99-101: Computing @ Carnegie Mellon

Students currently on university suspension are permitted to take no more than three courses per semester at another institution and no more than a total of five courses.

Withdrawal or Leave of Absence

A student who decides to leave the university must meet with their BXA advisor and complete a Withdrawal or Leave of Absence form. Withdrawal means leaving the university with no intention of returning. Leave of Absence means temporarily leaving the university with a stated intention to return. A withdrawal or leave of absence from the university at any time up to and including the last day of classes (excluding the final examination period), means that grades of W will be recorded for all classes for the semester. Financial responsibility for the semester is dependent upon the date of and the reasons for filing the form. Questions about financial responsibility should be directed to the HUB.

A leave of absence may be voluntary or involuntary. If the leave is voluntary, the student may return any time within four years following the beginning of the leave by filing an Application for Return from Leave of Absence form. If the leave is involuntary, that is, required for academic or disciplinary reasons, the conditions for return will be stated.

BXA Intercollege Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

52-190 BXA Seminar I: Building the Wunderkammer
Fall: 9 units
BXA Seminar I introduces first-year and rising sophomore internal transfer students to the field of interdisciplinary work through the concept of the Wunderkammer, the cabinet of wonders. How do we identify and categorize objects? How do we define their position in the world and in a collection? What kind of knowledge is conveyed through context, representation, and juxtaposition? This class considers how interdisciplinary work can be produced, analyzed, justified and—most importantly—contextualized. Students engage with theoretical and practical readings from across disciplines, with particular emphasis on interpretive theory. Weekly readings in aesthetic and critical theory introduce students to a particular vocabulary of analysis, practiced in class discussion and written responses. Students will conceive, research, produce and present a creative final project at the end of the semester.

52-290 Literacy Across Disciplines
Intermittent: 9 units
This course is intended for CFA students who want to improve their writing and communication skills, with a focus on targeting non-specialist audiences. Assignments and readings will cover formats including artists? statements, grant and other funding applications, and other project proposals. Students will also acquire the critical vocabulary to contextualize their creative work in contemporary conversations about the arts. This course will give you the opportunity to develop skills in identifying and targeting audiences in a variety of rhetorical modes and genres. This course is especially well-suited to sophomores and juniors, but is open to all years.

52-291 BXA Seminar II: Transferring Knowledge
Spring: 9 units
BXA Seminar II is intended for students transferring into a BXA program during their sophomore year or beyond. We'll consider how knowledge is represented across different modes of media—what language, what symbols, what logic guides knowledge acquisition and expression in your varied disciplines? Students engage with theoretical and practical readings from across disciplines, with particular emphasis on interpretive theory. Weekly readings in aesthetic and critical theory introduce students to a particular vocabulary of analysis, practiced in class discussions and written responses. Students will produce written assignments as well as creative responses to the course material.

52-292 BXA Student Advisory Council
Intermittent: 3 units
This course will provide opportunities for students to promote and refine the mission of the BXA programs. Students will develop and practice leadership skills, including collaboration, communication, and project management. Students will be responsible for planning and running BXA student events, including info sessions, social hours, skills workshops, and alumni events. Students are encouraged to think about how to engage other interdisciplinary scholars and artists as well as how to present their own work and programs to the larger university community.

52-390 BXA Undergraduate Research Project
All Semesters
The BXA Undergraduate Research Project is for students who want to work on a self-designed project with the one-to-one guidance of a faculty advisor. The project should be interdisciplinary in nature, and can be a scholarly and/or creative endeavor. The project may take the form of a written thesis, a compilation of creative works, an outreach project, etc. The project topic must be pre-approved by the faculty member who agrees to supervise the project and assign a letter grade for the course. Projects are to be completed in one semester, may be worth 3, 6, 9, or 12 units of academic credit, and cannot be taken concurrently with the BXA Capstone Project during the senior year. To register, students must submit an "Undergraduate Research Project Proposal Form" signed by both the student and the faculty advisor, along with a proposal, to their BXA academic advisor.

52-391 BXA Junior Portfolio
Spring
To better assess the goals and needs of BXA students as they enter their final year and prepare for senior-level projects (e.g. BXA Capstone Project), all students will review their own work and assemble a portfolio during the spring semester of their junior year. Students should work with their BXA advisors and their concentration faculty advisors to assemble a portfolio that represents their academic and creative milestones over the course of their college career. This portfolio also includes reflective written components to allow students to present a narrative of their history with BXA, and identify their goals, visions, ideas and concerns for their future work—both for senior year and beyond. Students should provide an assessment of the areas of intersection between their academic and artistic interests, offer their own specific goals for their academic career, and give a self-evaluation of their performance and opportunities to-date, in light of the programs' broader pedagogical goals.

