ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

102. Product Engineering Basics. (C)

The course targets non-engineering majors interested in understanding engineering approaches to product fabrication. The course covers a broad variety of engineering topics including mechanical, electrical, computer and material science. Many of these topics would normally be full courses in themselves. This course intends to teach familiarity with a focus on hands-on practice as applied to products. Students will briefly use equipment such as MTS materials testing machines, mills, lathes, oscilloscopes, laser cutters, photodiodes, motors, servos, microcomputers as well as engineering software such as Solidworks, C compilers, Labview, Matlab, and Cambridge Engineering Selector. The class concludes with independent projects.

125. (CIS 125) Technology and Policy. (C)

Have you ever wondered why sharing music and video generates such political and legal controversies? Is information on your PC safe and should law enforcement be able to access information you enter on the Web? Will new devices allow tracking of your every move and every purchase? CIS 125 is focused on developing an understanding of existing and emerging technologies, along with the political, societal and economic impacts of those technologies. The technologies are spread across a number of engineering areas and each of them raise issues that are of current concern or are likely to be a future issue.

203. Engineering Ethics. (C)

The practice of engineering requires more than creativity, diligence, and technical knowledge: it demands the tools to manage the conflicting needs of clients, managers, and the public; an ability to act responsibly when problems arise; and, above all, strong communication skills. This course will examine the major ethical issues associated with engineering practice while enhancing students' technical writing. Through the study of important case studies like the Great Molasses Flood, the Space Shuttle Challenger disaster, and the Deepwater Horizon oil spill, we will learn about the responsibilities of engineering professionals, as well as the causes and consequences of technological failure.

205. Applications of Scientific Computing. (C) Prerequisite(s): Prior exposure to computing via courses such as EAS 105, CIS 110, or ESE 112. Math 114, Sophomore standing.

This course will discuss a number of canonical problems and show how numerical methods are used to solve them. Lectures will introduce the underlying theory and the relevant numerical methods. Students will be expected to implement solutions to the problems using MATLAB. The course will use the visualization capabilities of MATLAB to provide students with a geometric interpretation of the key ideas underlying the numerical methods. Topics to be covered will include: The solution of systems of linear systems equations with application to problems such as force balance analysis and global illumination computation. Representing and computing coordinate transformations with applications to problems in graphics, vision and robotics. Transform Coding with applications to the analysis of audio signals and image compression. Analysis of variance and the search for low dimensional representations for high dimensional data sets egs. Google's PageRank algorithm. Least Squares model fitting with applications to data analysis. Analysis of linear dynamical systems with applications to understanding the modes of vibration of mechanical systems. The analysis of stochastic systems governed by state transition matrices.

210. Introduction to Nanotechnology. (A)

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

301. (EAS 505) Climate Policy and Technology. (C)

The course will exam Pacala and Socolow's hypothesis that "Humanity already possesses the fundamental scientific, technical and industrial know-how t solve the carbon and climate problem for the next half-century." Fifteen "climate stabilization wedges" i.e., strategies that each have the potential to reduce carbon emissions by 1 billion ons per year by 2054, will be examined in detail. Technology and economics will be reviewed. Socio-political barriers to mass-scale implementation will be discussed. Pacala and Socolow note "Every element in this portfoloio has passed beyond the laboratory bench and demonstration project; many are already implemented somewhere at full industrial scale".

L/R 303. (BE 303) Ethics, Social, and Professional Responsibility for Engineers. (A)

Provides an overview of the ethical, social, and professional responsibilities of engineers, as engineering professionals, as members of engineering organizations and as investigators in research. The course will make extensvie use of student group presentations and in the analysis of cases based on real-world problems with ethical dimensions, many drawn from current news. The case studies will vary from year to year, but will be chosen to be relevant to studens interested in different careers in engineering, including research.

306. (EAS 506) Electricity and Systems Markets. (C)

The course discusses the existing electricity system from technical, economic, and policy perspectives. Basic power system engineering will be reviewed early in the course. Generation, transmission, distribution, and end-use technologies and economics will be discussed. Additional topics will include system operation, industry organization, government regulation, the evolution of power markets, environmental policy, and emerging technologies.

