Proposal for Revising the Undergraduate Physics Curriculum
Version 1.14

Undergraduate Curriculum Committee

September 29, 2021

1 TODO

- Update example syllabi to match faculty meeting presentations.
- Fix the prereq table.
- Follow up with Rena
- Find Tony comments?

2 Changes Since the Previous Version

This proposal has been updated since the previous version based on feedback from the assigned faculty reviews and any other comments which have been received.

- The contents of the example course syllabi of Section 12 have been revised based on the presentations at the (first) annual faculty curriculum review.

Contents

3 Objectives of the Proposal

An example schedule of student course work without the revisions proposed here is shown in Table 1 for students taking honors physics. An example schedule for students that transfer to UC Davis for their junior year is shown in Table 2. There are many different trajectories through our program, but most are some variation on these two. For consistent comparisons, all the example schedules in this proposal assume the students take 122A and one capstone course in the winter, and two capstone courses in the spring. Many other lab courses and offerings are possible.

Table 1: An example schedule satisfying the *current requirements* for an undergraduate physics major that takes the 9H series and 122A. Physics course numbers are shown with the number of units in parenthesis. Math courses start with M. Courses in italics are electives or have at least two different offerings per year. Course CAP is a capstone elective, and course X is any advanced elective.

Year	Fall	Winter	Spring
Freshman	9HA(5) *M21B(4)*	9HB(5) *M21C(4)*	9HC(5) *M21D(4)*
Sophomore	9HD(5) *M22A(3)*	9HE(5) *M22B(3)*	40(4) *80(4)*
Junior	104A(4) 105A(4) 102(1)	105B(4) 110A(4)	110B(4) 115A(4)
Senior	110C(4) 112(4) 115B(4)	*122A(4)* *CAP(4)* *CAP(4)*	*X(3-4)* *X(3-4)* *CAP(4)*

Table 2: An example schedule satisfying the *current requirements* for an undergraduate physics major that transfers to UC Davis in their junior year and takes 122A. Physics course numbers are shown with the number of units in parenthesis. Courses in italics are electives or have at least two different offerings per year. Course CAP is a capstone elective, and course X is any advanced elective. Note that PHY 102 is generally considered to be much more work than a typical one-unit course.

Year	Fall	Winter	Spring
Junior	9D(4) 104A(4) 105A(4) 102(1)	105B(4) 110A(4) *80(4)*	40(4) 110B(4) 115A(4)
Senior	110C(4) 112(4) 115B(4)	*122A(4)* *CAP(4)* *CAP(4)*	*X(3-4)* *X(3-4)* *CAP(4)*

There are some deficiencies in the current course of study:

- Physics majors who complete 9HD or 9D in the fall of their sophomore year have little to do for the rest of the year. The honors sequence has 9HE, but that course does not contain any content which is a prequisite for upper division class work. The recent addition of 40 and 80 is helpful in that it provides something for students to do during this time, but the problem still remains that they do not make progress on the upper division core course work, and 80 is not taken by all students. The result of this stalling is that the junior and senior year are a race to complete the degree requirements, leaving very little flexibility or time for advanced electives.

- Students that transfer to UC Davis for their junior year face a wall of course work that they have to handle in the first quarter: math methods, mechanics, and modern physics. Many also take 102, which is nominally a one-unit course, but generally nearly as much work as a four-unit course. For many students, these are also the first courses they encounter that require solving challenging homework problems. We have two trains of students running through our program and the fall of their junior year is the train wreck where they collide.

- The current curriculum does not include sufficient computing practice for our students. It is useful to consider what a physics degree would look like if we taught calculus the same way we teach computing. Students would arrive their freshman year and take an introductory calculus course. Then, they would take their physics courses, which would never mention calculus. At some point in their junior or senior year, they would take a one quarter course called "Calculus in Physics" which would attempt to show all the ways we use calculus in physics. Our students are experts at calculus because they learn how to use the tool, and then apply it, again and again, throughout their course work. To remain relevant in the modern world (or even the world from 20 years ago) our majors need more practice in the use of computing as an essential tool for solving physics problems.

- Four-year students typically graduate with around 180 units. Within the College of Letters and Science, we are allowed to require a maximum of 110 units in our majors. The current BS physics major requires a minimum of 108 units to complete. Fitting the canon of undergraduate physics into such a tight space is extremely challenging. Students complain that we waste time teaching some topics again and again (e.g. Special Relativity from scratch) while completely dropping other topics (e.g. Classical Hamiltonians). The problem is particularly acute for applied physics majors, where core material must be dropped to make space for course work outside of physics.

- The prerequisite structure of the upper division courses creates many tiers. As an extreme example, 122 requires 112, which requires 115A, which requires 104A and 105A, both of which require the 9 series. This, combined with the rapid pace, leaves very little flexibility for students once they start their junior year. For example, missing any of the four-unit courses in the junior year of Table 1 requires an exception to prerequisites or an extra year to graduate.

This proposal aims to make significant improvements on each of these issues.

4 Proposed BS Requirements

The proposed required courses for a BS in physics are presented in Tables 3 and 4. Example schedules are presented in Tables 5-7.

A primary feature of this proposal is that incoming transfer students now overlap in some courses with sophomores that took the honors physics sequence. This eliminates the stalling of our four-year students while relieving some of the intense academic pressure on incoming transfer students. Our experience has been that the best of our transfer students perform as well as the best of our four-year students, once they have sufficient time to adjust, and this proposal gives them that time. Accelerating students that took the honors sequence also provides tremendous additional flexibility to their schedule. The example schedule in Table 5 assumes the student takes each class nearly as soon as possible, leaving ample time in their senior year for additional electives.

Transfer students that wish to complete their degree in two years are still highly constrained, but instead of facing three upper division courses immediately upon arrival they now start with one upper division course. Take the time to compare fall quarter of the junior year in Tables 2 and 7, this is a major feature of this proposal. This gentle introduction does not come at the cost of dramatically increased unit loads later on: transfer students can still complete the degree without exceeding 13 units of physics course work in any quarter.

The college imposes a limit of 110 units of required course work, including prerequisites, for any major. Within a particular major, options that exceed this limit are permitted, as long as a path that stays below the limit is available. The current BS physics major requires a minimum of 108 units. This proposal takes advantage of the remaining two units and brings the minimum to 110 units. This slightly increases total unit pressure on students, which particularly affects those transfer students who have only two-years to absorb them. However, the proposal replaces the one-unit course PHY 102 with the more accurately credited four-unit PHY 45 course. Also, the major stress point for transfer students is in their first quarter, which this proposal substantially improves. The proposal also adds significantly more schedule flexibility, which should also help alleviate pressure.

Table 3: Preparatory Subject Matter

Units: 53-54. *: recommended, ‖ concurrently

Course		Units	Offered	Prereqs	Name
MAT	21A	4	FWS		Differential Calculus
	21B	4	FWS	21A	Integral Calculus
	21C	4	FWS	21B	Partial Derivatives and Series
	21D	4	FWS	21C	Vector Analysis
	22A	3	FWS	21C	Linear Algebra
	22B	3	FWS	22A	Differential Equations
PHY	9A	5	FS	21B	Classical Physics *(Class. Mech.)*
	9B	5	FW	9A,21C	Classical Physics *(Waves, Thermo., Optics.)*
	9C	5	WS	9B,21D	Classical Physics *(Elec. and Magn.)*
	9D	4	FS	9C,22A	Modern Physics *(Rel. and Quant. Mech.)*
	or				
PHY	9HA	5	F	‖21B/‖21M	Honors Physics *(Class. Mech.)*
	9HB	5	W	21B/21M	Honors Physics *(Rel. and Stat. Mech.)*
	9HC	5	S	21C	Honors Physics *(Waves and Quant. Mech.)*
	9HD	5	F	21D	Honors Physics *(Elec. and Magn.)*
PHY	40	4	F		Introduction to Physics Computation
	45	4	W	40,9C/9HD,‖22B	Computational Physics
	80	4	WS	40†,9C/9HD	Experimental Techniques
PHY	185*	1	S		Careers in Physics
	190*	1	F		Careers in Physics

†: Instructor permission may be obtained to take PHY 80 without the PHY 40 prerequisite.

Table 4: Depth Subject Matter

Units: 42-46. *: recommended, ‖: concurrently.