52-392 BXA Seminar III: Deconstructing Disciplines
Spring: 9 units
The BXA Seminar III will engage BXA juniors in examination of critical theory, the structure of disciplinary knowledge, interdisciplinary approaches and methods, and the purpose, categories, and components of research. The course will meet weekly at the beginning of the semester and biweekly or bimonthly at the second half with time given to completing individual projects. The requirements include short readings, participation in online and seminar discussions, individual self-assessment exercises, the production of small creative works and/or research projects, and presentation of work during both BXA Kaleidoscope and a separate class research showcase held during the final exam period. BXA Seminar III is in preparation for the BXA Capstone Project and/or other senior research projects (Dietrich/MCS/SCS thesis, or CFA senior studio work).

52-401 BXA Seminar IV: Capstone Project Research
Fall and Spring
The BXA Capstone gives BXA students the opportunity to demonstrate the extent of their interdisciplinary work over the course of their academic career. The Capstone should include elements that span the student's CFA and SCS concentrations (for BCSA students), CFA and DC concentrations (for BHA students), CFA and MCS concentrations (for BSA students) or CFA concentration and Engineering major (for EA additional major students). The project can be either a scholarly or creative endeavor, and may take one of many possible forms (e.g., a written thesis, a compilation of creative work or works, an experiment and report, a computer program or animation, etc.). The BXA Capstone sequence covers both semesters of a student's senior year. In the fall, students are enrolled in 52-401 BXA Seminar IV: Capstone Fall (9 units), which meets weekly to discuss strategies for managing research, planning the project and larger theoretical issues related to interdisciplinary work. At the end of the fall course, students will have produced a Capstone Project proposal, an annotated bibliography and multiple versions of their project pitch. In the spring, students enroll in 52-402 BXA Seminar: Capstone Spring (9 units), which has no required classroom time. Instead, students spend the semester doing the research and foundational work necessary for the project, as well as meeting with their faculty and BXA advisors as they create their Capstone Project and prepare to present it at the annual Meeting of the Minds Undergraduate Research Symposium held each May. Students will only be enrolled in 52-401 (18 units) when they are unable to complete a two-semester sequence and need to gain special permission by the BXA Director/Academic Advisor. Students will only be enrolled in 52-401 (18 units) when they are unable to complete a two-semester sequence and need to gain special permission by the BXA Director/Academic Advisor.

52-402 BXA Seminar V: Capstone Project Production
Fall and Spring: 9 units
The BXA Capstone gives BXA students the opportunity to demonstrate the extent of their interdisciplinary work over the course of their academic career. The Capstone should include elements that span the student's CFA and SCS concentrations (for BCSA students), CFA and DC concentrations (for BHA students), CFA and MCS concentrations (for BSA students) or CFA concentration and Engineering major (for EA additional major students). The project can be either a scholarly or creative endeavor, and may take one of many possible forms (e.g., a written thesis, a compilation of creative work or works, an experiment and report, a computer program or animation, etc.). The BXA Capstone sequence covers both semesters of a student's senior year. In the fall, students are enrolled in 52-401 BXA Seminar IV: Capstone Fall (9 units), which meets weekly to discuss strategies for managing research, planning the project and larger theoretical issues related to interdisciplinary work. At the end of the fall course, students will have produced a Capstone Project proposal, an annotated bibliography and multiple versions of their project pitch. In the spring, students enroll in 52-402 BXA Seminar: Capstone Spring (9 units), which has no required classroom time. Instead, students spend the semester doing the research and foundational work necessary for the project, as well as meeting with their faculty and BXA advisors as they create their Capstone Project and prepare to present it at the annual Meeting of the Minds Undergraduate Research Symposium held each May.

52-590 BXA Internship
All Semesters
An internship is a supervised professional work experience with clear links to a student's academic goals. BXA students may choose to complete a BXA Internship for elective credit with appropriate individuals or organizations within or outside of Carnegie Mellon University. Junior and senior BXA students in good academic standing are eligible to receive academic credit for one internship. Grading is pass/no pass only. Prior to enrolling in an internship, the student must have a "BXA Internship Agreement Form" signed by their site supervisor and approved by their BXA academic advisor.