400. (EAS 500) Technical Communication in Engineering Practice. (C) Prerequisite(s): SEAS undergraduates must have already fulfilled their SEAS Writing Requirement.

Students will learn methods and approaches for written technical communication within the engineering environment. These include strategies for maximum effectiveness in writing technical documentation, reports, instructions, and proposals. Assignments will include self-editing and peer editing techniques, as well as strategies to effectively mentor other writers.

401. (EAS 501) Energy and Its Impacts: Technology, Environment, Economics, Sustainability. (A) Any University student interested in energy and its impacts, who is a Junior or Senior. Students taking the course as EAS 501 will be given assignments commensurate with graduate standing.

The objective is to introduce students to one of the most dominating and compelling areas of human existence and endeavor: energy, with its foundations in technology, from a quantitative sustainability viewpoint with its association to economics and impacts on environment and society. This introduction is intended both for general education and awareness and for preparation for careers related to this field, with emphasis on explaining the technological foundation. The course spans from basic principles to applications. A review of energy consumption, use, and resources; environmental impacts, sustainability and design of sustainable energy systems; introductory aspects of energy economics and carbon trading; methods of energy analysis; forecasting; energy storage; electricity generation and distribution systems (steam and gas turbine based power plans, fuel cells), fossil fuel energy (gas, oil, coal) including nonconventional types (shale gas and oil, oil sands, coalbed and tight-sand gas), nuclear energy wastes: brief introduction to renewable energy use: brief introduction to solar, wind, hydroelectric, geothermal, biomass; energy for buildings, energy for transportation (cars, aircraft, and ships); prospects for future energy systems: fusion power, power generation in space.

Students interested in specializing in one or two energy topics can do so by choosing them as their course project assignments.

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

499. Senior Capstone Project. (C)

The Senior Capstone Project is required for all BAS degree students, in lieu of the senior design course. The Capstone Project provides an opportunity for the student to apply the theoretical ideas and tools learned from other courses. The project is usually applied, rather than theoretical, exercise, and should focus on a real world problem related to the career goals of the student. The one-semester project may be completed in either the fall or sprong term of the senior year, and must be done under the supervision of a sponsoring faculty member. To register for this course, the student must submit a detailed proposal, signed by the supervising professor, and the student's faculty advisor, to the Office of Academic Programs two weeks prior to the start of the term.

402. (EAS 502) Renewable Energy and Its Impacts: Technology, Environment, Economics, Sustainability. (B) Prerequisite(s): Junior Standing.

The objective is to introduce students to the major aspects of renewable energy, with its foundations in technology, association to economics, and impacts on ecology and society. This introduction is intended both for general education and awareness and for preparation for careers related to this field. The course spans from basic principles to applications. A review of solar, wind, biomass, hydroelectric, geothermal energy, and prospects for future energy systems such as renewable power generation in space.

403. (EAS 503) Energy Systems and Policy. (C)

This is a survey course that will examine the current U.S. energy industry, from production to consumption, and its impacts on local, regional, and the global environment. The course will seek to provide a fuller understanding of existing energy systems, ranging from technical overviews of each, a review of industry organization, and an exploration of the well-established policy framework each operates within. Near-term demands upon each energy supply system will be discussed, with particular focus on environmental constraints. Policy options facing each energy industry will be reviewed.

449. (IPD 549) Product Development in Entrepreneurial Ventures. (B)

A product is any artifact, service or experience for which a buyer is willing to pay. Product Design & Development is at the core of entrepreneurship. Though in modern mythology it is a solitary effort by a passionate individual, entrepreneurship is frequently more successful when pursued in an interdisciplinary environment. Though it rarely requires the greatest time investment, concentration of personnel, the majority of the funding or even the greatest depth of expertise to accomplish, excellent product design can be the difference between a successful and failed venture. A poorly designed "product "can prevent a venture from being successful. An excellently designed product can make a competent business plan much more successful. A well defined and designed product solution will create differentiation, and can not only meet customer expectation but can create desirability. Through the review and discussion of case studies, lecture subjects, guest lecturers, field trips, and a semester long interdisciplinary team project, this class will provide insight into the problem identification and product design processes, user needs research, intellectual property research, experience design, Industrial Design, Interface Design, brand development and product centric fundraising processes.