Course		Units	Offered	Prereqs	Name
PHY	104A	4	FS	9C/9HD,MAT 22B	Mathematical Physics
	105A	4	W	9C/9HD,‖MAT 22B	Classical Mechanics I
	105B	4	S	105A,40†	Classical Mechanics II
	110A	4	W	104A	Electricity and Magnetism I
	110B	4	S	110A,9HD/‖9D	Electricity and Magnetism II
	112	4	F	104A,9D/9HD	Thermodynamics and Stat. Mech.
	115A	4	F	104A,105A,9D/9HD	Quantum Mechanics I
	115B	4	W	115A	Quantum Mechanics II
	115C*	4	S	115B,45/ECS 36B	Applications of Quantum Mechanics
PHY	116A	4	F	80	Phys. Instr. with A&D Electronics.
	116B	4	W	80,45/ECS 36B	Phys. Instr. for Data Acquisition.
	or				
PHY	122A/B	4	WS	80,104A,105A,110B & ‖112 ‖115A	Advanced Physics Laboratory
	Any two of				(all three recommended):
PHY	110L	1	S	45/ECS 36B, ‖110B	Comp. Lab in Electricity and Magn.
	112L	1	F	45/ECS 36B, ‖112	Comp. Lab in Statistical Mechanics
	115L	1	W	45/ECS 36B, ‖115B	Comp. Lab in Quantum Mechanics

†: Instructor permission may be obtained to take PHY 105B without the PHY 40 prerequisite.
Electives: Additional electives to bring the total number of 3-4 unit upper division courses to 14, including at least three from capstone courses. (3-4 courses, totaling 12-16 units with current offerings)
Total Units: 110-112

Table 5: An example schedule satisfying the *proposed requirements* for an undergraduate physics major that takes the 9H series and 122A. Physics course numbers are shown with the number of units in parenthesis. Math courses start with M. Courses in italics are electives or have at least two different offerings per year. Course CAP is a capstone elective, and course X is any advanced elective. Rate is 3-9 physics units per quarter in junior and senior year.

Year	Fall	Winter	Spring
Freshman	9HA(5) *M21B(4)*	9HB(5) *M21C(4)*	9HC(5) *M21D(4)*
Sophomore	9HD(5) *M22A(3)* 40(4)	105A(4) *M22B(3)* 45(4)	105B(4) *104A(4)* *80(4)*
Junior	115A(4) 112+L(5)	115B+L(5) 110A(4)	*115C(4)* 110B+L(5)
Senior	*X(3-4)*	*122A(4)* *CAP(4)*	*CAP(4)* *CAP(4)*

Table 6: An example schedule satisfying the *proposed requirements* for an undergraduate physics major that takes the 9 series and 122A. Physics course numbers are shown with the number of units in parenthesis. Math courses start with M. Courses in italics are electives or have at least two different offerings per year. Course CAP is a capstone elective, and course X is any advanced elective. Rate is 7-13 physics units per quarter in junior and senior year.

Year	Fall	Winter	Spring
Freshman	*M21A(4)*	*M21B(4)*	*M21C(4)* *9A(5)*
Sophomore	*M21D(4)* *9B(5)* 40(4)	*M22A(3)* *9C(5)*	*M22B(3)* *9D(4)* *80(4)*
Junior	*104A(4)* *X(3-4)*	105A(4) 110A(4) 45(4)	105B(4) 110B+L(5)
Senior	115A(4) 112+L(5)	115B+L(5) *122A(4)* *CAP(4)*	*115C(4)* *CAP(4)* *CAP(4)*

Table 7: An example schedule satisfying the *proposed requirements* for an undergraduate physics major that transfers to UC Davis in their junior year, without Physics 9D or 40 equivalents, and takes 122A. Physics course numbers are shown with the number of units in parenthesis. Courses in italics are electives or have at least two different offerings per year. Course CAP is a capstone elective, and course X is any advanced elective. Rate is 12-13 units per quarter. Note that only one upper division course is required in the first quarter of junior year, compared to three upper division courses in the current program.

Year	Fall	Winter	Spring
Junior	9D(4) 40(4) *104A(4)*	105A(4) 110A(4) 45(4)	105B(4) 110B+L(5) *80(4)*
Senior	115A(4) 112+L(5) *X(3-4)*	115B+L(5) *122A(4)* *CAP(4)*	*115C(4)* *CAP(4)* *CAP(4)*

Several new courses have been added, some are no longer offered, and others require changes to their content:

- 9A-D and 9HA-D are largely unchanged, however, some fine adjustments may be needed to ensure that the 9 series plus 104A are sufficient preparation for 112. Also, there are some minor adjustments to the math prerequisites.

- 9HE is no longer offered. This course is effectively an elective, with content that varies from instructor to instructor. By removing it, we allow the students in the honors sequence to start toward the core material sooner, leaving more time for advanced electives. With the more relaxed schedule in their senior year, it seems highly plausible that physics majors will take more advanced electives.

- 104A: This course will now be offered in both fall and spring, as discussed further in the discussion of prerequisites. Most students taking honors physics will take the course in the spring, while most transfer students will take the course in the fall. Two offerings will remove a major bottleneck, result in smaller class sizes, and will allow the course to be pitched slightly differently in these two quarters, to better reflect student preparation.

- 105: The timing of the 105AB sequence is adjusted to start in winter. The content of 105AB should be at a level appropriate for a sophomore completing 9HD in the previous quarter. There is no prerequisite for 104A, but typically students will take 104A either concurrently with 105B or before 105A.

- 110: The present curriculum devotes three quarters of required upper division course work to Electricity and Magnetism (110ABC). This proposal eliminates 110C and increases the pace of 110AB. Students must reliably enter 110 having adequate preparation in vector calculus, curvilinear coordinates, Lorentz transformation, relativistic mechanics, and introductory electricity and magnetism. This material must be covered adequately in the 9 series and 104A.

- 112: The 115A prerequisite for 112 has been removed, and the treatment must rely on quantum from the PHY 9 series instead. PHY 9 and 9H must both reliably cover discrete energy levels from the particle in a box and simple harmonic oscillator. Fermi and Bose statistics will need to be introduced independently in 112.

- The 115AB sequence is extended to include an elective third quarter: 115C. The prerequisites are 104A and 105A. The elective third quarter, 115C, adds 45 as a prerequisite, and the course includes extensive computational problems. The extra time should also allow coverage of new elective topics (for example Quantum Information Theory).

- 45, 110L, 112L, and 115L: PHY 45 is a new required four-unit course in computational physics. Students are also required to take at least two of three new one-unit computing lab courses 110L, 112L, and 115L. These courses are discussed in more detail in Section **??**.

- 102 and 104B: these computational courses will no longer be offered and will no longer be required for any major.

- The 116ABC sequence adds PHY 80 as a prerequisite and is reduced to a two quarter sequence 116AB. In the current program, there is significant duplication of PHY 80 content in PHY 116A and PHY 116C, so no content is lost in this reorganization. The lab courses are discussed in detail in Section 7.

Example syllabi for the new required courses and existing courses affected by this proposal are presented in Section 12.

This proposal is approximately neutral with respect to the cost of instruction if we assume that the cost of electives is held constant (we of course have no obligation to do so.) The second offering of 104A, the new required course 45, and the new required one unit computing labs add a total of three new instructors. But dropping courses 9HE, 102, 104B, 110C and 116C frees 4.3 instructors, for a net decrease of 1.3 instructors. If the need for more sections of 80 requires an additional instructor (currently typically two, although three were initially planned for 2020-2021) there would be a decrease of 0.3 instructors. Additional fall offerings for 122A/B could be added as well, if needed to meet demand.

5 Theoretical Physics

At the core of any undergraduate physics degree are the following topics in theoretical physics:

- Classical Mechanics (105AB): the fundamental principles of physical laws (e.g. least action and symmetries) are taught in a familiar and intuitive context.

- Electromagnetism (110AB): a remarkable special case of classical phenomenon that anticipates non-Newtonian physics (e.g. special relativity, gauge theories). No other force in nature can be understood so completely in such a straight forward fashion.

- Quantum Mechanics (115AB): the rules governing the microscopic world are different from those governing our familiar macroscopic world. The rules are not intuitive but they can be codified and used to make quantitative predictions which can be experimentally verified.