Carnegie Mellon University-Wide Studies Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

99-101 Computing @ Carnegie Mellon
Fall and Spring: 3 units
Computing@Carnegie Mellon (C@CM) is a 3-unit, pass/fail mini course that will help you develop foundational computing and information literacy skills, focusing on the tools and technologies that are specific to Carnegie Mellon so you can be successful in your other academic courses. All undergraduate students are required to take the course. C@CM is offered in a hybrid format through the Open Learning Initiative's (OLI) online course environment; meaning that you'll complete your coursework online and attend a face-to-face recitation session for review and supplemental instruction.

Course Website: http://www.cmu.edu/c-cm/

99-104 Carnegie Skills Workshop
All Semesters: 3 units
Carnegie Skills Workshop (CSW) is a 3-unit course that helps students to define, locate, evaluate, organize and present information. CSW focuses on essential tools and technologies necessary for the successful completion of research and writing projects assigned in other courses. The same skills are indispensable at any stage in a person's professional career and personal life. All undergraduate students at CMU-Qatar are required to take the CSW course. Incoming students are expected to take CSW during the fall semester.

99-190 Managing Stress, Restoring Harmony
Fall: 6 units
The course is designed to explore the subject of stress and how it can best be managed to achieve optimal health and wellbeing. Topics addressed will include: the environmental, mental and emotional components of stress, factors that affect the experience of stress, how stress contributes to illness, and an overview of various stress management techniques. Several lectures will be supported by Carnegie Mellon faculty and staff.

99-194 Intimate Relationships & Sexual Health
Fall: 6 units
This course will explore the expression of human relationships and sexuality. Emphasis will be placed on college health and the social, cultural and health factors that affect relational interactions. This course is designed to assist students with improved functioning in personal relationships, provide information to take care of their sexual health and help them acquire skills to make decisions now and in the future. Topic areas will include relationships, sexual behavior, sexual health and interpersonal skills. Academic support will be provided by campus and community partners.

99-236 Introduction to Environmental Ideas
Spring: 9 units
By recognizing that environmental problems are themselves complex and require insights from both scientific and social perspectives, the University-wide Minor in Environmental Studies urges students to gain proficiency in different disciplinary habits of thinking about environmental problems. This course fulfills a requirement for the University-wide Minor in Environmental Studies. This course will introduce students from any undergraduate major at CMU to key methods and approaches for inquiry in the framework of Environmental Studies. Students will build up their ability to recognize and apply diagnostic criteria; understand key principles and terms; and take part in an informed discussion about ways of seeing, and creating interventions for environmental problems as social and scientific challenges. There are no pre-requisites for this course. Students will develop skills and apply concepts to different scenarios of environmental crisis.

99-250 Seminar for Peer Tutors
Fall and Spring: 4.5 units
SPECIAL PERMISSION REQUIRED: YES The purpose of this training course is to provide undergraduates with the knowledge, skills, and experience necessary to become effective Peer Tutors. Throughout the course, students will be exposed to the mission and goals of Academic Development and the Peer Tutoring Program. The class lasts approximately nine weeks and is generally offered in the spring term from February through April. The course explores the roles and responsibilities of the tutor while offering insights into effective tutoring strategies through interactive discussion and role plays. In addition, trainees work hands-on with experienced tutors to troubleshoot potential problems and situations. Students will gain experience in group dynamics, communication skills, study strategies, referral resources, leadership, and creating a supportive learning environment. Teaching practice is an integral part of the training program. Students must complete an application in person or electronically at https://www.cmu.edu/acadev/jobs/index.html and then be interviewed by the instructor(s) to determine if the student possesses the basic qualifications.

Course Website: http://www.cmu.edu/acadev/studentjobs/

99-251 Seminar for Supplemental Instruction
Fall and Spring: 4.5 units
SPECIAL PERMISSION REQUIRED: YES The purpose of this training course is to provide undergraduates with the knowledge, skills and experience necessary to become effective Supplemental Instruction (SI) and EXCEL Leaders. Throughout the course, students will be exposed to the mission and goals of Academic Development and the Supplemental Instruction Program. The class lasts approximately ten weeks and is generally offered in the spring term from February through April. Course participants will actively explore collaborative learning instructional practices, learning theory, group dynamics, study strategies, and communication and leadership skills in order to create a supportive learning environment. Teaching practice is an integral part of the training program. Students must complete an application in person or electronically at (http://www.cmu.edu/acadev/studentjobs/index.html) and then be interviewed by the instructor(s) to determine if the student possesses the basic qualifications.