500. (EAS 400) Technical Communication in Engineering Practice. (C) This course is not intended for non-native speakers of English and will not address their specific language needs. Students whose native language is not English should register for EAS 510.

Students will learn methods and approaches for written technical communication within the engineering environment. These include strategies for maximum effectiveness in writing technical documentation, reports, instructions, and proposals. Assignments will include self-editing and peer editing techniques, as well as strategies to effectively mentor other writers.

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

501. (EAS 401) Energy and its Impacts: Technology, Environment, Economics, Sustainability.. (A) Any university student interested in energy and its impacts, who is a graduate student or who is an undergraduate Junior or Senior seeking graduate course credit. Students taking the course as EAS 501 will be given assignments commensurate with graduate standing.

The objective is to introduce students to one of the most dominating and compelling areas of human existence and endeavor: energy, with its foundations in technology, from a quantitative sustainability viewpoint with its association to economics and impacts on environment and society. This introduction is intended both for general education and awareness and for preparation for careers related to this field, with emphasis on explaining the technological foundation. The course spans from basic principles to applications. A review of energy consumption, use, and resources; environmental impacts, sustainability and design of sustainable energy systems; introductory aspects of energy economics and carbon trading; methods of energy analysis; forecasting; energy storage; electricity generation and distribution systems (steam and gas turbine based power plans, fuel cells), fossil fuel energy (gas, oil, coal) including nonconventional types (shale gas and oil, oil sands, coalbed and tight-sand gas), nuclear energy wastes: brief introduction to renewable energy use: brief introduction to solar, wind, hydroelectric, geothermal, biomass; energy for buildings, energy for transportation (cars, aircraft, and ships); prospects for future energy systems: fusion power, power generation in space.

Students interested in specializing in one or two energy topics can do so by choosing them as their course project assignments.

502. (EAS 402) Renewable Energy and Its Impacts: Technology, Environment, Economics, Sustainability.. (B)

The objective is to introduce students to the major aspects of renewable energy, with its foundations in technology, association to economics, and impacts on ecology and society. This introduction is intended both for general education and awareness and for preparation for careers related to this field. The course spans from basic principles to applications. A review of solar, wind, biomass, hydroelectric, geothermal energy, and prospects for future energy systems such as renewable power generation in space.

506. (EAS 306) Electricity and Systems Markets. (B)

The course discusses the existing electricity system from technical, economic, and policy perspectives. Basic power system engineering will be reviewed early in the course. Generation, transmission, distribution, and end-use technologies and economics will be discussed. Additional topics will include system operation, industry organization, government regulation, the evolution of power markets, environmental policy, and emerging technologies.

503. (EAS 403) Energy Systems and Policy. (C)

This is a survey course that will examine the current U.S. energy industry, from production to consumption, and its impacts on local, regional, and the global environment. The course will seek to provide a fuller understanding of existing energy systems, ranging from technical overviews of each, a review of industry organization, and an exploration of the well-established policy framework each operates within. Near-term demands upon each energy supply system will be discussed, with particular focus on environmental constraints.

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

505. (EAS 301) Climate Policy and Technology. (C)

The course will exam Pacala and Socolow's hypothesis that "Humanity already possesses the fundamental scientific, technical and industrial know-how t solve the carbon and climate problem for the next half-century." Fifteen "climate stabilization wedges" i.e., strategies that each have the potential to reduce carbon emissions by 1 billion ons per year by 2054, will be examined in detail. Technology and economics will be reviewed. Socio-political barriers to mass-scale implementation will be discussed. Pacala and Socolow note "Every element in this portfoloio has passed beyond the laboratory bench and demonstration project; many are already implemented somewhere at full industrial scale".