- Statistical Mechanics (112): provides the crucial statistical explanation for how microscopic laws ultimately produce the macroscopic world which we inhabit.

This proposal includes a procedure for maintaining example syllabi for the core courses to ensure these topics are being consistently and effectively covered. While this proposal need not resolve all of the issues, a digest of the current discussion is provided here:

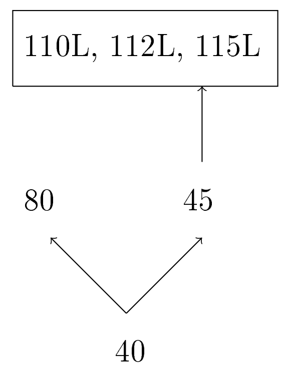

Figure 1: Prerequisite structure of computational courses.

- It is generally agreed that 105A needs to cover Hamiltonian mechanics, but this has not been managed reliably.
- We need to find a consistent location to cover the calculus of variations.
- There is support for covering waveguides in 110AB. Waveguides are a possible topic for 110L (not taken by every student) They could also be added to 80 with an experimental focus (which will be taken by every student).
- The treatment of radiation in 110AB is limited.
- PHY 104A plays a central role in providing students with the analytic techniques needed for upper division course work. This course has been far too topical for the central role it plays in our program.
- While this proposal doesn't include any changes to PHY 115AB, but we should develop and discuss example syllabi for this course along with the other core courses.

Example syllabi are presented in Section 12.

6 Computational Physics

One of the major objectives of this proposal is to better integrate computational physics throughout the curriculum. To do so, students must have a consistent set of tools that can be relied upon in later courses. The course descriptions in the course catalog will not reference specific tools, to allow this to evolve over time, but in a consistent manner. In this proposal, the supported computational tools are:

- Scientific computing tools for Python: NumPy, SciPy, MatPlotLib, and Jupyter Notebooks via Anaconda
- C/C++
- Computer Algebra: Mathematica or SymPy

The entire Scientific Python ecosystem is easily accessible to students for any major OS for free through Anaconda. No graphical features of C/C++ will be explored. If necessary, C++ programs will pass data by text file to SciPy for plotting. SymPy is not as mature as Mathematica, but comes with the significant advantages of being freely available within Anaconda and interoperable with SciPy.

In 2018, we added a new required course, PHY 40, which introduces programming with both C++ and python. This format leaves no time for symbolic computation and little time for exploring additional features of Scientific Python beyond the basic Python language. This proposal modifies the computational content of existing courses and adds several new required courses:

- 40: This four-unit course, which has no prerequisites and assumes no prior knowledge of programing, provides an introduction to programming using examples from computational physics. It includes a short introduction to symbolic manipulations using a computer algebra system. The specific tools covered (which will not be included in the course description) are Scientific Python and either SymPy or Mathematica.

- 45: This new four-unit course, Computational Physics, will have the PHY 9 series through E&M as a prerequisite (9C/9HD) as well as PHY 40. PHY 45 will replace the requirement for 102 or 104B. The focus will be on solving physics problems at the conceptual level of the 9 series using computational physics. It will introduce the C++ programming language and continue using Scientific Python.

- 80: is a new four-unit lab course introduced in 2018 which includes extensive use of scientific python for data analysis and presentation, including curve fitting and plotting scientific data. In this proposal, 80 is required for all majors. It adds 40 as a prerequisite, but with an exception intended for AB majors as described in Section 11.

- 110L, 112L, and 115L: These three new one-unit computational lab courses are designed to be taken concurrently with 110B, 112, and 115B. They are computational problem solving labs related to E&M, statistical mechanics, and quantum mechanics. The emphasis will be on solving problems from upper division physics using computing at the level of PHY 45. One unit courses should involve three hours of academic work per week as described below. One instructor could teach all three of these courses in a single year, which would count toward instructor workload as a single three unit course. Each course is offered in a different quarter, so students get three units of computational problem-solving spread across an entire year. Due to unit limits, we only require two of these courses, but all three are recommended.

- 105B: this course now has PHY 40 as a prerequisite and can therefore include computational problems in mechanics using Scientific Python or computer algebra.

- 115C: This new elective course has PHY 45 as a prerequisite and is intended to include extensive computational problem solving as an integral part of the course.

Physics BS majors will be required to take 18 units (23 recommended) of course work that involves extensive computing exercises. Furthermore, once student computing abilities are on more solid ground, capstone and advanced elective courses could further evolve to include additional computing exercises and add 45 (or at least 40) as a prerequisite. All applied majors include 45 or an equivalent, so, for example, even 140A could include a computational component.

One-unit workload: It is important that 110L, 112L, and 115L are taught as one-unit courses. A one-unit course should involve three hours of total academic work per week, which in this case includes the one hour of scheduled lecture time. For example, an appropriate workload would be five computing assignments due every two weeks during the ten week quarter. Each assignment would be introduced with a one-hour lecture, with a second one-hour lecture devoted to helping students complete the assignment. The assignments should take about five hours to complete, including one hour of help.

7 Lab Course Work

In traditional lab courses, students conduct scientific experiments, gain crucial hands on experience, and see theoretical concepts from a new perspective. The unit cap on required coursework places extreme time pressure on these essential lab experiences: BS physics majors are only required to take four units of upper division traditional lab work, although many opt to take more.

Physics 80 was introduced in 2018, and is currently a prerequisite for Physics 122A/B. It is anticipated that this will relieve some of the intense time pressure in these courses. The 122 labs cycle students through experimental stations, and enrollment in each quarter is limited by the number of available stations. This proposal makes some adjustments to the prerequisites of 122A/B which would allow for fall offerings. This will help meet the expected increase in demand for 122A/B due to increased enrollment. As can be seen in Table 5, many seniors have room to take 122A/B in the fall of their senior year. We also plan to add additional stations to 122A/B, which is independent from this proposal.

In this proposal, Physics 80 is also added as a prerequisite for the 116 (Instrumentation) sequence as well. Physics 80 covers some of the content in current versions of 116A (passive analog electronics) and 116C (computation with scientific python and statistical analysis). Therefore, the three quarter 116 sequence (A,B, and C) becomes a two quarter sequence, with 116A covering analog and digital electronics, and 116B covering data acquisition with microprocessors and FPGAs. For additional flexibility, 116B no longer has 116A as a prerequisite, as sufficient analog electronics is covered in 80.

Physics 80 and 116 share the same dedicated lab space. The primary time for taking 80 will be in spring quarter, but it will also be offered in fall, and possibly winter, while 116A and 116B will be offered in fall and winter respectively. The department plans to expand the lab space available for 80 and 116 to meet the needs of increase enrollment.

8 Prerequisites

An overview of the prerequisite structure is shown in Fig. 2. The graph reveals 104A as a major bottleneck in our program, as it requires the most advanced material from the first tier (MAT 22) but is required for most upper division classes, such as 110A and 115A. The committee spent a great deal of time considering different ways to relieve or accommodate this bottleneck but in the end decided two offerings is the only effective way to achieve the goals of this proposal. This stems from the fact that incoming transfer students must start on 104A immediately upon arrival in fall to complete the remaining upper division courses in two years, but sophomores finishing 9HD in the fall are not generally ready to take 104A until the spring.

It appears from the graph that 45 is a potential bottleneck as well, but it is less severe. It does not require MAT 22A so can be taken sooner than 104A, and it is only needed for top tier courses such as 115C and the computational lab courses, which can be postponed until senior year.

