

EN.540 (CHEMICAL & BIOMOLECULAR ENGINEERING)

EN.540.101. Chemical Engineering Today. 1 Credit.

A series of weekly lectures to introduce students to chemical and biomolecular engineering and its role as a profession in addressing contemporary technological, social, ethical, and economic issues in today's world. The lectures will include examples of how chemical and biomolecular engineers apply the principles of physics and chemistry to develop new products, improve process efficiencies, and alleviate the strain on the ecosystem through the design of novel environmentally conscious processes. In addition, the lectures will highlight exciting new areas now being advanced by chemical and biomolecular engineers, such as biochemical engineering, tissue engineering, nanoparticle fabrication, and processing smart polymers for applications in computer technology and as sensors. Freshmen Only.

Area: Engineering

EN.540.111. Matlab Made Easy. 2 Credits.

Computer programming is as crucial a tool for modern engineering as calculus. Engineers use computers for almost everything: from design and manufacturing in industry to data collection and analysis in research. In this course, students will use a piece of popular engineering software, Matlab, to learn the fundamentals of programming. We will start simple, exploring such questions as: What is a program? How can we use loops and branches to accomplish a task? What exactly is Matlab doing when it's running a script? Finally, we will build upon the fundamentals of programming to tackle relevant engineering problems. This course will help ChemBE students excel in subsequent engineering courses, such as Modeling and Statistics for ChemBEs, Separations, and Chemical Kinetics, by giving students' knowledge of the tool that helps solve complex engineering problems.

Area: Engineering

EN.540.202. Introduction to Chemical & Biological Process Analysis. 4 Credits.

Introduction to chemical and biomolecular engineering and the fundamental principles of chemical process analysis. Formulation and solution of material and energy balances on chemical processes. Reductionist approaches to the solution of complex, multi-unit processes will be emphasized. Introduction to the basic concepts of thermodynamics as well as chemical and biochemical reactions.

Prerequisite(s): (AS.030.101 OR AS.030.103) AND (AS.171.101 OR AS.171.107) AND (AS.030.102 OR AS.030.103 OR AS.110.109 OR AS.171.102)

Area: Engineering

EN.540.203. Engineering Thermodynamics. 3 Credits.

Formulation and solution of material, energy, and entropy balances with an emphasis on open systems. A systematic problem-solving approach is developed for chemical and biomolecular process-related systems. Extensive use is made of classical thermodynamic relationships and constitutive equations for one and two component systems. Applications include the analysis and design of engines, refrigerators, heat pumps, compressors, and turbines.

Prerequisite(s): EN.540.202;AS.110.202

Area: Engineering

EN.540.204. Practical Applications of Thermodynamics to Complex Phase Equilibria. 3 Credits.

The topics in this course include thermodynamic models for multicomponent phase equilibrium including vapor liquid equilibrium, phase diagrams, activity models and colligative properties in both non-electrolyte and electrolyte solutions. A link between average thermodynamic properties and microstates and molecular interactions is made via a discussion of intermolecular forces and the partition function. Also covered are thermodynamic relationships to describe chemical equilibria, and basic concepts in quantum mechanics and statistical mechanics.

Prerequisite(s): EN.540.203 AND EN.540.305

Area: Engineering

EN.540.290. Chemical Engineering Modeling and Design for Sophomores. 3 Credits.

The courses EN.540.290, 291, 390, and 391 guide the students through the open-ended problems in product and process design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the creation of new products to fulfill a societal need. Process design concerns the quantitative description of processes which serve to produce chemically-derived materials and the estimation of process profitability. Students work in small teams to complete a major project demonstrating their understanding of and proficiency in the principles of unit operations and design. Students report weekly both orally and in writing on their accomplishments. Some projects are single semester, but others can be multi-semester. Students can start in any semester and can work on projects for as many semesters as they want.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

Area: Engineering

EN.540.291. Chemical Engineering Modeling and Design for Sophomores. 3 Credits.

The courses 540.290, 291, 390, and 391 guide the students through the open-ended problems in product and process design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the creation of new products to fulfill a societal need. Process design concerns the quantitative description of processes which serve to produce chemically-derived materials and the estimation of process profitability. Students work in small teams to complete a major project demonstrating their understanding of and proficiency in the principles of unit operations and design. Students report weekly both orally and in writing on their accomplishments. Some projects are single semester, but others can be multi-semester. Students can start in any semester and can work on projects for as many semesters as they want.

Area: Engineering

EN.540.301. Kinetic Processes. 4 Credits.

Review of numerical methods applied to kinetic phenomena and reactor design in chemical and biological processes. Homogeneous kinetics and interpretation of reaction rate data. Batch, plug flow, and stirred tank reactor analyses, including reactors in parallel and in series. Selectivity and optimization considerations in multiple reaction systems. Non isothermal reactors. Elements of heterogeneous kinetics, including adsorption isotherms and heterogeneous catalysis. Coupled transport and chemical/biological reaction rates.

Prerequisite(s): EN.540.203 AND EN.540.303

Area: Engineering

EN.540.303. Transport Phenomena I. 3 Credits.

Molecular mechanisms of momentum transport (viscous flow), energy transport (heat conduction), and mass transport (diffusion). Isothermal equations of change (continuity, motion, and energy). The development of the Navier Stokes equation. The development of non isothermal and multi component equations of change for heat and mass transfer. Exact solutions to steady state, isothermal unidirectional flow problems, to steady state heat and mass transfer problems. The analogies between heat, mass, and momentum transfer are emphasized throughout the course. Co-requisite: AS.110.302, Introduction to the field of transport phenomena

Prerequisite(s): AS.110.302 and EN.540.202

Area: Engineering

EN.540.304. Transport Phenomena II. 4 Credits.

Dimensional analysis and dimensionless groups. Laminar boundary layers, introduction to turbulent flow. Definition of the friction factor. Macroscopic mass, momentum and mechanical energy balances (Bernoulli's equation). Metering of fluids. Convective heat and mass transfer. Heat and mass transfer in boundary layers. Correlations for convective heat and mass transfer. Boiling and condensation. Interphase mass transfer.

Area: Engineering

EN.540.306. Chemical & Biomolecular Separation. 4 Credits.

This course covers staged and continuous-contacting separations processes critical to the chemical and biochemical industries. Separations technologies studied include distillation, liquid-liquid extraction, gas absorption, membrane ultrafiltration, reverse osmosis, dialysis, adsorption, and chromatography. Particular emphasis is placed on the biochemical uses of these processes and consequently on how the treatment of these processes differs from the more traditional approach.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.540.203 AND EN.540.303

Area: Engineering

EN.540.307. Cell Biology for Engineers. 3 Credits.