507. Intellectual Property and Business Law for Engineers. (C)

Engineers are often on the front line of innovation. The goal of this course is to introduce engineering students to the basics of Intellectual property (IP) and business laws that they will encounter throughout their careers. Understanding these laws is critical for the protection of IP and for the creation and success of high-tech start-up ventures. Market advantage in large part springs from a company's IP. Without legal protection and correct business formation, proprietary designs, processes, and inventions could be freely used by competitors, ruining market advantage. A basic understanding of IP laws, contractual transactions, employment agreements, business structures, and debt-equity financing will help engineering students to become effective employees or entrepreneurs, to acquire investors, and to achieve success. Though open to students of all disciplines, the course will use case studies particular relevance to students of engineering and applied science.

510. Technical Communication and Academic Wrting for Non-native Speakers of English. (B)
Graduate students whose native language is English, but who would benefit from a course in Technical Communication, should take EAS 500.

Students will improve the grammar, word choice and organization of their professional writing by completing weekly writing assignments and a full-length research paper. Students will also give short oral presentations and receive feedback on pronunciation, wording, grammar and organization.

512. Engineering Negotiation. (C)

The goal of this course is to teach students of engineering and applied science to be effective negotiators. It aims to improve the way these students communicate i virtually any human interaction. The course intends to improve the ability of engineers and other technology disciplines to gain more support more quickly for projects, researc product and services development, and marketing. For those wanting to be entrepreneurs o r intrapreneurs, the course is designed essentially to find the most value possible in starting up and running companies. Based on Professor Diamond's innovative and renowned model of negotiation, it is intended to assist those for whom technical expertise is not enough to persuade others, internally and externally, to provide resources, promotions and project approvals; or to resolve disputes, solve problems and gain more opportunities.

Rejecting the 40-year-old notions of power, leverage and logic, the course focuses on persuasion by making better human connections, uncovering perceptions and emotions, and structuring agreements to be both collaborative and fair. This course is entrepreneurial in nature and can provide many times more value than traditional persuasion. The Getting More book has sold more than 1 million copies around the world and is also used by universities, corporations (Google), and U.S. Special Operations (SEALs, Green Berets, Special Forces, Marines) to save lives and reduce conflict. From the first day, students will do interactive cases based their own engineering-related problems and based on current problems in the news. There will be diagnostics enabling every student to assess his/her skill and improvements.

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

545. (IPD 545) Engineering Entrepreneurship I. (C) Prerequisite(s): Third or Fourth year or Graduate standing.

Engineers and scientists create and lead great companies, hiring managers when and where needed to help execute their vision. Designed expressly for students having a keen interest in technological innovation, this course investigates the roles of inventors and founders in successful technology ventures. Through case studies and guest speakers, we introduce the knowledge and skills needed to recognize and seize a high-tech entrepreneurial opportunity - be it a product or service - and then successfully launch a startup or spin-off company. The course studies key areas of intellectual property, its protection and strategic value; opportunity analysis and concept testing; shaping technology driven inventions into customer-driven products; constructing defensible competitive strategies; acquiring resources in the form of capital, people and strategic partners; and the founder's leadership role in an emerging high-tech company. Throughout the course emphasis is placed on decisions faced by founders, and on the sequential risks and determinants of success in the early growth phase of a technology venture. The course is designed for, but not restricted to, students of engineering and applied science and assumes no prior business education.

595. Foundations of Leadership. (C)

The goal of EAS 595 is to increase your capacity to effectively lead throughout your career and wherever you find yourself in an organization. This involves understanding and learning about yourself and about working effectively with others. The course starts with an identification of values, strengths, preferences and passions. It then proceeds with the personal and interpersonal and moves through the strategic aspects o f leadership by bringing together aspects of management science, social psychology, psychology of personality and behavioral economics. Topics include teamwork and team dynamics, identifying life's goals and dreams , decision making, valuing differences, understanding the dynamics of influence, using power with integrity, giving and receiving feedback, leading change, and discovering where we can make our contribution.