Course Website: http://www.cmu.edu/acadev/studentjobs/

99-252 Seminar for Academic Coaching
Fall and Spring: 4.5 units
SPECIAL PERMISSION REQUIRED: YES The purpose of this training course is to provide undergraduates with the knowledge, skills and experience necessary to become effective Academic Coaches (AC's). Throughout the course, students will be exposed to the mission and goals of Academic Development and the Academic Coaching Program. The class lasts approximately nine weeks and is generally offered in the spring term from February through April. Students will gain experience in effective and efficient study strategies, learning theory, communication skills, group dynamics, referral resources and how to create a supportive learning environment. Teaching practice is an integral part of the training program. Students must complete an application in person or electronically at (https://www.cmu.edu/acadev/jobs/index.html) and then be interviewed by the instructor(s) to determine if the student possesses the basic qualifications.

Course Website: http://www.cmu.edu/acadev/studentjobs/

99-270 Summer Undergraduate Research Apprenticeship
Summer
This course consists of student participation in projects focused on undergraduate research or creative inquiry under the direction of a Carnegie Mellon faculty member. Tenure track, teaching track, research track, librarian track, and special faculty may serve as SURA mentors. The subject of the inquiry, the number of units, and the criteria for grading are to be determined by the student and the faculty mentor. This agreement should be formalized in a one-page apprenticeship verification form that includes documented approval from the faculty mentor with a copy to be submitted to the Undergraduate Research Office. The students are responsible for finding a faculty member who is willing and able to supervise them on campus over the summer. In addition to the research experience, course requirements include a series of workshop sessions over the course of the summer that will introduce students to the basics of research design. Students will also be expected to present and/or attend the campus-wide undergraduate research symposium, Meeting of the Minds, in May of the following year. Students may register for a maximum of nine units with work to be completed over an eight-week period during the summer all term.

99-275 Summer ReCharge
Summer: 3 units
The goal of this course is to provide students with the tools they will need to become better equipped to handle the challenges they have or will face in their academic experiences. It is designed to promote student awareness of the necessary components of a successful educational experience. Each week, students will engage in self-awareness activities and group discussion of topics in key areas shown to be predictive of student success. Through discussion with peers, exposure to academic findings, and self-reflection essays, this course will provide students with the opportunity for self-growth and allow them to become better connected with the campus community.

99-347 Global Health: Gender Equality
Fall: 3 units
NOTE: THIS IS A WEEKEND COURSE ONLY: November 1-3, 2019. It will be held on the University of Pittsburgh's campus. The address is: Sennott Square, Rm 2400. With each global health crisis, the interconnectedness of populations around the globe becomes more pronounced. Diseases not only affect the health of communities, but they have a profound impact on political, economic, and social stability within countries and regions. This course engages the interdisciplinary nature of global health by approaching the issue through the lens of the Sustainable Development Goals (SDG) developed by the United Nations. The SDGs range in focus from good health and well-being to gender equality to clean water and sanitation to affordable, clean energy. By engaging the ways that health has a stake in these goals, the course will bring the expertise of faculty from the University of Pittsburgh and CMU as well as practitioners to understand and address the issue surrounding global health from a myriad of perspectives and avenues. With an applied focus, the course will assist students in engaging and advocating for a community on a global health issue through a policy memo. This iteration of the course will examine gender equality and SDG #5.

99-352 IDeATe: Soft Fabrication Skills
Fall and Spring: 1 unit
PLEASE NOTE: The specific Saturday meeting dates for the A3 section of this micro course are January 26, February 2, and February 9. Textiles are a ubiquitous part of our everyday tactile experience. This workshop series aims to introduce textile techniques to participants with diverse backgrounds across the CMU campus. The fabrication skills and concepts that will be covered in this course will be taught from an interdisciplinary approach to merge practices in arts and technology. Students will learn methods of working with fabric such as hand and machine sewing, felting and knitting, along with merging aspects of digital fabrication and physical computing using flexible materials. Through discussions and demos, participants will have the opportunity to explore new methods of fabrication to integrate into their own practice.