This course explores fundamental structural details and molecular functions of different parts of the cell. Considerable emphasis is placed on experimental/quantitative approaches to answering these questions. Topics include Central dogma and the nucleus; protein trafficking; ion transporters; cytoskeleton; molecular motors; cell cycle and cell division; signal transduction, cell growth and cancer; cell death, the extracellular matrix; cell adhesion, cell junctions and epithelium; and muscle contraction, cell motility and morphogenesis.

Prerequisite(s): Cell Biology restriction: students who have completed AS.020.306 may not enroll.

Area: Natural Sciences

EN.540.309. Product Design Part 1. 3 Credits.

This course guides the student through the steps of product design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the selection of best products to fulfill the needs. Students work in small teams to complete a major project demonstrating their understanding of and proficiency in the primary objectives of the course. Students report several times both orally and in writing on their accomplishments. This course is the first part of a two-semester sequence that optionally can be taken instead of EN.540.314 Chemical and Biomolecular Engineering Product Design. The material covered is the same as in EN.540.314, but more time is allowed so that laboratory tests can be performed and/or prototypes can be made. Note that students must take 540.310 to complete this sequence and before receiving credits for 540.309.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.540.303 AND EN.540.490;EN.540.306 AND EN.540.301
Area: Engineering

EN.540.310. Product Design Part 2. 3 Credits.

This course is the second part of a two semester sequence (with EN.540.309) that optionally can be taken instead of EN.540.314 Chemical and Biomolecular Engineering Product Design. Students continue to work with their team on their product design project. Students report several times both orally and in writing on their accomplishments. The material covered is the same as in EN.540.314, but more time is allowed so that laboratory tests can be performed and/or prototypes can be made. Note that both courses, EN.540.309 and EN.540.310 must be taken to satisfy the Undergraduate degree requirement of the Chemical and Biomolecular Engineering program. The two courses can be started in any term. Recommended Course Background: EN.540.301, EN.540.304, EN.540.311 or EN.540.313 or permission of instructor.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.540.309
Area: Engineering

EN.540.311. Projects in ChemE Unit Operations with Experiments. 4 Credits.

This course challenges students with laboratory projects that are not well-defined. Students work in groups to develop an effective approach to experiments. They identify the important operating variables, decide how best to obtain them using measured or calculated values. Based on their results they predict, carryout, analyze and improve experiments. Each student analyzes three of the following projects: distillation, gas absorption, and one of the projects in EN.540.313. In addition to technical objectives, this course stresses oral and written communication. Students will have additional meeting times with the instructors and some writing professors outside of class.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.540.301 AND EN.540.304 AND EN.540.306 AND EN.661.315;EN.540.490 can be taken concurrently with EN.540.311
Area: Engineering
Writing Intensive

EN.540.313. Projects in ChemBE Unit Operations with Experiments. 4 Credits.

This course challenges students with laboratory projects that are not well-defined. Students work in groups to develop an effective approach to experiments. They identify the important operating variables, decide how best to obtain them using measured or calculated values. Based on their results they predict, carryout, analyze and improve experiments. Each student analyzes at least two of the following biomolecular projects: bioreactor, biocatalysis and membrane separation and one of the projects in EN.540.311. In addition to technical objectives, this course stresses oral and written communication. Students will have additional meeting times with the instructors and some writing professors outside of class.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.540.301 AND EN.540.304 AND EN.540.306 AND EN.661.315;EN.540.490 can be taken concurrently with EN.540.313

Area: Engineering
Writing Intensive

EN.540.314. ChemBE Product Design. 3 Credits.

This course guides the student through the contrasting aspects of product design and of process design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the selection of best products to fulfill the needs. Process design concerns the quantitative description of processes, which serve to produce many commodity chemicals, the estimation of process profitability, and the potential for profitability improvement through incremental changes in the process. Students work in small teams to complete a major project demonstrating their understanding of and proficiency in the primary objectives of the course. Students report several times both orally and in writing on their accomplishments.

Prerequisite(s): EN.540.490;EN.540.303;EN.540.306 AND EN.540.301
Area: Engineering

EN.540.315. Process Design with Aspen. 2 Credits.

Prerequisite(s): EN.540.490;EN.540.303;EN.540.306 AND EN.540.301
Area: Engineering

EN.540.390. Chemical Engineering Modeling and Design for Juniors. 3 Credits.

The courses EN.540.290, 291, 390, and 391 guide the students through the open-ended problems in product and process design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the creation of new products to fulfill a societal need. Process design concerns the quantitative description of processes which serve to produce chemically-derived materials and the estimation of process profitability. Students work in small teams to complete a major project demonstrating their understanding of and proficiency in the principles of unit operations and design. Students report weekly both orally and in writing on their accomplishments. Some projects are single semester, but others can be multi-semester. Students can start in any semester and can work on projects for as many semesters as they want.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Area: Engineering

EN.540.391. Chemical Engineering Modeling and Design for Juniors. 3 Credits.

The courses 540.290, 291, 390, and 391 guide the students through the open-ended problems in product and process design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the creation of new products to fulfill a societal need. Process design concerns the quantitative description of processes which serve to produce chemically-derived materials and the estimation of process profitability. Students work in small teams to complete a major project demonstrating their understanding of and proficiency in the principles of unit operations and design. Students report weekly both orally and in writing on their accomplishments. Some projects are single semester, but others can be multi-semester. Students can start in any semester and can work on projects for as many semesters as they want.
Area: Engineering

EN.540.400. Project in Design: Pharmacokinetics. 3 Credits.

This is a design course in which the design projects will be to develop pharmacokinetic models of the human body that can be used to understand the temporal distribution, spatial distribution and bioavailability of pharmaceutical drugs. The course (and software to be developed) will cover the spectrum of factors affecting pharmaceutical bioavailability including drug formulation, mode of dosing and dosing rate, metabolism and metabolic cascades, storage in fatty tissues, and diffusional limitations (such as in crossing the blood-brain barrier or diffusional differences between normal and cancerous cells). The goal is to develop process models of the human body that will predict pharmaceutical bioavailability as a function of time and organ (or cell) type that will work for a wide variety of pharmaceuticals including small molecules, biologics, and chemotherapy agents. This course is organized to replicate group project work as it is practiced in industry. The class is divided into groups (typically 3 or 4 students) and each group will meet separately each week with the instructor. Hence, there is no regularly scheduled class times; student groups sign up for weekly meeting times using Starfish in Blackboard. These meetings typically will be 90 minutes long. The expectations and assignments for this course are quite different from most other courses. There are no weekly lectures by the instructor. Rather, each week each group will make a PowerPoint presentation on the week's topic or their progress on their project.
Area: Engineering, Natural Sciences

EN.540.401. Projects in Design: Alternative Energy. 3 Credits.