546. Engineering Entrepreneurship II. (C) Prerequisite(s): EAS 545.

This course is the sequel to EAS 545 and focuses on the planning process for a new technology venture. Like its prerequisite, the course is designed expressly for students of engineering and applied science having a keen interest in technological innovation. Whereas EAS 545 investigates the sequential stages of engineering entrepreneurship from the initial idea through the early growth phase of a startup company, EAS 546 provides hands-on experience in developing a business plan for such a venture. Working in teams, students prepare and present a comprehensive business plan for a high-tech opportunity. The course expands on topics from EAS 545 with more in-depth attention to: industry and marketplace analysis; competitive strategies related to high-tech product/service positioning, marketing, development and operations; and preparation of sound financial plans. Effective written and verbal presentation skills are emphasized throughout the course. Ultimately, each team presents its plan to a distinguished panel of recognized entrepreneurs, investors and advisors from the high-tech industry.

590. Commercializing Information Technology. (C)

EAS 590 provides real world, hands-on learning on what it's like to actually start a high-tech company. We do that by using the Lean LaunchPad framework for Web start-ups. This class is not about how to write a business plan. Instead you will be getting your hands dirty talking to customers, partners, competitors, as you encounter the chaos and uncertainty of how a start-up actually works.

EAS 590 provides real world, hands-on learning on what it's like to actually start a high-tech company. We do that by using the Lean LaunchPad framework for Web start-ups. This class is not about how to write a business plan. Instead you will be getting your hands dirty talking to customers, partners, competitors, as you encounter the chaos and uncertainty of how a start-up actually works.

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

591. Leading Technology Teams.

Engineers routinely work in teams collaborating with experts from multiple fields to address increasingly large complex problems/opportunities. EAS 591, Leading Technology Teams, focuses on the dynamics of innovative, interdisciplinary, cross-functional teams. We examine ways to improve team performance by exploring technology leadership issues from multiple perspectives (i.e., the individual, the team, and the organization). Developing skills to be an effective technology team member, leader, and/or sponsor will provide you with a competitive advantage, not only for getting your first job but also for success throughout your career.

898. CPT Research Practicum.. (C)

SM 900. Resp Conduct Res Eng. (C)

101. Introduction to Engneering. (A)

This course is intended to introduce students to the field of engineering. It will expose students to the engineering disciplines through hands-on laboratory experiences. In addition, the course will provide tutorials on how to use important software packages as well as a "Professional Preparation" module through studies of communication (writing and speaking skills), ethics, leadership and teamwork. This course is ideal for any freshman interested in exploring the possibility of studying engineering at Penn. The course counts as as a engineering requirement in SEAS.

212. Concepts in Micro- and Nanotechnology. (C) Prerequisite(s): Math 104 and Physics 93/140 (or higher), or permission of the instructor.

Seminar/Lecture course on micro- and nanotechnology intended for nonspecialists. This course will discuss how very small structures and devices, as well as systems comprising these devices, are fabricated and characterized, with application examples from microelectronics, microelectromechanical systems, and quantum devices and systems. Current societal and ethical implications of micro- and nanotechnology, as well as creation and exploitation of commercial opportunities, will be discussed.

503. Engineering in Oil, Gas and Coal, from Productin to End Use. (C)

While conventional wisdom is that the world is running out of fossil fuels, technical advances such as deep water production, directional drilling, hydrofracturing, and the refining of non-conventional crude oil sources has increased the resource base significantly and there are well over 100 years of reserves of oil, natural gas and coal. The effect of technology advances has been most profound in the United States, where net energy imports are projected to fall to 12% of consumption by 2020. Excellent, highly technical careers are available in these industries, with opportunities to reduce their impact on the environment and in particular on climate change. The course will cover engineering technology in oil, natural gas and coal from production through end use. It will equip graduating students with the knowledge to contribute in these industries and to participate in informed debate about them

L/R 251. Analytical Methods for Engineering. (B) Prerequisite(s): MATH 240 or equivalent along with sophomore standing in SEAS, or permission of the instructor(s).