The most notable changes to the prerequisite structure are:

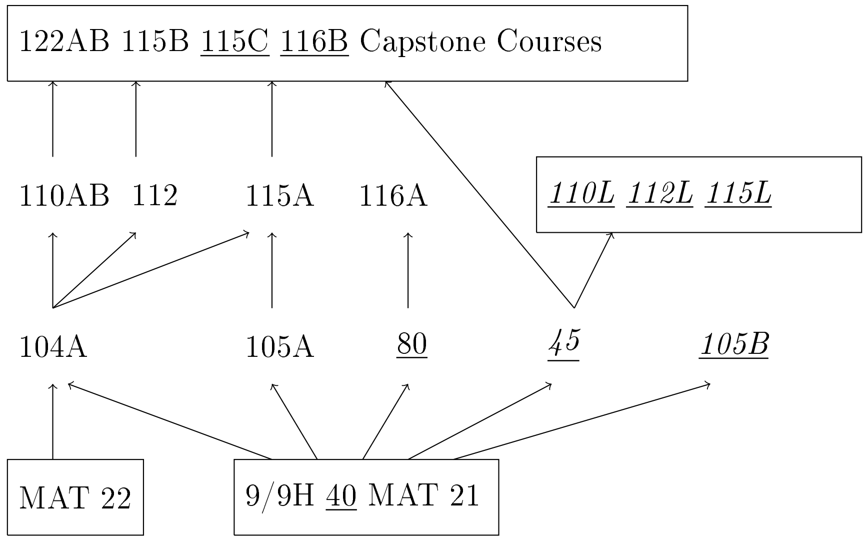

Figure 2: NEEDS WORK??? Consider adding years... The prerequisite structure of physics and related math courses. Courses within a box may have an internal prerequisite structure not shown. For clarity, in some cases only the most advanced prerequisites are shown. Prerequisites within a sequence (e.g. 112L has concurrent prerequisite with 112) are not shown. All required courses are shown. Underlined courses have a significantly computational component. Italicized courses are required for a BS in Physics but can be safely omitted from the Astrophysics major, as they do not serve as prerequisites for other required courses in that major.

- 80 adds 40 as a prerequisite, with an exception for AB majors as described in Section 11.
- 112 does not require 115A anymore, 104A and 9A-D must suffice instead.
- 110A does not require 105A anymore.
- 105B requires 40, so computational examples can be used in this course.
- 122A/B adds a 115A prerequisite, which was implicit when 115A was a prerequisite for 112. Both 112 and 115A are allowed to be concurrent, which will not be possible unless we add a fall offering of 122.

The new prerequisite structure is considerably more flexible. In the junior year of Tables 30 and 7 missing or failing 104A or 105A jeopardizes a timely graduation, but instructor permission from one course (110A or 115A) will allow the student to proceed on schedule. The situation in Table 5 is even more forgiving.

9 Proposed BS with Specialization in Astrophysics

The Astrophysics specialization requires updates to the prerequisites for PHY 151-158, mainly to accommodate the new schedule which offers PHY 105A in the fall and to add PHY 40 as a new required course. The Astrophysics specialty courses now include 158, for a total of five, from which four are chosen. Limits on the number of units precludes including PHY 45, and the related lab courses, to the program. However, the PHY 151-158 courses have already begun to include extensive computational physics directly related to astrophysics.

The proposed required courses for the Astrophysics specialization are presented in Tables 8 and 9. To avoid version conflicts, some information in Tables 3 and 4 is not duplicated in these tables. Example schedules are presented in Table 10.

Table 8: Preparatory Subject Matter: Astrophysics and Applied Physics

Units: 49-50. *: recommended, ‖: concurrently.

Course		Units
MAT	21A	4
	21B	4
	21C	4
	21D	4
	22A	3
	22B	3
PHY	9A	5
	9B	5
	9C	5
	9D	4
	or	
PHY	9HA	5
	9HB	5
	9HC	5
	9HD	5
PHY	40	4
	80	4
PHY	185*	1
	190*	1

Table 9: Depth Subject Matter: Astrophysics

Units: 60-64. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
PHY	104A	4			
	105A	4			
	108	3	S	9D/9HD	Optics
	108L	1	S	‖108	Optics Laboratory
	110A	4			
	110B	4			
	112	4			
	115A	4			
	115B	4			
PHY	157	4	S#	(Same as 122A/B)	Astronomy Instrumentation and Data Analysis Lab
	or				
PHY	122A/B	4			Advanced Physics Laboratory
	Choose four of				
PHY	151	4	F#	‖40,‖104A	Stellar Structure and Evolution
	152	4	F#	‖40,‖104A	Galactic Structure and the Interstellar Medium
	153	4	W#	40,104A,‖105A	Extragalactic Astrophysics
	156	4	W#	40,104A,‖105A	Introduction to Cosmology
	158	4	S	40,104A,105A	Galaxy Formation
	Any two of				:
PHY	105B	4			
	116A	4			
	116B	4			
	129A	4			
	130A	4			
	130B	4			
	150	4			Special Topics
	154	4	S#	40,105B,110B,115A	Astro. Appl. of Phys.
	155	4	W	104A,105B,110A	General Relativity
GEL	163	4			Planetary Geology and Geophysics
	At most one of				
PHY	194HAB	8			Special Study for Honors Students
	195	5			Senior Thesis
	199	4-5			Special Study for Adv. Undergrads.

Note: PHY108 has alternative prerequisites (PHY 7C and 21D) intended for non-majors. PHY 150 must be an astro topic and requires prior department approval.
Total Units: 109-114

Table 10: An example schedule for the junior and senior year of an Astrophysics major. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives. In most cases, the 9D requirement is satisfied before the junior year. The upper table starts with PHY 151 and the lower with 152.

Year	Fall	Winter	Spring
Junior	40 104A 151# (9D)	105A 110A 153#	80 110B *105B/150*
Senior	115A 152# 112	115B 156# *130A/155/GEL 163*	108+L 157/122A/B *158#/129A/130B*

Year	Fall	Winter	Spring
Junior	40 104A 152# (9D)	105A 110A 156#	80 110B *105B/158#*
Senior	115A 151# 112	115B 153# *130A/155/GEL 163*	108+L 157/122A/B *154#/129A/130B*

10 Proposed Applied Physics majors

The Applied Physics majors require the preparatory courses in Table 8 and the depth courses listed in Table 11. Together, these required courses account for 73-74 units, leaving 37 credits for concentration courses as detailed in the following tables. This proposal includes modifications to all of the Applied Physics majors:

- All Applied Physics majors now require PHY 40, 45, and 80, two computing labs (from 110L,112L, and 115L), and two upper division lab courses (from 122A/B, 116A, and 116B), except where noted.

- The Computational Physics major does not require PHY 45 and ECS 36B now satisfies the prerequisite for the computing labs. The elective choices from ECS have been extended. See Table 12.

- The Physical Electronics major does not include 116AB as part of the upper division lab requirement, only 122A/B is required. The major includes a large amount of electronics from the EEC department. Due to unit limits, only one computational lab is required. See Table 13.

- The Materials Science major is renamed Materials Physics, and the elective choices for have been extended. Students may use one EMS lab course to satisfy their requirement for two upper division lab courses. See Table 15.

- In the past, the Atmospheric Physics major required the Physical and Chemical Oceanography course (GEL 150A), which now has extensive prerequisites that would exceed the unit limit. The Oceanography thrust of this course has been relocated to the electives, including the more easily obtained (GEL 116N). The list of Atmospheric Physics electives has been extended. See Table 16.

- The Physical and Chemical Oceanography course (GEL 150A) is not offered every year and now has extensive prerequisites. Therefore, the Physical Oceanography major might not be achievable in two years for students that have not already satisfied these prerequisites. The prerequisites for reaching GEL 150A are now included in the concentration courses. See Table 17. Additional example schedules are provided in Tables 18 and 19.
- The Chemical Physics major requires 15 credits of lower division General Chemistry course work which severely limits the number of upper division course that can be required in this major. The course requires 115B and 140A as concentration courses. See Table 20.

These proposed updates to the Applied Physics majors are narrowly focused on the new required courses and prerequisite structure, with some essential updates for changes to courses outside the department. Some of the majors, particularly Chemical Physics, might benefit from more extensive and targeted revisions, which will be considered after the new program is implemented.

Table 11: Depth Subject Matter: All Applied Physics Majors

Units: 24.

Course		Units
PHY	104A	4
	105A	4
	110A	4
	110B	4
	112	4
	115A	4

Table 12: Computational Physics

Additional Preparatory Courses:
Units: 12 units. *: recommended, #: not offered every year, ‖: concurrently.

Course		Units	Offered	Prereqs	Name
ECS	36A	4	FWS		Programming and Problem Solving
	36B	4	FWS		Software Dev. and OOP in C++
	36C	4	FWS		Data Structures, Algorithms, and Programming

Concentration Courses:
Units: 17 units. *: recommended, #: not offered every year, ‖: concurrently.