This course is a group design project (i.e. not a lecture course) to use chemical process simulation tools to model a real-world, alternative-energy process of interest to Chemical and Biomolecular Engineers. The goal of the project will be to develop a process model that is sufficiently complete and robust that it can be used to understand the important factors in the process design and/or operation. This design project is focused on the role alternative energy will play in our country's future. About a third of the course will be devoted to understanding the role of energy and alternative energy in the US and world economies. The remainder of the course will be devoted to a technical and economic analysis of the an alternative energy technology. This course is organized to replicate group project work as it is practiced in industry. The class is divided into groups (typically 3 or 4 students) and each group will meet separately each week with the instructor. Hence, there is no regularly scheduled class times; student groups sign up for weekly meeting times using Starfish in Blackboard. These meetings typically will be 60 minutes long. The expectations and assignments for this course are quite different from most other courses. There are no weekly lectures by the instructor. Rather, each week each group will make a PowerPoint presentation on the week's topic or their progress on their project. Meets with EN.540.619

Prerequisite(s): EN.540.202 AND EN.540.203 AND EN.540.301 AND EN.540.305

Area: Engineering

EN.540.402. Metabolic Systems Biotechnology. 3 Credits.

The aim of this course is to provide a fundamental understanding of the quantitative principles and methodologies of systems biology and biochemical engineering of metabolism. This includes concepts of cellular growth, cellular stoichiometric models, metabolic networks, metabolite fluxes, and genome-scale metabolic models. Quantitative methods and systems biology approaches for metabolic flux analysis and metabolic control theory will be included as well as an analysis of biochemical systems and bioreactors including a consideration of mass transport processes.

Prerequisite(s): AS.020.306 OR (EN.580.440 OR EN.580.441) OR EN.540.307

Area: Engineering

EN.540.403. Colloids and Nanoparticles. 3 Credits.

Fundamental principles related to interactions, dynamics, and structure in colloidal, nanoparticle, and interfacial systems. Concepts covered include hydrodynamics, Brownian motion, diffusion, sedimentation, electrophoresis, colloidal and surface forces, polymeric forces, aggregation, deposition, and experimental methods. Modern topics related to colloids in nano- science and technology will be discussed throughout the course with frequent references to recent literature. Meets with EN.540.603

Area: Engineering, Natural Sciences

EN.540.405. Modern Data Analysis and Machine Learning for ChemBEs. 3 Credits.

This class will provide an introduction for chemical and biomolecular engineering students to modern methods of measuring and testing hypotheses using experimental or computational data. The course will cover methods of regression and data analysis such as linear and nonlinear regression, Bayesian analysis and principal or independent component analysis. The course will introduce concepts of machine learning including linear and nonlinear separation, neural networks, Gaussian processes and will provide exposure to deep learning concepts. The course will focus generally on image data and will consider topics of image processing, feature extraction and will cover for general data dimensionality reduction. Familiarity with computer programming (ideally Python), statistics and linear algebra are prerequisites.

Area: Engineering

EN.540.409. Dynamic Modeling and Control. 4 Credits.

Introduction to modeling, dynamics, and control. Unsteady state analysis of biomolecular and chemical process control systems. State space and Laplace transform techniques, block diagram algebra, and transfer functions. Feedback and feedforward control. Frequency response and stability analysis. Applications in chemical engineering (chemical reactors and separative processes) as well as biomolecular engineering (biosynthesis, pharmacokinetic modeling and biomolecular modeling based upon central dogma/gene expression). Introduction to nonlinear dynamics.

Prerequisite(s): EN.540.301 AND EN.540.306

Area: Engineering, Quantitative and Mathematical Sciences

EN.540.414. Computational Protein Structure Prediction and Design. 3 Credits.

This class will introduce the fundamental concepts in protein structure, biophysics, optimization and informatics that have enabled the breakthroughs in computational structure prediction and design. Problems covered will include protein folding and docking, design of ligand-binding sites, design of turns and folds, design of protein interfaces. Class will consist of lectures and hands-on computer workshops. Students will learn to use molecular visualization tools and write programs with the PyRosetta protein structure software suite, including a computational project. Programming experience is recommended.

Area: Engineering

EN.540.415. Interfacial Science with Applications to Nanoscale Systems. 3 Credits.

Nanostructured materials intrinsically possess large surface area (interface area) to volume ratios. It is this large interfacial area that gives rise to many of the amazing properties and technologies associated with nanotechnology. In this class we will examine how the properties of surfaces, interfaces, and nanoscale features differ from their macroscopic behavior. We will compare and contrast fluid-fluid interfaces with solid-fluid and solid-solid interfaces, discussing fundamental interfacial physics and chemistry, as well as touching on state-of-the-art technologies.

Area: Engineering

EN.540.418. Projects in the Design of a Chemical Car. 2 Credits.

Ready to put those concepts from class into practice? Members work over the course of the semester to design and build a chemically powered vehicle that will compete with other college teams at the American Institute of Chemical Engineers (AIChE) Regional Conference. In this course, the students work in small groups to design and construct the chassis along with chemically powered propulsion and break mechanisms within the constraints of the competition. In addition, students will give oral presentation, write reports, and do thorough safety analysis of their prototypes. Both semesters (EN.540.418 and EN.540.419) must be completed with passing grades to receive credit. This course may be repeated.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

Area: Engineering

EN.540.419. Projects in the Design of a Chemical Car. 2 Credits.

Ready to put those concepts from class into practice? Members work over the course of the semester to design and build a chemically powered vehicle that will compete with other college teams at the American Institute of Chemical Engineers (AIChE) Regional Conference. In this course, the students work in small groups to design and construct the chassis along with chemically powered propulsion and break mechanisms within the constraints of the competition. In addition, students will give oral presentation, write reports, and do thorough safety analysis of their prototypes. Both semesters (EN.540.418 and EN.540.419) must be completed with passing grades to receive credit.

Area: Engineering

EN.540.421. Project in Design: Pharmacodynamics. 3 Credits.

This is continuation of 540.400 Project in Design: Pharmacokinetics. It is a design course in which the design projects will be to develop pharmacodynamic models of the human body that can be used to understand the physiologic effects of drugs on the body. The course (and software to be developed) will cover the spectrum of ways in which pharmaceuticals affect human physiology. The goal is to develop process models of the human body that will predict pharmaceutical effects as a function of time and organ (or cell) type that will work for a wide variety of pharmaceuticals including small molecules, biologics, and chemotherapy agents. This course is organized to replicate group project work as it is practiced in industry. The class is divided into groups (typically 3 or 4 students) and each group will meet separately each week with the instructor. Hence, there is no regularly scheduled class times; student groups sign up for weekly meeting times using Starfish in Blackboard. These meetings typically will be 90 minutes long. The expectations and assignments for this course are quite different from most other courses. There are no weekly lectures by the instructor. Rather, each week each group will make a PowerPoint presentation on the week's topic or their progress on their project. Prerequisites 540.421 has a prerequisite of

540.400 Pharmacokinetics

Prerequisite(s): EN.540.400

Area: Engineering, Natural Sciences

EN.540.422. Introduction to Polymeric Materials. 3 Credits.