This course introduces students to physical models and mathematical methods that are widely encountered in various branches of engineering. Illustrative examples are used to motivate mathematical topics including ordinary and partial differential equations, Fourier analysis, eigenvalue problems, and stability analysis. Analytical techniques that yield exact solutions to problems are developed when possible, but in many cases, numerical calculations are employed using programs such as Matlab and Maple. Students will learn the importance of mathematics in engineering.

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

375. Biological Data Science I - Fundamentals of Biostatistics. (C) Prerequisite(s): Sophomores and Juniors only.

The purpose of this course is to provide students with skills to analyze and interpret small and large biological data sets. Fundamentals in probability and statistics will be taught through the use of homework problems, case studies and projects focused on computational analysis of biological data. Topics covered include: Populations and samples; random variable; discrete and continuous probability distributions; exploratory data analysis; descriptive statistics; confidence intervals; expectations; variances; central limit theorem; independence; hypothesis testing; fitting probability models; pvalues; goodness-of-fit tests; correlation coefficients; non-parametric tests; ANOVA; linear regression; bootstrapping; and maximum likelihood estimation.

512. Nonlinear Dynamics and Chaos. (C) Prerequisite(s): MATH 240 or ENM 510, Senior or Master's standing in engineering.

This course covers the essential mathematics behind continuous and discrete nonlinear dynamical systems with applications in Physics, Biology, Chemistry and Engineering. It covers one-dimensional, two-dimensional, three-dimensional and n-dimensional flows for continuous systems and one-dimensional flows for discrete systems. It also covers Cantor's set theory and Fractals.

220. Discrete Dynamical Systems and Chaos. (C) Prerequisite(s): MATH 103, MATH 104 and MATH 114 (Calculus of a Single Variable and some knowledge of Comples Numbers).

This course will cover the mathematics behind the dynamics of discrete systems and difference equations. Topics include: Real function iteration, Converging and Diverging sequences, Periodic and chaotic sequences, Fixed-point, periodic-point and critical-point theories, Bifurcations and period-doubling transitions to chaos, Symbolic dynamics, Sarkovskii's theorem, Fractals, Complex function iterations, Julia and Mandelbrot sets. In the past, mathematics was learned only through theoretical means. In today's computer age, students are now able to enjoy mathematics through experimental means. Using numerous computer projects, the student will discover many properties of discrete dynamical systems. In addition, the student will also get to understand the mathematics behind the beautiful images created by fractals. Throughout the course, applications to: Finance, Population Growth, Finding roots, Differential Equations, Controls, Game and Graph Problems, Networks, Counting Problems and other real-world systems will be addressed.

321. Engineering Statistics. (C)

This course covers the topics in probability and statistics with an emphasize on the application of probability theories and statistical techniques to practical engineering problems. Mathematical derivations of theorems will be presented whenever it is necessary to illustrate the concepts involved, however.

L/R 427. (MEAM527) Finite Elements and Applications. (A) Prerequisite(s): MATH 241 or ENM 251 and PHYS 151.

The objective of this course is to equip students with the background needed to carry out finite elements-based simulations of various engineering problems. The first part of the course will outline the theory of finite elements. The second part of the course will address the solution of classical equations of mathematical physics such as Laplace, Poisson, Helmholtz, the wave and the Heat equations. The third part of the course will consist of case studies taken from various areas of engineering and the sciences on topics that require or can benefit from finite element modeling. The students will gain hand-on experience with the multi-physics, finite element package FemLab.

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

L/R 502. Numerical Methods and Modeling. (B) Sinno.Prerequisite(s): Knowledge of a computer language, Math 240 and 241; ENM 510 is highly recommended; or their equivalents.

Numerical modeling using effective algorithms with applications to problems in engineering, science, and mathematics, and is intended for graduate and advanced undergraduate students in these areas. Interpolation and curve fitting, numerical integration, solution of ordinary and partial differential equations by finite difference, and finite element methods. Includes use of representative numerical software packages such as MATLAB PDE Toolbox.

520. Principles and Techniques of Applied Math I. (A) Prerequisite(s): Basic theory of ordinary and partial differential equations.