Course		Units	Offered	Prereqs	Name
	122A	4	FWS		Algorithm Design & Analysis
	Choose one of				
	110L	1			
	115L	1			
	112L	1			
	Choose one of				
ECS	120	4	FWS		Theory of Computation
	122B	4	WS		Algorithm Design & Analysis
	132	4	FWS		Probability & Stat Modeling
	171	4	F		Machine Learning
	Choose two of				
PHY	122A/B	4			
	116A	4			
	116B	4			

Additional Electives: (8 units) Two courses for a total of at least 8 units of additional upper division course work from ECS, MAT, or PHY.
Total Units: 110-111

Example schedule: In most cases, the 9D requirement is satisfied before junior year, but an example including 9D is included. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives.

Year	Fall	Winter	Spring
Junior	ECS 36A 40 104A	ECS 36B 105A 110A	ECS 36C 80 110B+L (9D)
Senior	ECS 122A 112 115A	*ECS 122B/120/132* *116B* *140A*	122A *140B*

Table 13: Physical Electronics

Additional Preparatory Courses:

Units: 8 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
ENG	17	4	FWS		Circuits I
PHY	45	4			

Concentration Courses:

Units: 29 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
EEC	100	4	FW		Circuits II
	115B*	4			
	140A	4			
	140B*	4			
	122A/B	4			
	Choose one of				
	110L	1			
	115L	1			
	112L	1			
	Choose four of				
EEC	110A	4	WS		Electronic Circuits I
	110B	4	S		Electronic Circuits II
	140A	4	FW		Principles of Device Physics I
	140B	4	S		Principles of Device Physics II
	150A	4	WS		Intro. to Signals & Systems I
	150B	4	F		Intro. to Signals & Systems II

Total Units: 110-111

Table 14: Example two-year schedule for Physical Electronics major: In most cases, the PHY 9D and ENG 17 requirements are satisfied before the junior year, but the first example shows how those courses can be accommodated. The second example considers a student that completed PHY 9HD,40,45,80, 105A and ENG 45 prior to their junior year. A particular feature of this major is the ability to take graduate courses in the senior year. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives.

Year	Fall	Winter	Spring
Junior	(ENG 17) 40 104A	EEC 100 45 110A 105A	(9D) 80 110B+L
Senior	112 115A *EEC 140A*	140A *EEC 110A* *EEC 150A*	122A/B *EEC 110B* *EEC 245/249*
Junior Junior	104A EEC 100	110A *EEC 110A* *EEC 140A*	110B+L *EEC 110B* *EEC 140B*
Senior	112 115A *EEC 210/240*	140A 115B *EEC 212/243*	140B 122A/B *EEC 245/249*

Table 15: Materials Physics

Additional Preparatory Courses:
Units: 8 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
PHY	45	4			
ENG	45	4	FWS		Properties of Materials

Concentration Courses:
Units: 29-33 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
	115B	4			
	140A	4			
	140B	4			
	Choose two of				
	110L	1			
	115L	1			
	112L	1			
	Choose two of				
EMS	162	4	W		Structure & Characterization
	160+164	7	F+W		Thermo+Kinetics
	170	4	S		Sustainable Energy
	172	4	F		Smart Materials
	174	4	S		Mech. Behavior of Materials
	180	4	F		Materials in Eng. Design
	Choose two of				
PHY	122A/B	4			
	116A	4			
	116B	4			
	at most one of				
EMS	162L	3	W		Structure & Characterization Lab
	170L	3	S		Sustainable Energy Lab
	172L	3	F		Smart Materials Lab
	174L	3	S		Mech. Behavior of Materials Lab

Total Units: 110-115

Example schedule: In most cases, the PHY 9D and ENG 45 requirement is satisfied before the junior year, but an example including these courses is shown. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives.

Year	Fall	Winter	Spring
Junior	40 104A (ENG 45)	45 110A 105A	80 110B+L (9D)
Senior	112+L 115A *EMS 180*	140A 115B 116B	140B 122A *EMS 174*

Table 16: Atmospheric Physics

Additional Preparatory Courses:
Units: 8 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
PHY	45	4			
GEL	50*	3	FWS		Physical Geology
ATM	60	4	F		Intro. to Atmospheric Sci.

Concentration Courses:
Units: 28-30 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
ATM	120	4	F		Atmos. Thermo. and Cloud Physics
	121A	4	W		Atmospheric Dynamics
	121B	4	S		Atmospheric Dynamics
	Choose two of				
	110L	1			
	115L	1			
	112L	1			
	Choose two of				
PHY	122A/B	4			
	116A	4			
	116B	4			
	Choose two of				
PHY	105B	4			
	105C	4	#		Continuum Mechanics
GEL	116N	3	S	GEL 50	Oceanography
	150A	4	S#	GEL 116N,55	Physical and Chemical Oceanography
	150B	3	W	GEL 50	Geological Oceanography
ATM	124	3	F	ATM 60	Meteorological Instruments & Observations
	128	4	W		Radiation and Satellite Meteorology
	158	4			Boundary-Layer Meteorology

Total Units: 109-112

Example schedule: In most cases, the PHY 9D and GEL 50 are taken before the junior year, but an example including these courses is shown. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives.

Year	Fall	Winter	Spring
Junior	40 104A ATM 60 (9D)	45 105A 110A (GEL 50)	80 *105B* 110B+L
Senior	ATM 120 112+L 115A *ATM 124*	ATM 121A 140A 115B 116B	ATM 121B 140B 122A

Table 17: Physical Oceanography

Additional Preparatory Courses:
Units: 15 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
CHE	2A	5	FW		
PHY	45	4			
GEL	50	3	FWS		Physical Geology
	55	3	F	CHE 2A	Intro. to Geochemistry

Concentration Courses:
Units: 20-21 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
GEL	116N	3	S	GEL 50	Oceanography
	150A	4	S#	GEL 116N,55	Physical and Chemical Oceanography
	Choose two of				
	110L	1			
	115L	1			
	112L	1			
	Choose two of				
PHY	122A/B	4			
	116A	4			
	116B	4			
	Choose one of				
PHY	105B	4			
	105C	4	#		
GEL	150B	3	W	GEL 50	Geological Oceanography

Total Units: 108-110
Note: For transfer students arriving in their junior year, this degree may not be possible to complete in two years. Students should seek instructor permission to take GEL 150A alongside 116N prerequisite if it is offered in their junior year.

Example schedule: In most cases, the PHY 9D, CHE 2A, and GEL 50 requirements will be satisfied before the junior year, but an example including these courses is shown. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives.

Year	Fall	Winter	Spring
Junior	40 104A (CHE 2A) (9D)	45 105A 110A (GEL 50)	80 110B+L GEL 116N
Senior	GEL 55 112+L 115A	*GEL 150B* *116B*	GEL 150A *122A*

Table 18: Example two-year schedule for Physical Oceanography major: This schedule assumes student took CHE 2A, GEL 50, and PHY 9D before the Junior year, and student receives instructor permission to take GEL 150 concurrently with GEL 116N. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives.

Year	Fall	Winter	Spring
Junior	40 104A GEL 55	45 105A 110A	110B+L GEL 116N GEL 150A
Senior	80 112+L 115A	*GEL 150B* *116B*	 *122A*

Table 19: Example four-year schedule for Physical Oceanography major. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives. If GEL 150A is not offered in junior year, it can be taken in senior year.

Year	Fall	Winter	Spring
Freshman	MAT 21A CHE 2A	MAT 21B GEL 50	MAT 21C 9A
Sophomore	MAT 21D 9B GEL 55	MAT 22A 9C	MAT 22B 9D GEL 116N
Junior	40 104A	45 110A 105A	80 110B+L GEL 150A
Senior	115A 112+L	GEL 150B	

Table 20: Chemical Physics

Additional Preparatory Courses:
Units: 19 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
CHE	2A	5	FW		General Chemistry
	2B	5	WS		General Chemistry
	2C	5	FS		General Chemistry
PHY	45	4			

Concentration Courses:
Units: 17 units. *: recommended, #: not offered every year, ||: concurrently.