Polymeric materials are ubiquitous in our society from Nature-made proteins and polysaccharides to synthetic plastics and fibers. Their applications range from day-to-day consumables to high performance materials used in critically demanding areas, such as aviation, aerospace and medical devices. The objective of this course is to provide an introductory overview on the field of polymer science and engineering. Students will learn some basic concepts in polymer synthesis, characterization, and processing. With the basic concepts established, industrial applications of polymeric materials will be discussed in two categories: structural polymers and functional polymers. Structural polymers, including plastics, fibers, rubbers, coatings, adhesives, and composites, will be discussed in terms of their structure, processing, and property relationship with a flavor of industrial relevant products and applications. Future trends in developing environmentally friendly polymers from renewable resources ("green polymer chemistry") will also be covered. Lectures on functional polymers will be focused on their unique properties that are enabled by rational molecular design, controlled synthesis and processing (e.g. supramolecular assembly, and microfabrication). This class of specialty materials can find their use in high performance photovoltaics, batteries, membranes, and composites, and can also serve as "smart" materials for use in coatings, sensors, medical devices, and biomimicry.

Area: Engineering

EN.540.428. Supramolecular Materials and Nanomedicine. 3 Credits.

Nanomedicine is a quickly growing area that exploits the novel chemical, physical, and biological properties of nanostructures and nanostructured materials for medical treatments. This course presents basic design principles of constructing nanomaterials for use in drug delivery, disease diagnosis and imaging, and tissue engineering. Three major topics will be discussed, including 1) nanocarriers for drug delivery that are formed through soft matter assembly (e.g., surfactants, lipids, block copolymers, DNA, polyelectrolytes, peptides), 2) inorganic nanostructures for disease diagnosis and imaging (e.g., nanoparticles of gold and silver, quantum dots and carbon nanotubes), and 3) supramolecular scaffolds for tissue engineering and regenerative medicine. Students are expected to learn the physical, chemical and biological properties of each nanomaterial, the underlying physics and chemistry of fabricating such material, as well as their advantages and potential issues when used for biomedical applications. This course will also provide students opportunities for case studies on commercialized nanomedicine products. After this class, students should gain a deeper understanding of current challenges in translating nanoscience and nanotechnology.

Area: Engineering

EN.540.436. Design: Pharmacokinetics/Dynamics. 3 Credits.

This is a one semester overview of year long course; students that want a comprehensive understanding of pharmacokinetics and pharmacodynamics should take the 2 courses EN.540.400 and EN.540.421. This course covers the principles of pharmacokinetics and pharmacodynamics. Computer models of pharmacokinetic and pharmacodynamics behavior will be developed and then used to design better drug delivery regimens and to analyze drug chemistry modifications. The course (and software to be developed) will cover the spectrum of factors affecting pharmaceutical effects on physiology including drug formulation, mode of dosing and dosing rate, metabolism and metabolic cascades, storage in fatty tissues, and diffusional limitations (such as in crossing the blood-brain barrier or diffusional differences between normal and cancerous tissues). This course is organized to replicate group project work as it is practiced in industry. The class is divided into groups (typically 3 or 4 students) and each group will meet separately each week with the instructor. Hence, there is no regularly scheduled class times; student groups sign up for weekly meeting times using Starfish in Blackboard. These meetings typically will be 90 minutes long. The expectations and assignments for this course are quite different from most other courses. There are no weekly lectures by the instructor. Rather, each week each group will make a PowerPoint presentation on the week's topic or their progress on their project.

Prerequisites: EN.540.436 has a prerequisite of 540.301 Kinetic Processes

Prerequisite(s): EN.540.301

Area: Engineering, Natural Sciences

EN.540.437. Application of Molecular Evolution to Biotechnology. 3 Credits.

One of the most promising strategies for successfully designing complex biomolecular functions is to exploit nature's principles of evolution. This course provides an overview of the basics of molecular evolution as well as its experimental implementation. Current research problems in evolution-based biomolecular engineering will be used to illustrate principles in the design of biomolecules (i.e. protein engineering, RNA/DNA engineering), genetic circuits and complex biological systems including cells. Meets with EN.540.637

Prerequisite(s): AS.020.305 OR EN.580.221 OR permission of instructor.

Area: Engineering, Natural Sciences

EN.540.438. Advanced Topics in Pharmacokinetics and Pharmacodynamics I. 3 Credits.

This course involves a semester-long project in pharmacodynamics. Topics are chosen in consultation with instructor.

Prerequisite(s): EN.540.400 AND (EN.540.421 OR EN.540.436)

Area: Engineering, Natural Sciences

EN.540.439. Advanced Topics in Pharmacokinetics and Pharmacodynamics I. 3 Credits.

This course involves a semester-long project in pharmacodynamics. Topics are chosen in consultation with instructor.

Prerequisite(s): EN.540.421 OR EN.540.436

Area: Engineering, Natural Sciences

EN.540.440. Micro/Nanotechnology: The Science and Engineering of Small Structures. 3 Credits.

The field of micro / nanotechnology has been gaining tremendous momentum as evidenced by an explosive rise in the number of publications, patents and commercial activities. This is an introductory course intended to expose students to the field as well as real world applications. Lectures will include an overview of scaling of material properties at the nanoscale, micro and nanofabrication methods and essential analytical tools of relevance to the field. All through the course, we will go over electronic, optical and biological applications of emerging micro and nanoscale devices and materials. Co-listed with EN.540.640.

Area: Engineering

EN.540.452. Eukaryotic Cell Biotechnology. 2 Credits.

This course involves integrated lecture/discussion and laboratory components to review and participate in current and emerging topics involving eukaryotic biotechnology. Lectures and discussions review how fundamentals of biochemical kinetics and biomolecular engineering are connected to emerging problems in mammalian, algal, and stem cell biotechnology. Laboratory activities are connected to diverse scientific and technological fundamental topics on these same themes. Journal article and research presentations provide a context for laboratory activities with respect to emerging industrial applications for eukaryotic cell types. Research design and strategy is discussed in terms of its ultimate implementation in laboratory, pilot plant, and eventually manufacturing facilities. Methodologies implemented include cell and metabolic engineering for improving yields and production rates of proteins, cells, and tissues. Example topics include expansion of mammalian, stem cells, and algae for the production of membrane proteins, biologics, biofuels, and complex metabolites. Consent of instructor only.

Area: Engineering

EN.540.455. Current Topics in DNA Nanotechnology Practicum. 3 Credits.

Research laboratory elective course where students can learn DNA nanotechnology and build nanostructures.

EN.540.460. Polymer Physics. 3 Credits.