Course Website: https://courses.ideate.cmu.edu/99-352

99-353 IDeATe: CAD and Laser Cutting
Fall and Spring: 1 unit
PLEASE NOTE: The specific meeting dates for the A3 section of this micro course are February 16, February 23, March 2. The specific meeting dates for the B3 section of this micro course are January 27, February 3, February 10. This micro course is an introduction to Computer Aided Design (CAD) and the use of laser cutters for fabrication. Students will learn the basics of CAD and will receive hands-on training in the use of laser cutters to turn their designs into physical objects. Students who complete this course will be able to use the IDeATe facility's laser cutters on their own for future course work or personal projects.

Course Website: https://courses.ideate.cmu.edu/99-353

99-355 IDeATe: Introduction to Arduino
Fall and Spring: 1 unit
PLEASE NOTE: The specific meeting dates for the A3 section of this micro course are January 27, February 3, February 10. The specific meeting dates for the B3 section of this micro course are February 16, February 23, March 2. This practical course is designed to quickly take students from beginner to basic functional knowledge of the Arduino microcontroller in three weekend 5-hour sessions. You can expect to learn a) how to write and upload simple code for the Arduino to perform basic logic functions like reading a switch to change a motor's direction, b) how to integrate a variety of physical inputs including knobs, distance sensors, and light sensors, c) how to integrate a variety of physical outputs such as motors, lights, and speakers, and d) how to put all of these together to build simple self-contained low-cost low-power systems. The course culminates in students producing and artful and/or functional interactive creation of their own design. Enrolled students have access to IDeATe's well-equipped Physical Computing Laboratory in the basement of Hunt Library. Undergraduates, graduate students, faculty, and staff interested in learning new skills in an interdisciplinary environment are welcome. There are no technical prerequisites.

Course Website: http://courses.ideate.cmu.edu/99-355

99-356 IDeATe: Digital Media Literacies: Great World Challenge
Fall and Spring: 9 units
This course introduces students to new media for ethically finding, evaluating, producing and sharing artistic and scholarly innovations. It allows students the opportunity to gain practice with and exposure to tools, technologies and processes which support data analysis, visualization, communication, presentation and sharing through a variety of emerging and established dissemination channels. Students who excel in the course may be further supported in identifying and pursuing appropriate publication outlets for their research. The course will be of particular interest to students planning to engage in further undergraduate research opportunities.

99-357 IDeATe: Pragmatic Photography
Fall and Spring: 1 unit
PLEASE NOTE: The specific meeting dates for the A3 section of this micro course are January 27, February 3, February 10. The specific meeting dates for the B3 section of this micro course are February 16, February 23, March 2. Pragmatic Photography is a digital imaging course for the non-photographer. A tech-first approach provides a strong grounding in the core concepts and techniques of image-based media. This course will enable students to create photographs for project documentation. This class will not require special cameras or software; students will use commonly-available photo-editing software to create images using DSLRs, point and click cameras, or their cell phones. The course focuses on general principles that apply across different equipment and software.

99-358 IDeATe: Introduction to the Unity Game Engine
Fall and Spring: 1 unit
PLEASE NOTE: The specific meeting dates for the A3 section of this micro course are January 20, February 3, February 10. The specific meeting dates for the B3 section of this micro course are February 16, February 23, March 2. This course is designed for students with little to no experience working with game engines as entry point into the field of game development. Students will learn the basics of the Unity3D engine, and to creatively and effectively build their own simple games. This course will cover topics such as navigating and using the engine, basic game programming in C#, user interface development and introductory game design principles. Students will be assessed based on the functionality of their games and will receive further feedback on their implementation, execution and creativity.

99-361 IDeATe Portal
Spring: 9 units
IDeATe Portal courses introduce students to key aspects of critical, creative, and technical practice and prepare them to engage in productive interdisciplinary Collaborative Studio coursework in IDeATe minor areas. In section A: Inflatables and Soft Sculpture, students will focus on the design, fabrication, and creative applications of sculptural and inflatable forms created from soft materials. Section B: Intelligent Environments highlights the motivation and requirements for intelligent environments and components that could be used to add functionality to existing environments. Section D: Learning About Learning is a hands-on experiential class where students will gain knowledge, expertise, and empathy towards how humans learn, how we learn from objects, how we learn from our spaces, and how our objects and spaces learn from us. Full descriptions available at https://courses.ideate.cmu.edu/99-361

Course Website: https://courses.ideate.cmu.edu/99-361

Course Descriptions

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