Course		Units	Offered	Prereqs	Name
CHE	124A	3	F		Inorganic Chemistry
	110BC*				Physical Chemistry
	128ABC*				Organic Chemistry
	129A*				Organic Chemistry Lab
	210B*				Quantum Chemistry
EMS	147*				Principles of Polymer Materials Science
	115B	4			
	140A	4			
	140B*	4			
	Choose two of				
	110L	1			
	115L	1			
	112L	1			
	Choose one of				
PHY	122A/B	4			
	116A	4			
	116B	4			

Total Units: 109-110

Example schedule: In most cases, the PHY 9D and CHE 2 requirements are satisfied before the junior year, but an example including these courses is shown. Physics course numbers are shown unless otherwise indicated. Courses in italics are electives.

Year	Fall	Winter	Spring
Junior	(CHE 2A) 40 104A (9D)	(CHE 2B) 45 110A 105A	(CHE 2C) 80 110B+L
Senior	112+L 115A CHE 124A	140A 115B 116B	122A

11 Proposed AB Physics Major

The proposed requirements for the AB Physics major are listed in Tables 21 and 22. To avoid version conflicts, some information in Tables 3 and 4 is not duplicated in these tables.

The AB degree has a cap of 80 units of which at least 36 must be upper division. This imposes an effective limit of 44 units of lower division course work, which includes all prerequisites. The current degree requirements include 46 units of lower-division course work and therefore exceed the cap by two units. This proposal adds PHY 40 as a prerequisite for PHY 80, which would add four more units of required lower division course work to this major. For this reason, PHY 80 may be taken without PHY 40 *with instructor permission*. AB majors will be encouraged to take 40, but to accommodate those who do not, PHY 80 students who have not taken PHY 40 will be paired with a lab partner who has. The current AB degree requires 82 units, which was approved by the Education Policy Committee in the past despite exceeding the cap. This proposal requires 81 units for the AB, which still exceeds the cap, but by one less unit than the current requirements.

In case the campus does not approve this major because of the one unit excess, our fallback will be to allow students to choose either the optics lab (108+108L) or 122A/B (recommended) for a lab experience. This provides a path that does not require 80 and 40 and therefore remains below the 80 unit cap. However, this solution would significantly weaken the effectiveness of this major, as there would be no way to ensure that students take 80 and 122A/B, which provide essential lab experience.

Table 21: Preparatory Subject Matter

Units: 45-51. *: recommended, || concurrently

Course		Units	Offered	Prereqs	Name
MAT	21A	4			
	21B	4			
	21C	4			
	21D	4			
	22A	3			
	22B	3			
PHY	9A	5			
	9B	5			
	9C	5			
	9D	4			
	or				
PHY	9HA	5			
	9HB	5			
	9HC	5			
	9HD	5			
PHY	40*	4	F		Introduction to Physics Computation
	80	4	WS	40†,9C/9HD	Experimental Techniques
PHY	185*	1			
	190*	1			

†: Instructor permission may be obtained to take PHY 80 without the PHY 40 prerequisite.

Table 22: Depth Subject Matter

Units: 32-35. *: recommended, ||: concurrently.

Course		Units
PHY	104A	4
	105A	4
	110A	4
	110B	4
	112	4
	115A	4
PHY	122A/B	4
PHY	110L*	1
	112L*	1
	115L*	1
	At least one of	
PHY	129A	4
	130A	4
	140A	4
	151	4
	152	4
	153	4
	156	4
	158	4

Electives: Additional electives to bring the total number of 3-4 unit upper division courses (excluding PHY 160) to at least 36 units.
Foreign Language: The AB degree requires proficiency in a language other than English (15 units)
Total Units: 81-90 units, excluding language requirement.

12 Example Course Syllabi

This section contains example syllabi for new courses and existing courses impacted by this proposal. The first paragraph for each course is a brief description suitable for the course catalog, and is generally much less specific than the details that follow. This is to allow some flexibility to maintain the course content within the department without contradicting the course catalog.

Instructors are expected to satisfy the brief course description as listed in the course catalog, but are not obliged to follow the detailed example syllabi shown here. However, many of these courses are prerequisite courses, so instructors are expected to consider how their course content decisions will impact downstream courses.

The specific computational tools (e.g. Scientific Python, C++) will not be included in the course catalog description. This is to allow the department some flexibility to evolve independently over time. However, the choice of tool set needs to be coordinated throughout the department. It would be extremely disruptive if the instructor for PHY 40 or 45 made changes to the tool set without coordinating with the rest of the department. Specific details about the current computational tool set will be publicly available on the department website, including guidance for installation.

PHY 40 — Introduction to Computational Physics (4): Introduction to programming with examples from numerical analysis and computational physics. Introduction to modern tools used for scientific analysis and computer algebra.

The language for this course will be Python/Anaconda, with some symbolic manipulation via Mathematica or the developing Python equivalent (SymPy). The supported operating systems will be Windows, MacOS, and Linux. The course introduces the Python language and the Scientific Python ecosystem in the context of an introduction to numerical analysis. The major topics of numerical analysis are introduced with the most elementary of algorithms, for example numerical integration via Newton-Cotes methods (e.g. Simpson's rule) are covered, but Gaussian Quadrature methods are not. The Scientific Python tools, which generally implement more sophisticated algorithms, can then be used with a basic understanding of how they work. This approach minimizes formal pedagogy, so that the students can learn by coding themselves. This course has no prerequisites, but most of the elementary techniques are intuitively graphical. For example, Simpson's method of integration can be easily explained as estimating the area under the curve. Whenever possible, special cases with analytic solutions are used to validate the numerical approach.

There are a surprising large number of excellent textbooks, some dated and many quite recent, in computational physics. These syllabi use Gezerlis for references when possible because the textbook is available as a PDF from the UCD library. Giordano is a particularly excellent source for approachable problems.

The core course content is:

- Python language elements: variables, conditionals, loops, input and output, and lists. Taught through a series of simple math problems: from arithmetic, geometric and Taylor series, to the quadratic equation. (6 hours)

- Scientific Python ecosystem: numpy, matplotlib, scipy including 1-D arrays, plotting, and numerical analysis tools. Taught as encountered.

- Fundamental limits to numerical analysis: representation of numbers on computers, errors from approximation and round-off. (2 hours) [Gezerlis 2]

- Differentiation: Finite difference and error estimation, scipy tools. (2 hours) [Gezerlis 3.3]

- Integration: Newton-Cotes methods, scipy tools (2 hours) [Gezerlis 7.2]

- Roots: bisection, Newton's method, secant method, scipy tools. (2 hours) [Gezerlis 5.2.4-5.2.6]

- Monte Carlo: Quadrature, scipy tools (2 hours) [Gezerlis 7.7.2]

- Ordinary Differential Equations: Euler and Verlet/Leap frog methods, Mass on spring with damping, Euler-Cromer Kepler problem (5 hours) [Gezerlis 8.2, Giordano 4.1]

- Computer Algebra (5 hours): Mathematica or SymPy

- Analytic solutions to special cases are calculated and used throughout the course to validate the numerical approach.

The time allocated for core material is generous, which should leave room for topical material. Example topical approachable material:

- Cellular Automata: Game of Life

- Sorting: Bubble sort, Merge Sort, scipy tools
- Chaos: Logistics Map, Period Doubling
- Fractals: Mandelbrot Set
- Fourier Series: visualization for square wave
- Simulating Musical Instruments (Giordano 11)

PHY 45 — Computational Physics (4): Algorithms and programming techniques used in computational physics with examples from introductory physics.

This course will continue to use Python/Anaconda, but will also introduce the C/C++ language. The supported operating systems will be Windows, MacOS, and Linux. The algorithms and problems considered will be more sophisticated than in PHY 40 taking advantage of the fact that students have completed at least PHY 9C/9HD, MAT 21D, and MAT 22A sequences. As some students will be taking MAT 22B concurrently, the more challenging differential equation related material should be left until the second half of the course.