This course will cover the physics aspect of macromolecular/polymeric materials. We will discuss the molecular origin of key physical phenomena, such as chain relaxation, time temperature superposition, free volume, high strain rate behavior, phase transitions, flow and fracture as well as physical aging. Many real world examples will be used throughout the course. We will also discuss the recent advances in biopolymers, polymers for 3D printing, electro-spinning and polymers for tissue engineering. Students should have introductory training in Materials Science.

Prerequisite(s): AS.030.101 AND AS.171.101

Area: Engineering, Natural Sciences

EN.540.462. Polymer Design and Bioconjugation. 3 Credits.

This course will focus on conventional to most recent inventions on polymer and conjugation chemistry. The weekly lectures will include the reaction strategy, designs and characterization techniques, structure-property relationship, simplistic approaches and versatile application oriented-solutions to Biomaterials and Tissue engineering related challenges. Students will learn how to devise creative strategies, process design and product development. Preliminary knowledge of organic chemistry is expected.

Area: Engineering, Natural Sciences

EN.540.465. Engineering Principles of Drug Delivery. 3 Credits.

Fundamental concepts in drug delivery from an engineering perspective. Biological organisms are viewed as highly interconnected networks where the surfaces/interfaces can be activated or altered 'chemically' and 'physically/mechanically'. The importance of intermolecular and interfacial interactions on drug delivery carriers is the focal point of this course. Topics include: drug delivery mechanisms (passive, targeted); therapeutic modalities and mechanisms of action; engineering principles of controlled release and quantitative understanding of drug transport (diffusion, convection); effects of electrostatics, macromolecular conformation, and molecular dynamics on interfacial interactions; thermodynamic principles of self-assembly; chemical and physical characteristics of delivery molecules and assemblies (polymer based, lipid based); significance of biodistributions and pharmacokinetic models; toxicity issues and immune responses.

Prerequisite(s): Students may take EN.540.465 or EN.540.665, but not both.;EN.540.303

Area: Engineering, Natural Sciences

EN.540.468. Introduction to Nonlinear Dynamics and Chaos. 3 Credits.

An introduction to the phenomenology of nonlinear dynamic behavior with emphasis on models of actual physical, chemical, and biological systems, involving an interdisciplinary approach to ideas from mathematics, computing, and modeling. The common features of the development of chaotic behavior in both mathematical models and experimental studies are stressed, and the use of modern data-mining tools to analyze dynamic data will be explored. Knowledge of Linear Algebra and Ordinary Differential Equations is a prerequisite (at an undergraduate level); Some computing experience is desirable. Emphasis will be placed on the geometric/visual computer-aided description and understanding of dynamics and chaos.

Prerequisite(s): Students may receive credit for only one of EN.553.473 OR EN.553.673 OR EN.540.468 OR EN.540.668.;((AS.110.201 OR AS.110.212) AND (AS.110.302 OR AS.110.306)) OR EN.553.291

Area: Engineering, Quantitative and Mathematical Sciences

EN.540.490. Introduction to Chemical Process Safety. 1 Credit.

An elementary introduction to chemical process safety, this course covers a selection of topics in chemical process safety analysis and management, taken against the backdrop of real processes and process accidents. Topics include materials compatibility, risk assessment, reactive chemical hazard, process hazard analysis via the HAZOP method, fire/explosion and toxic release incidents, incident investigation, inerting with nitrogen, and Inherently Safer Design

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.540.203 AND EN.540.303

Area: Engineering

EN.540.501. Independent Research. 3 Credits.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.502. Independent Study. 0 - 3 Credits.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.503. Independent Research. 1 - 3 Credits.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.509. Undergraduate Internship. 1 Credit.

Internship unpaid and approved by ChemBE faculty.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.511. Group Undergraduate Research. 1 - 3 Credits.

Students do individual projects (or in collaboration with faculty and/or graduate students) in areas basic to chemical engineering. This section has weekly research group meeting that students are expected to attend.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.513. Group Undergraduate Research. 1 - 3 Credits.

Students do individual projects (or in collaboration with faculty and/or graduate students) in areas basic to chemical engineering. This section has weekly research group meeting that students are expected to attend.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.596. Summer Internship.

Summer internship paid and approved by ChemBE faculty.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.597. Research. 3 Credits.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.598. Summer Internship. 1 Credit.

Summer internship unpaid and approved by ChemBE faculty.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.599. Independent Study - Summer. 0 - 3 Credits.

Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.540.600. Chemical and Biomolecular Engineering Seminar. 1 Credit.

Lectures are presented on current subjects relevant to chemical engineering. Attendance at 80% of departmental seminars is required to receive credit for this class.

Area: Engineering

EN.540.601. Chemical and Biomolecular Engineering Seminar. 1 Credit.

Area: Engineering

EN.540.602. Metabolic Systems Biotechnology. 3 Credits.

The aim of this course is to provide a fundamental understanding of the quantitative principles and methodologies of systems biology and biochemical engineering of metabolism. This includes concepts of cellular growth, cellular stoichiometric models, metabolic networks, metabolite fluxes, and genome-scale metabolic models. Quantitative methods and systems biology approaches for metabolic flux analysis and metabolic control theory will be included as well as an analysis of biochemical systems and bioreactors including a consideration of mass transport processes.

Area: Engineering

EN.540.603. Colloids and Nanoparticles. 3 Credits.

Fundamental principles related to interactions, dynamics, and structure in colloidal, nanoparticle, and interfacial systems. Concepts covered include hydrodynamics, Brownian motion, diffusion, sedimentation, electrophoresis, colloidal and surface forces, polymeric forces, aggregation, deposition, and experimental methods. Modern topics related to colloids in nano- science and technology will be discussed throughout the course with frequent references to recent literature. Meets with EN.540.403

Area: Engineering

EN.540.604. Transport Phenomena in Practice. 3 Credits.

Required course for ChemBE Masters students

Area: Engineering, Quantitative and Mathematical Sciences

EN.540.605. Modern Data Analysis and Machine Learning for ChemBEs. 3 Credits.

This class will provide an introduction for chemical and biomolecular engineering students to modern methods of measuring and testing hypotheses using experimental or computational data. The course will cover methods of regression and data analysis such as linear and nonlinear regression, Bayesian analysis and principal or independent component analysis. The course will introduce concepts of machine learning including linear and nonlinear separation, neural networks, Gaussian processes and will provide exposure to deep learning concepts. The course will focus generally on image data and will consider topics of image processing, feature extraction and will cover for general data dimensionality reduction. Familiarity with computer programming (ideally Python), statistics and linear algebra are prerequisites.

Area: Engineering

EN.540.606. Chemical & Biomolecular Separation. 4 Credits.

This course covers staged and continuous-contacting separations processes critical to the chemical and biochemical industries. Separations technologies studied include distillation, liquid-liquid extraction, gas absorption, membrane ultrafiltration, reverse osmosis, dialysis, adsorption, and chromatography. Particular emphasis is placed on the biochemical uses of these processes and consequently on how the treatment of these processes differs from the more traditional approach. Only with permission of the instructor. Co-listed with EN.540.306

Area: Engineering

EN.540.607. Renewable Energy Technologies. 3 Credits.