This course is targeted to engineering PhD students in all areas. It will focus on the stud of linear spaces (both finite and infinite dimensional) and of operators defined on such spaces. This course will also show students how powerful methods developed by the study of linear spaces can be used to systematically solve problems in engineering. The emphasis in this course will not be on abstract theory and proofs but on techniques that can be used to solve problems. Some examples of techniques that will be studied include, Fourier eries, Green's functions for ordinary and partial differential operators, eigenvalue problems for ordinary differential equations, singular value decomposition of matrices, etc.

503. Introduction to Probability and Statistics. (A) Prerequisite(s): MATH 240 or equivalent.

Introduction to combinatorics: the multiplication rule, the pigeonhole principle, permutations, combinations, binomial and multinomial coefficients, recurrence relations, methods of solving recurrence relations, permutations and combinations with repetitions, integer linear equation with unit coefficients, distributing balls into urns, inclusion-exclusion, an introduction to probability. Introduction to Probability: sets, sample setsevents, axioms of probability, simple results, equally likely outcomes, probability as a continuous set function and probability as a measure of belief, conditional probability, independent events, Bayes' formula, inverting probability trees. Random Variables: discrete and continuous, expected values, functions of random variables, variance. Some Special Discrete Random Variables: Bernoulli, Binomial, Poisson, Geometric, Pascal (Negative Binomial) Hypergeometric and Poisson.

Some Special Continuous Random Variables: Uniform, Exponential, Gamma, Erlang, Normal, Beta and Triangular. Joint distribution functions, minimum and maximum of independent random variables, sums of independent random variables, reproduction properties. Properties of Expectation: sums of random variables, covariance, variance of sums and correlations, moment-generating function. Limit theorems: Chebyshev's inequality, law of large numbers and the central-limit theorem. Extra Topics: Generating random numbers and simulation, Monte-Carlo methods, The Poisson Process and Queueing Theory, Stochastic Processes and Regular Markov Chains, Absorbing Markov Chains and Random Walks.

510. Foundations of Engineering Mathematics - I. (A) Prerequisite(s): MATH 240, MATH 241 or equivalent.

This is the first course of a two semester sequence, but each course is self contained. Over the two semesters topics are drawn from various branches of applied mathematics that are relevant to engineering and applied science. These include: Linear Algebra and Vector Spaces, Hilbert spaces, Higher-Dimensional Calculus, Vector Analysis, Differential Geometry, Tensor Analysis, Optimization and Variational Calculus, Ordinary and Partial Differential Equations, Initial-Value and Boundary-Value Problems, Green's Functions, Special Functions, Fourier Analysis, Integral Transforms and Numerical Analysis. The fall course emphasizes the study of Hilbert spaces, ordinary and partial differential equations, the initial-value, boundary-value problem, and related topics.

ENGINEERING AND APPLIED SCIENCE (EG) {EAS}

511. Foundations of Engineering Mathematics - II. (B) Prerequisite(s): ENM 510 or equivalent.

Vector Analysis: space curves, Frenet - Serret formulae, vector theorems, reciprocal systems, co and contra variant components, orthogonal curvilinear systems. Matrix theory: Gauss-Jordan elimination, eigen values and eigen vectors, quadratic and canonical forms, vector spaces, linear independence, Triangle and Schwarz inequalities, n-tuple space.Variational calculus: Euler-Lagrange equation, Finite elements, Weak formulation, Galerkin technique, FEMLAB. Tensors: Einstein summation, tensors of arbitrary order, dyads and polyads, outer and inner products, quotient law, metric tensor, Euclidean and Riemannian spaces, physical components, covariant differentiation, detailed evaluation of Christoffel symbols, Ricci's theorem, intrinsic differentiation, generalized acceleration, Geodesics.

L/R 521. Principles and Techniques of Applied Math II. (B)

This course is a continuatin of ENM 520 (or equivalent) and deals with classcial methods in applied mathematics. The topics to be covered include: Functions of a Complex Variable, Partial Differential Equations, Asymptotic and Perturbawtin Methods, and Convex Analysis and Variational Methods.