The core material is:

- C/C++ language elements: variables, conditionals, loops, input and output, arrays and pointers. Taught through a series of computing tasks as in 40. (6 hours)
- Continued use of Scientific Python, particularly for plotting and matrices. Some problems will be solved twice: once in Python and once in C++. Taught as encountered.
- Matrices: Linear Algebra, Eigenvalues and Eigenvectors [Gezerlis 4] (3 hours)
- Molecular Dynamics: Direct Simulation [Giordano 9] (2 hours)
- Monte Carlo Techniques: Pseudo-random Numbers, Inverse Transform Sampling, Importance Sampling, Random Walks [Gezerlis 7.7.1-7.7.4, Giordano 7] (3 hours)
- Ordinary Differential Equations: Runge-Kutta, Shooting Method [Gezerlis 8.2-3] (3 hours)
- Partial Differential Equations: Diffusion, Relaxation [Garcia 6,8] (3 hours)
- Fourier Analysis: Spectral methods [Gezerlis 6.4.1-6.4.3, Garcia 8.2] (4 hours)

This leaves plenty of time for topical problems, such as:

- Projectile motion with air resistance [Giordano 2.2] (ODEs)
- Chaos in the Driven Nonlinear Pendulum [Giordano 3.2] (ODEs)
- Extensions to the Kepler problem: precession and Kirkwood gaps [Giordano 4.3, 4.5] (ODEs)
- Charged particle in a magnetic field via Runge Kutta (ODEs)
- Kinetic energy of particle in a box [Gezerlis 3.4] (Differentiation)
- Normal modes of a mass/spring/pendulum system (Matrices)

- Eigenvalues of the Schrodinger equation [Gezerlis 4.5] (Matrices)
- Shooting Method Solution to Schrodinger Equation [Giordano 10.2] (QM / ODE)
- Relaxation Method for solving Laplaces's Equation [Giordano 5.1] (EM / PDEs)
- Manhattan Project, critical mass [Garcia 6.3] (Diffusion / PDEs)
- Direct simulation of an Ideal Gas [Giordano 9] (SM / Molecular Dynamics)
- Analytic solutions to special cases are calculated and used throughout the course to validate the numerical approach.

PHY 80 — Experimental Techniques (4): Experimental techniques. Design of circuits. Data analysis, sources of noise, statistical and systematic uncertainties. Light sources, detection, and measurement in basic optical systems.

PHY 80 uses Scientific Python for data analysis. With PHY 40 added as a prerequisite, this component can be more ambitious:

- Plotting and Curve fitting (Current focus)
- Fourier Analysis: discrete sampled data and Shannon-Nyquist, periodogram (New)
- Monte Carlo: generating simulated experimental data. (Expand)
- Machine Learning (Optional)

PHY 104A — Introductory Methods of Mathematical Physics (4): Introduction to the mathematics used in upper division physics courses, including applications of vector spaces, Fourier analysis, partial differential equations.

This course includes review of some material from MAT 21D and MAT 22AB, In particular, instructors teaching 104A should coordinate with the instructor for 110A to ensure that vector calculus is being adequately covered. The amount of time devoted to review can be adjusted in the fall and spring offerings to best suit the class composition, which will be predominantly students from the PHY 9 series, including transfer students, in the fall, versus 9H students in the spring. Textbook: Mathematical Methods in the Physical Sciences, 3rd Edition by Mary L. Boas. It might be beneficial to leave vector analysis until the end of course, as many students will start 110A in the following quarter. Note that treatment of Fourier Transforms is restricted to the limit of the Fourier Series as the period becomes infinite.

Example coverage:

- Quick Review of Complex Numbers (Ch. 2) (as needed - 1.5 hour)
- Quick Review of Sequences and Series, including Taylor (1.1-1.15) (as needed - 1.5 hour)
- Linear Algebra (3.6-3.12,3.14,12.6) (6 hours)
- Fourier Series and Transforms (7.1-7.12) (6 hours)
- Dirac Delta Function (8.11) (1.5 hours)
- Legendre Series (12.1-12.10) (3 hours)
- Partial Differential Equations (Intro+13.2) (3 hours)
- Series Solutions to PDEs (13.3-13.8) (3 hours)
- Review of Vector Calculus (Ch. 6) (important for 110A - 3 hours)

PHY 104B — Intermediate Methods of Mathematical Physics (4): Continuation of 104A. Contour Integration, Fourier Transforms, and other topics in Mathematical Physics.

This is more topical than PHY 104A, but some topics should be routinely covered:

- Contour Integration (Ch. 14)
- Fourier Transforms

while others are at the discretion of the instructor:

- Tensors (Ch. 10)
- Group Theory
- Green Functions
- Probability and Statistics (Ch. 15)

PHY 110A — Electricity & Magnetism (4): Theory of electrostatics, magnetostatics, electrodynamics and radiation.

The first quarter of 110 focuses on electrostatics and magnetostatics (Griffiths 1-6). An example schedule:

- Week 1: quick review on vector analysis, Coulomb's law, Gauss's law, electric potential (2.1,2.2, 2.3)
- Week 2: electric energy, conductors, image method (Cartesian only) (2.4, 2.5, 3.2)
- Week 3: Laplace's equation (Cartesian) (3.1, 3.3.1)
- Week 4: Laplace's equation (spherical only), multipole expansion (3.3.2, 3.4)
- Week 5: dipole in E, polarization, bound charge (4.1, 4.2)
- Week 6: displacement field (4.3)
- Week 7: review of Lorentz force, Bio-Savart, Ampere's law (5.1, 5.2, 5.3)
- Week 8: magnetic potential, multipole expansion, dipole in B (5.4, 6.1)
- Week 9: magnetization, bound current, H field (6.1, 6.2, 6.3)

PHY 110B — Electricity & Magnetism (4): Theory of electrostatics, magnetostatics, electrodynamics and radiation.

The second quarter focuses on electrodynamics and radiation (Griffiths 7-12). An example schedule:

- Week 1: motional EFM, Faraday's law (7.1, 7.2)
- Week 2: inductance, magnetic energy, Maxwell equations (7.2, 7.3)
- Week 3: conservation laws (8)
- Week 4: plane wave, energy, momentum of a plane wave (9.1, 9.2)
- Week 5: reflection and refraction, absorption and dispersion (only for insulating medium) (9.3, 9.4)
- Week 6: retarded potential formulation (10.1-2)
- Week 7: radiation from dipoles (11.1)
- Week 8: review of Lorentz transformation and relativistic mechanics (12.1, 12.2)
- Week 9: relativistic electrodynamics (12.3)

This version omits wave guides (9.5) and radiation from point charges (11.2). These topics could be included by spending less time on other topics.

PHY 110L — Computing Lab for Electricity and Magnetism (1): Applications of computational physics to problems from Electricity and Magnetism.

This course, which has one hour of lecture per week, includes extensive problems from numerical physics related to PHY 110AB, using the techniques introduced in PHY 40 and 45.

See comments in Section 6 regarding workload for one unit courses. Example topics for assignments include:

- Variations of related problems from PHY 45.
- Visualizing Electric and Magnetic fields (Gezerlis 1.7)
- Multipole Expansion (Gezerlis 4.2)
- Magnetic Fields produced by current distribution (Giordano 5.3-4)
- Waves on a String: Spectral methods (Giordano 6.4)
- Relaxation Method Solution to Laplace's Equation (Giordano 5.1-2, Garcia 8)
- Fourier Analysis: Spectral method (Garcia 8.2)
- Waveguides
- Analytic solutions to special cases are calculated and used throughout the course to validate the numerical approach.

PHY 112L — Computing Lab for Statistical Mechanics (1): Applications of computational physics to problems from Statistical Mechanics.

This course, which has one hour of lecture per week, includes extensive problems from numerical physics related to PHY 105A and 112, using the techniques introduced in PHY 40 and 45.

See comments in Section 6 regarding workload for one unit courses. Example topics for assignments include:

- Variations of related problems from PHY 45.
- Testing the Stefan-Boltzmann Law (Gezerlis 6.6)
- Mean Field Theory Solution to Ising Model (Giordano 8.2)
- Metropolis Algorithm (Giordano 8.3)
- Phase Transitions (Giordano 8.4-8.5)
- Monte Carlo Simulation of Dilute Gas (Giordano 9.1)
- Melting (Giordano 9.2)
- Protein Folding (Giordano 12.1)
- Analytic solutions to special cases are calculated and used throughout the course to validate the numerical approach.

PHY 115L — Computing Lab for Quantum Mechanics (1): Applications of computational physics to problems from Classical and Quantum Mechanics.

This course, which has one hour of lecture per week, includes extensive problems from numerical physics related to PHY 115A and 115B, using the techniques introduced in PHY 40 and 45.