This course will discuss the recent progress of renewable energy technologies, emphasizing a perspective from chemical engineering. Engineering principles in terms of mass and energy balance, phase equilibrium, kinetics and catalysis, transport, etc. will be applied to analyze the performance of new energy conversion and storage technologies. Topics of interest include solar cells, fuel cells, batteries and biofuels.

Area: Engineering

EN.540.610. Chemical and Biomolecular Engineering Design: Spring. 3 Credits.

This course is one part of a two semester sequence. This course guides the student through the contrasting aspects of product design and of process design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the selection of best products to fulfill the needs. Process design concerns the quantitative description of processes which serve to produce many commodity chemicals, the estimation of process profitability, and the potential for profitability improvement through incremental changes in the process. Students work in small teams to complete a major project demonstrating their understanding of and proficiency in the primary objectives of the course. Students report several times both orally and in writing on their accomplishments. Laboratory tests can be performed and/or prototypes can be made. Note that both courses, 540.609 and 540.610 must be taken, the two courses can be started in any term.

Area: Engineering

EN.540.614. Computational Protein Structure Prediction and Design. 3 Credits.

This class will introduce the fundamental concepts in protein structure, biophysics, optimization and informatics that have enabled the breakthroughs in computational structure prediction and design. Problems covered will include protein folding and docking, design of ligand-binding sites, design of turns and folds, design of protein interfaces. Class will consist of lectures and hands-on computer workshops. Students will learn to use molecular visualization tools and write programs with the PyRosetta protein structure software suite, including a computational project. Programming experience is recommended.

Area: Engineering

EN.540.615. Interfacial Science with Applications to Nanoscale Systems. 3 Credits.

Nanostructured materials intrinsically possess large surface area (interface area) to volume ratios. It is this large interfacial area that gives rise to many of the amazing properties and technologies associated with nanotechnology. In this class we will examine how the properties of surfaces, interfaces, and nanoscale features differ from their macroscopic behavior. We will compare and contrast fluid-fluid interfaces with solid-fluid and solid-solid interfaces, discussing fundamental interfacial physics and chemistry, as well as touching on state-of-the-art technologies.

Area: Engineering

EN.540.619. Projects in Design: Alternative Energy. 3 Credits.

This course is a group design project (i.e. not a lecture course) to use chemical process simulation tools to model a real-world, alternative-energy process of interest to Chemical and Biomolecular Engineers. The goal of the project will be to develop a process model that is sufficiently complete and robust that it can be used to understand the important factors in the process design and/or operation. This design project is focused on the role alternative energy will play in our country's future. About a third of the course will be devoted to understanding the role of energy and alternative energy in the US and world economies. The remainder of the course will be devoted to a technical and economic analysis of an alternative energy technology. This course is organized to replicate group project work as it is practiced in industry. The class is divided into groups (typically 3 or 4 students) and each group will meet separately each week with the instructor. Hence, there is no regularly scheduled class times; student groups sign up for weekly meeting times using Starfish in Blackboard. These meetings typically will be 60 minutes long. The expectations and assignments for this course are quite different from most other courses. There are no weekly lectures by the instructor. Rather, each week each group will make a PowerPoint presentation on the week's topic or their progress on their project. Graduate level. Meets with EN.540.401

Prerequisite(s): EN.540.202 AND EN.540.203 AND EN.540.301 AND EN.540.305

Area: Engineering

EN.540.621. Project in Design: Pharmacodynamics. 3 Credits.

This is continuation of 540.400 Project in Design: Pharmacokinetics. It is a design course in which the design projects will be to develop pharmacodynamic models of the human body that can be used to understand the physiologic effects of drugs on the body. The course (and software to be developed) will cover the spectrum of ways in which pharmaceuticals affect human physiology. The goal is to develop process models of the human body that will predict pharmaceutical effects as a function of time and organ (or cell) type that will work for a wide variety of pharmaceuticals including small molecules, biologics, and chemotherapy agents. This course is organized to replicate group project work as it is practiced in industry. The class is divided into groups (typically 3 or 4 students) and each group will meet separately each week with the instructor. Hence, there is no regularly scheduled class times; student groups sign up for weekly meeting times using Starfish in Blackboard. These meetings typically will be 90 minutes long. The expectations and assignments for this course are quite different from most other courses. There are no weekly lectures by the instructor. Rather, each week each group will make a PowerPoint presentation on the week's topic or their progress on their project. Prerequisites 540.421 has a prerequisite of Pharmacokinetics .

Prerequisite(s): EN.540.632

Area: Engineering, Natural Sciences

EN.540.622. Introduction to Polymeric Materials. 3 Credits.

Polymeric materials are ubiquitous in our society from Nature-made proteins and polysaccharides to synthetic plastics and fibers. Their applications range from day-to-day consumables to high performance materials used in critically demanding areas, such as aviation, aerospace and medical devices. The objective of this course is to provide an introductory overview on the field of polymer science and engineering. Students will learn some basic concepts in polymer synthesis, characterization, and processing. With the basic concepts established, industrial applications of polymeric materials will be discussed in two categories: structural polymers and functional polymers. Structural polymers, including plastics, fibers, rubbers, coatings, adhesives, and composites, will be discussed in terms of their structure, processing, and property relationship with a flavor of industrial relevant products and applications. Future trends in developing environmentally friendly polymers from renewable resources ("green polymer chemistry") will also be covered. Lectures on functional polymers will be focused on their unique properties that are enabled by rational molecular design, controlled synthesis and processing (e.g. supramolecular assembly, and microfabrication). This class of specialty materials can find their use in high performance photovoltaics, batteries, membranes, and composites, and can also serve as "smart" materials for use in coatings, sensors, medical devices, and biomimicry.

Area: Engineering

EN.540.628. Supramolecular Materials and Nanomedicine. 3 Credits.

Nanomedicine is a quickly growing area that exploits the novel chemical, physical, and biological properties of nanostructures and nanostructured materials for medical treatments. This course presents basic design principles of constructing nanomaterials for use in drug delivery, disease diagnosis and imaging, and tissue engineering. Three major topics will be discussed, including 1) nanocarriers for drug delivery that are formed through soft matter assembly (e.g., surfactants, lipids, block copolymers, DNA, polyelectrolytes, peptides), 2) inorganic nanostructures for disease diagnosis and imaging (e.g., nanoparticles of gold and silver, quantum dots and carbon nanotubes), and 3) supramolecular scaffolds for tissue engineering and regenerative medicine. Students are expected to learn the physical, chemical and biological properties of each nanomaterial, the underlying physics and chemistry of fabricating such material, as well as their advantages and potential issues when used for biomedical applications. This course will also provide students opportunities for case studies on commercialized nanomedicine products. After this class, students should gain a deeper understanding of current challenges in translating nanoscience and nanotechnology into medical therapies.