540. Topics In Computational Science and Engineering. (M) Prerequisite(s): Background in ordinary and partial differential equations; proficiency in a programming language such as MATLAB, C, or Fortran.

This course is focused on techniques for numerical solutions of ordinary and partial differential equations. The content will include: algorithms and their analysis for ODEs; finite element analysis for elliptic, parabolic and hyperbolic PDEs; approximation theory and error estimates for FEM.

600. Functional Analysis. (C) Prerequisite(s): ENM 500, ENM 501 or ENM 510, ENM 511 or equivalent.

This course teaches the fundamental concepts underlying metric spaces, normed spaces, vector spaces, and inner-product spaces. It begins with a discussion of the ideals of convergence and completeness in metric spaces and then uses these ideas to develop the Banach fixed-point theorem and its applications to linear equations, differential equations and integral equations. The course moves on to a study of normed spaces, vector spaces, and Banach spaces and operators defined on vector spaces, as well as functional defined between vector spaces and fields. The course then moves to the study of inner product spaces, Hilbert spaces, orthogonal complements, direct sums, and orthonormal sets. Applications include the study of Legendre, Hermite, Laguerre, and Chebyshev polynomials, and approximation methods in normed spaces. The course then concludes with a study of eigenvalues and eigenspaces of linear operators and spectral theory in finite-dimensional vector spaces.

700. Biotechnology Seminar. (C)

This is a seminar course where students hear different perspectives in the biotechnology and pharmaceutical industry. Speakers will discuss their experiences in business startups, technology transfer, bioinformatics, pharmaceutical houses, and academics.

ENGINEERING AND APPLIED SCIENCE
(EG) {EAS}

601. Special Topics in Engineering Mathematics - Nonlinear Dynamics and Chaos. (B) Prerequisite(s): Permission of Instructor.

This course covers the essential mathematics behind continuous and discrete nonlinear dynamical systems with applications in Physics, Biology, Chemistry and Engineering. It covers one-dimensional, two-dimensional, three-dimensional and n-dimensional flows for continuous systems and one-dimensional flows for discrete systems. It also covers Cantor's set theory and Fractals.

BIOTECHNOLOGY (BIOT)

599. Biot Independent Study. (C)

105. Introduction to Scientific Computing.

This course will provide an introduction to computation and data analysis using MATLAB - an industry standard programming and visualization environment. The course will cover the fundamentals of computing including: variables, functions, decisions, iteration, and recursion. These concepts will be illustrated through examples and assignments which show how computing is applied to various scienti?c and engineering problems. Examples will be drawn from the simulation of physical and chemical systems, the analysis of experimental data, Monte Carlo numerical experiments, image processing, and the creation of graphical user interfaces. This course does not assume any prior programming experience but will make use of basic concepts from calculus and Newtonian physics.

250. Energy Systems, Resources and Technology. (C) Prerequisite(s): Basic understanding of chemistry and physics.

The course will present a comprehensive overview of the global demand for energy, and the resource availability and technology used in its current and future supply. Through a personal energy audit, students will be made aware of the extensive role that energy plays in modern life, both directly, through electricity and transportation fuel, and indirectly in the manufacturing of goods they use. The course will cover how that energy is supplied, the anticipated global growth in energy demand, the resource availability and the role of science and technology in meeting that demand in a world concerned about climate change. The roles of conservation, improved efficiency and renewable energy in meeting future demand in a sustainable, environmentally benign way will be covered.

504. Fundamental Concepts in Nanotechnology. (C)

This is a Master's level course that seeks to teach the physics needed to begin a study of engineering and science at the nanometer scale. Since the nanometer scale is so close to the quantum scale, much of the course deals with an introduction to quantum mechanics but the course also includes discussions in solid-state physics, electricity and magnetism and mechanics. The objective of the course is to teach the physics that an engineering student would need to have in order to do experimental work at the nanometer scale. In addition, this course will prepare the student to take more advanced courses in the Nanotechnology Program.

NANOTECHNOLOGY (NANO)

597. Master's Thesis Research. (C)

599. Master's Independent Study. (C)