See comments in Section 6 regarding workload for one unit courses. Example topics for assignments include:

- Variations of related problems from PHY 45.
- Symplectic Algorithms
- Extremizing the Action (Gezerlis 5.6)
- Solution of the Time-independent Schrodinger equation: Harmonic oscillator, Lennard Jones potential (Giordano 10.2).
- Variational Quantum Monte Carlo (Giordano 10.4, Gezerlis 7.8)
- Time-dependent Schrodinger equation: reflection of wave packets (Giordano 10.5)
- Spectral method solutions to Schrodinger equation. (Giordano 10.7)
- Matrix Representation of Interacting spin-half particles (Gezerlis 4.5)
- Analytic solutions to special cases are calculated and used throughout the course to validate the numerical approach.

PHY 116A — Physics Instrumentation with Analog and Digital Electronics (4): Experimental and theoretical study of important electronic circuits involving analog and digital components. Feedback, amplifiers, oscillators, noise, integrated circuits, digital logic, timers, analog-to-digital and digital-to-analog converters.

PHY 116B — Physics Instrumentation for Data Acquisition (4): Experimental application of modern high density integrated circuits. Automated data acquisition, microprocessors, field programmable gate arrays.

13 Department Approval Process

This section outlines procedures and other details necessary for approving the proposal. The faculty approval process will consist of an online vote based on a specific proposal version once all feedback has been assimilated. This proposal includes additional material to inform the decision that is not included in the vote. The faculty vote will be either "yes" or "no", with an optional comment, on a complete slate of specific changes:

- The new courses: PHY 45, 105L, 110L, and 115L.
- The eliminated courses: PHY 9HE, 102, 104B, 110C, and 116C.
- Substantially revised courses: 40, 110AB, and 116AB.
- The new BS physics requirements: Tables 3 and 4.
- The new Astro requirements: Tables 8 and 9.
- The new Applied Physics requirements: Tables 8, 11, 12, 13, 15, 16, 17, and 20.
- The new AB requirements: Tables 21 and 22.
- The new procedure for maintaining example syllabi within the department, described below.

This list leaves some details within the purview of the undergraduate curriculum committee (UGCC), notably:

- Purely cosmetic changes, such as renaming 104C as 104B, once 104B is eliminated.
- Class scheduling, such as when to offer each class and how many sections.
- Details about prerequisites that may have been missed in this proposal.
- Pursuing approval within the College of Letters and Science, which may require generating additional material. This material will likely include the example syllabi as presented here, as examples, with the understanding that the new procedure will provide long-term faculty control over this content.
- Implementing the proposal in a timely manner.

This leaves several follow-up items, which will be considered by the UGCC in the near future:

- The new non-required PHY 115C course.
- An update of the PHY 9H series (A-D).
- More extensive updates to the Applied Physics majors.

This proposal includes a new mechanism for maintaining official "Example Syllabi" for core courses. Near the end of spring quarter, a faculty meeting will be devoted to discussing details of the undergraduate program, including:

- Short reports from faculty on how required core courses were taught.
- The syllabi as taught, and how this differed from the example syllabi.

- Areas where student preparation was insufficient.

Following the faculty discussion, the UGCC will update the example syllabi as needed, and present these for an online faculty vote. If a majority of the faculty votes in favor of the new syllabi, the department website will be updated with the new version. If the faculty votes no, additional faculty meetings will be dedicated to resolving the controversy, and the old version (or no version if that does not exist) will be left in place until the matter is resolved. Example syllabi will be publicly presented as examples only, with a clear disclaimer that instructors will decide the specific content of their own courses. These syllabi are intended to help guide instructors in coordinating their instruction with the rest of the department, not to constain them.

14 Implementation

If the faculty approves the new program, we will begin to implement changes in the first year, even before the major requirements have move through the formal approval processc, by rescheduling our regular course offerings to the new schedule. The first year implements the changes for juniors and earlier, while allowing seniors to finish under the current schedule. In the tables below, only the courses directly impacted by this proposal are shown.

Changes to the curriculum are tracked in the integrated curriculum management system (ICMS). Each proposed change is approved at the level of UGCC/Vice-Chair, College, and then the Senate Committee on Courses of Instruction (COCI). We expect to begin this process in earnest during the Fall of 2021.

All departments with courses that include prerequisites that would be impacted have already been contacted (only ECE). We will also reach out to the departments hosting courses for our applied majors: they won't need to make any changes but they might appreciate notification about potential changes to enrollment.

Table 23: Implementation Year One Offerings
Italics: only if college approves in time, Bold: courses offered for seniors. Slashed: No longer offered.

Fall	Winter	Spring
9HA	9HB	9HC
9HD	~~9HE~~	
40		
	45	
~~102~~	~~104B~~	~~115A~~
104A		104A
	105A	105B
	110A	110B
116A	116B	116C
110C		
112		
115B		

If the new PHY 45 course is not approved in time, we can teach it as PHY 104B instead. There will be no offering of 115A in the first transition year, as seniors have already taken it, and juniors will not take it until their senior year in the new schedule. The one-unit computing lab courses will not be offered in the first year, as these courses can be taken in the senior year. All three sections of 116 will still be formally offered in the first year, but the content will be adjusted to match the plan: PHY 116A will cover the PHY 80 material, PHY 116B will cover the new 116A content, and PHY 116C will cover the new 116B content. Some students entering 116A will already have taken PHY 80, but for the vast majority, it will have been taught online, with quite different content.

By the second year, the new courses and requirements must be approved to avoid stalling the implementaion. The new program is fully implemented:

Table 24: Implementation Year Two Offerings
Slashed: No longer offered.

Fall	Winter	Spring
9HA	9HB	9HC
9HD		
40		
	45	
104A		104A
	105A	105B
~~110C~~	110A	110B
112		
115A	115B	
112L	115L	110L
116A	116B	~~116C~~

There is a straightforward mapping of new course offerings to time slots in the current program. This should avoid most schedule conflicts. So for instance, the new winter offering of 105A will occupy the time slot for 105B in the current program. The mapping of new course offerings to time slots (by course) in the current program are worked out in Table 25.

Table 25: Mapping of Course Schedule

Course	Current Course Time Slot
starting year one:	
40 (fall)	102 (labs)
	105A (lecture)
45	104B
105A	105B
110AB	Unchanged
104A (spring)	110B
105B	115A
starting year two:	
115A	105A
115B	105B

Table 26: Sophomore year during transition, Honors Physics

Year	Fall	Winter	Spring
Sophomore	9HD(5) M22A(3) 40(4)	105A(4) M22B(3) 104B(4)	105B(4) 104A(4) *80(4)*
Junior	115A(4) 112+L(5)	115B+L(5) 110A(4)	*115C(4)* 110B+L(5)

Table 27: Sophomore year during transition, Physics 9

Year	Fall	Winter	Spring
Sophomore	M21D(4) 9B(5) 40(4)	M22A(3) 9C(5) *80(4)*	M22B(3) 9D(4)
Junior	104A(4)	105A(4) 110A(4) 45(4)	105B(4) 110B+L(5)
Senior	115A(4) 112+L(5)	115B+L(5)	*115C(4)*

Table 28: Course Key

40	Introduction to Physics Computation
80	Experimental Techniques
104A	Math Methods
105A/B	Classical Mechanics
104B	Computational Physics, ignore 104A/105A pre-reqs.
105A/B	Classical Mechanics
110A/B	Electricity and Magnetism, no more 110C.
112	Statistical Mechanics
115ABC	Quantum Mechanics

Table 29: Junior year during transition

Year	Fall	Winter	Spring
Junior	104A(4)	105A(4)	105B(4)
	40(4)	104B(4)	80(4)
		110A(4)	110B(4)
Senior	115A(4)	115B+L(5)	*115C(4)*
	112+L(5)		

Table 30: Junior year, Transfer Students

Year	Fall	Winter	Spring
Junior	9D(4)	105A(4)	105B(4)
	40(4)	110A(4)	110B(5)
	104A(4)	45(4)	80(4)
Senior	115A(4)	115B+L(5)	*115C(4)*
	112+L(5)		

Table 31: Course Key

40	Introduction to Physics Computation
80	Experimental Techniques
104A	Math Methods
105A/B	Classical Mechanics
104B	Computational Physics, **ignore 104A/105A pre-reqs.**
105A/B	Classical Mechanics
110A/B	Electricity and Magnetism, **no more 110C.**
112	Statistical Mechanics
115ABC	Quantum Mechanics