Area: Engineering, Natural Sciences

EN.540.630. Thermodynamics, Statistical Mechanics, and Kinetics. 3 Credits.

In this course we will aim for understanding the thermodynamics of chemical and bio-molecular systems. We will first review classical, macroscopic thermodynamics covering concepts such as equilibrium, stability and the role of thermodynamic potentials. Our goal will be to gain a feel for the generality of thermodynamics. Statistical mechanics provides a link between the mechanics of atoms and macroscopic thermodynamics. We will introduce this branch in two distinct ways: 1) following standard methods of developing concepts such as ensembles and partition functions, and 2) where we will treat the basis of statistical mechanics as a problem in inference. With this foundation, we will consider concepts relevant to understanding the liquid state. Chemical transformations in a liquid are of importance in much of chemistry and biology; quasi-chemical generalizations of the potential distribution theorem will be introduced to present these ideas. We hope to give an overview of modern developments relating equilibrium work to non-equilibrium work, as these are of increasing importance in studies on single molecule systems. Course is open to Chemical and Biomolecular Engineering BS/MS Concurrent and MSE students.

Area: Engineering

EN.540.631. Kinetic Processes. 4 Credits.

Review of numerical methods applied to kinetic phenomena and reactor design in chemical and biological processes. Homogeneous kinetics and interpretation of reaction rate data. Batch, plug flow, and stirred tank reactor analyses, including reactors in parallel and in series. Selectivity and optimization considerations in multiple reaction systems. Non isothermal reactors. Elements of heterogeneous kinetics, including adsorption isotherms and heterogeneous catalysis. Coupled transport and chemical/biological reaction rates.

Area: Engineering

EN.540.632. Project in Design: Pharmacokinetics. 3 Credits.

This is a design course in which the design projects will be to develop pharmacokinetic models of the human body that can be used to understand the temporal distribution, spatial distribution and bioavailability of pharmaceutical drugs. The course (and software to be developed) will cover the spectrum of factors affecting pharmaceutical bioavailability including drug formulation, mode of dosing and dosing rate, metabolism and metabolic cascades, storage in fatty tissues, and diffusional limitations (such as in crossing the blood-brain barrier or diffusional differences between normal and cancerous cells). The goal is to develop process models of the human body that will predict pharmaceutical bioavailability as a function of time and organ (or cell) type that will work for a wide variety of pharmaceuticals including small molecules, biologics, and chemotherapy agents. This course is organized to replicate group project work as it is practiced in industry. The class is divided into groups (typically 3 or 4 students) and each group will meet separately each week with the instructor. Hence, there is no regularly scheduled class times; student groups sign up for weekly meeting times using Starfish in Blackboard. These meetings typically will be 90 minutes long. The expectations and assignments for this course are quite different from most other courses. There are no weekly lectures by the instructor. Rather, each week each group will make a PowerPoint presentation on the week's topic or their progress on their project.

Area: Engineering, Natural Sciences

EN.540.634. Special Topics in Thermodynamics. 3 Credits.

Area: Engineering

EN.540.635. Software Carpentry. 3 Credits.

A 'crash course' intended to teach new graduate students the fundamentals of programming and practical coding skills that will accelerate facility with computational aspects of graduate research. The course covers how computers work from the inside out, with an introduction to the Linux operating system. Programming will be taught primarily in Python, with an emphasis on solving research-related problems. This peer-taught course will cover variables, conditionals, loops, functions, classes, plotting, data structures and algorithms, with some advanced topics (C++, gradient-based minimization, Procrustes, eigenvalue/vector data analysis, embarrassingly parallel 'for' loops). No prior programming skills are required, but experience with an introductory computing language will be helpful. Familiarity with differential equations and linear algebra will be assumed.

Area: Engineering

EN.540.636. Design: Pharmacokinetics/Dynamics. 3 Credits.

One semester overview of year long course, students that want a comprehensive understanding of pharmacokinetics and pharmacodynamics should take the 2 all 540.632 Projects in Design: Pharmacokinetics Spring 540.621 Projects in Design: Pharmacodynamics. This course covers the principles of pharmacokinetics and pharmacodynamics. Computer models of pharmacokinetic and pharmacodynamics behavior will be developed and then used to design better drug delivery regimens and to analyze drug chemistry modifications.

Area: Engineering, Natural Sciences

EN.540.637. Application of Molecular Evolution to Biotechnology. 3 Credits.

One of the most promising strategies for successfully designing complex biomolecular functions is to exploit nature's principles of evolution. This course provides an overview of the basics of molecular evolution as well as its experimental implementation. Current research problems in evolution-based biomolecular engineering will be used to illustrate principles in the design of biomolecules (i.e. protein engineering, RNA/DNA engineering), genetic circuits and complex biological systems including cells. A course in Biochemistry or Molecular Biology is recommended. Meets with EN.540.437. Undergraduates with the appropriate background can take the course with permission of the instructor.

Area: Engineering, Natural Sciences

EN.540.638. Advanced Topics in Pharmacokinetics and Pharmacodynamics I. 3 Credits.

This course involves a semester-long project in pharmacodynamics. Topics are chosen in consultation with instructor.

Prerequisite(s): EN.540.400 AND EN.540.421 OR EN.540.436

Area: Engineering, Natural Sciences

EN.540.639. Advanced Topics in Pharmacokinetics and Pharmacodynamics I. 3 Credits.

This course involves a semester-long project in pharmacodynamics. Topics are chosen in consultation with instructor.

Prerequisite(s): EN.540.400 AND EN.540.421 OR EN.540.436

Area: Engineering, Natural Sciences

EN.540.640. Micro/Nanotechnology: The Science and Engineering of Small Structures. 3 Credits.

The field of micro / nanotechnology has been gaining tremendous momentum as evidenced by an explosive rise in the number of publications, patents and commercial activities. This is an introductory course intended to expose students to the field as well as real world applications. Lectures will include an overview of scaling of material properties at the nanoscale, micro and nanofabrication methods and essential analytical tools of relevance to the field. All through the course, we will go over electronic, optical and biological applications of emerging micro and nanoscale devices and materials. Co-listed with EN.540.440.

EN.540.652. Advanced Transport Phenomena. 3 Credits.

It is the goal of this course to move the graduate student (and advanced undergraduate student) from the introductory level of transport phenomena (undergraduate) to a level that will allow them to be effective in researching transport-related topics in a variety of biomedical, chemical and biochemical engineering areas. The basic equations that govern mass, momentum, and energy transport will be derived and used to solve problems that demonstrate the physical insight necessary to apply these equations to original situations. Some topics include solution techniques utilizing expansions of harmonic functions, singularity solutions, lubrication theory for flow in confined geometries, boundary layer theory, Stokes flow, forced convection, buoyancy-driven flow, Taylor-Aris dispersion, and reaction-diffusion. Open to PhD students as well as Chemical and Biomolecular Engineering BS/MSE Concurrent and MSE students.

Area: Engineering

EN.540.660. Polymer Physics. 3 Credits.

This course will cover the physics aspect of macromolecular/polymeric materials. We will discuss the molecular origin of key physical phenomena, such as chain relaxation, time temperature superposition, free volume, high strain rate behavior, phase transitions, flow and fracture as well as physical aging. Many real world examples will be used throughout the course. We will also discuss the recent advances in biopolymers, polymers for 3D printing, electro-spinning and polymers for tissue engineering. Students should have introductory training in Materials Science.

Area: Engineering, Natural Sciences

EN.540.661. Nanobioengineering Laboratory. 3 Credits.

Students explore different experimental methodologies in Nanobioengineering. Students work in small teams to complete one or more major projects expanding their understanding and applying their theoretical knowledge to practical problems. The course will employ a variety of experimental methods, from material synthesis to biological applications. Students report several times either orally and in writing on their accomplishments. Project meetings may be held outside of the appointed class time. Graduate students only

EN.540.663. Thermodynamic Independent Study. 3 Credits.

In this course, we will discuss the important role that thermodynamics plays in chemical engineering practice. After a short review of the first and second laws, we will examine how thermodynamic concepts affect mass and energy balances. We will discuss the properties of systems containing pure species and mixtures and how to analyze the behavior of ideal and real systems. We will estimate heat effects associated with temperature change, phase change, and chemical reaction. The theory associated with properties of pure fluids will be discussed along its application to flow processes. We will present the framework for understanding solution thermodynamics and mixing. Applications of thermodynamics especially important to chemical engineers, such as vapor-liquid equilibrium in distillation and chemical reaction equilibrium in kinetics and reaction engineering, will be discussed. Examples will serve to illustrate how thermodynamic calculations are an integral part of the design and optimization of chemical processes.

Area: Engineering

EN.540.665. Engineering Principles of Drug Delivery. 3 Credits.

Fundamental concepts in drug delivery from an engineering perspective. Biological organisms are viewed as highly interconnected networks where the surfaces/interfaces can be activated or altered 'chemically' and 'physically/mechanically'. The importance of intermolecular and interfacial interactions on drug delivery carriers is the focal point of this course. Topics include: drug delivery mechanisms (passive, targeted); therapeutic modalities and mechanisms of action; engineering principles of controlled release and quantitative understanding of drug transport (diffusion, convection); effects of electrostatics, macromolecular conformation, and molecular dynamics on interfacial interactions; thermodynamic principles of self-assembly; chemical and physical characteristics of delivery molecules and assemblies (polymer based, lipid based); significance of biodistributions and pharmacokinetic models; toxicity issues and immune responses. Recommended prerequisite: Transport Phenomena - EN.540.303 or equivalent

Prerequisite(s): Students may take EN.540.465 or EN.540.665, but not both.

Area: Engineering, Natural Sciences

EN.540.668. Introduction to Nonlinear Dynamics and Chaos. 3 Credits.

An introduction to the phenomenology of nonlinear dynamic behavior with emphasis on models of actual physical, chemical, and biological systems, involving an interdisciplinary approach to ideas from mathematics, computing, and modeling. The common features of the development of chaotic behavior in both mathematical models and experimental studies are stressed, and the use of modern data-mining tools to analyze dynamic data will be explored. Knowledge of Linear Algebra and Ordinary Differential Equations is a prerequisite (at an undergraduate level); Some computing experience is desirable. Emphasis will be placed on the geometric/visual computer-aided description and understanding of dynamics and chaos.

Prerequisite(s): Students may receive credit for only one of EN.553.473 OR EN.553.673 OR EN.540.468 OR EN.540.668.;((AS.110.201 OR AS.110.212) AND (S.110.302 OR AS.110.306) OR EN.553.291[C]

Area: Engineering, Quantitative and Mathematical Sciences

EN.540.671. Advanced Thermodynamics in Practice. 3 Credits.

In this course, we will discuss the important role that thermodynamics plays in chemical engineering practice. After a short review of the first and second laws, we will examine how thermodynamic concepts affect mass and energy balances. We will discuss the properties of systems containing pure species and mixtures and how to analyze the behavior of ideal and real systems. We will estimate heat effects associated with temperature change, phase change, and chemical reaction. The theory associated with properties of pure fluids will be discussed along its application to flow processes. We will present the framework for understanding solution thermodynamics and mixing. Applications of thermodynamics especially important to chemical engineers, such as vapor-liquid equilibrium in distillation and chemical reaction equilibrium in kinetics and reaction engineering, will be discussed. Examples will serve to illustrate how thermodynamic calculations are an integral part of the design and optimization of chemical processes.

Area: Engineering

EN.540.673. Advanced Chemical Reaction Engineering in Practice. 3 Credits.

Chemical reaction engineering deals with the analysis on data and the design of equipment in which reactions occur. Reactors may contain one or more phases and be used to conduct chemical or biochemical transformations. The course will cover the fundamental aspects of kinetics, data acquisition, data interpretation, heterogeneous catalysis and heat and mass transfer for each type of reactor. Special emphasis will be placed on the practical application of reaction engineering in the petrochemical, chemical, biochemical and materials industries. The course will make student aware of the needs and opportunities for chemical reaction engineering in industry.

Area: Engineering, Quantitative and Mathematical Sciences

EN.540.690. Chemical and Biomolecular Engineering Design. 3 Credits.

This course is one part of a two semester sequence in Chemical and Biomolecular Engineering Product Design. It is intended for students in the ChemBE master's program. This course guides the student through the complex process of new product design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the selection of best products to fulfill needs. Students work in small teams to develop a new product idea, design the product and then iterate on prototype development. Students report several times both orally and in writing on their accomplishments. Time is allowed so that laboratory tests can be performed and/or prototypes can be built. Note that generally both courses, 540.609 and 540.610 must be taken to complete the prototype development. The two courses can be started in any term.

Area: Engineering

EN.540.691. Chemical Engineering Modeling and Design for Graduate Students. 3 Credits.

This course guides student through the open-ended problems in product and process design. Product design concerns the recognition of customer needs, the creation of suitable specifications, and the creation of new products to fulfill a societal need. Process design concerns the quantitative description of processes which serve to produce chemically-derived materials and the estimation of process profitability. Students work in small teams to complete a major project demonstrating their understanding of and proficiency in the principles of unit operations and design. Students report weekly both orally and in writing on their accomplishments. Some projects are single semester, but others can be multi-semester. Students can start in any semester and can work on projects for as many semesters as they want.

EN.540.801. Graduate Research. 3 - 20 Credits.**EN.540.803. Independent Research. 3 - 20 Credits.**