EN.545 (CHEMICAL AND BIOMOLECULAR ENGINEERING)

EN.545.203. Engineering Thermodynamics. 3 Credits.
This course covers the formulation and solution of material, energy, and entropy balances, with an emphasis on open systems. A systematic problem-solving approach is developed for chemical process-related systems. Extensive use is made of classical thermodynamic relationships and constitutive equations. Applications include the analysis and design of engines, refrigerators, heat pumps, compressors, and turbines. Prerequisite(s): 540.202 Introduction to Chemical & Biological Process Analysis or permission of instructor. Corequisite(s): AS.110.202 Calculus III (Calculus of Several Variables). Course Note(s): Not for graduate credit.

EN.545.204. Applied Physical Chemistry. 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): 540.203 Engineering Thermodynamics and either 540.202 Introduction to Chemical & Biological Process Analysis or permission of instructor. 540.xxx courses are offered through the full-time Chemical & Biomolecular Engineering Department. Course Note(s): Not for graduate credit.

EN.545.301. Kinetic Processes. 3 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): 540.203 Engineering Thermodynamics and 540.303 Transport Phenomena I, and either 540.202 Introduction to Chemical & Biological Process Analysis or permission of instructor. 540.xxx courses are offered through the full-time Chemical & Biomolecular Engineering Department. Course Note(s): Not for graduate credit.

EN.545.303. Transport Phenomena I. 3 Credits.
This course provides an introduction to the field of transport phenomena, including molecular mechanisms of momentum transport (viscous flow); energy transport (heat conduction); mass transport (diffusion); isothermal equations of change (continuity, motion, and energy); the development of the Navier-Stokes equation; the development of non-isothermal and multicomponent equations of change for heat and mass transfer; and exact solutions to steady-state, isothermal unidirectional flow problems and to steady-state heat and mass transfer problems. The analogies between heat, mass, and momentum transfer are emphasized throughout the course. Prerequisite(s): A grade of C or better in Calculus I and II and 540.202 Introduction to Chemical & Biological Process Analysis or permission of instructor. 540.202 is offered through the fulltime Chemical & Biomolecular Engineering Department. Corequisite(s): 500.303 Applied Mathematics I or AS.110.302. Course Note(s): Not for graduate credit.

EN.545.304. Transport Phenomena II. 3 Credits.
Topics covered in this course include dimensional analysis and dimensionless groups, laminar boundary layers, introduction to turbulent flow, definition of the friction factor, macro-scopic 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, and interphase mass transfer. Prerequisite(s): 540.303 Transport Phenomena I. 540. xxx courses are offered through the full-time Chemical & Biomolecular Engineering Department. Course Note(s): Not for graduate credit.

EN.545.602. 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 genomescale 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.

EN.545.603. Colloids and Nanoparticles. 3 Credits.
This course explains the 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 nanoscience and technology will be discussed throughout the course, with frequent references to recent literature.

EN.545.604. Transport Phenomena in Practice. 3 Credits.
This course will provide a review of core concepts of transport phenomena (momentum, heat, and mass transfer). Chemical and biomolecular engineering problems that are relevant in the areas of medicine, biomaterials, and physiology will be discussed. Application areas will range from oxygen transport in lungs and delivery in tissues as an example of a gas–fluid interface; Fluid flow and shear stress, with blood as an example of a nonNewtonian fluid; molecular transport using cellular transport as an example; filtration and separation (membranes) using the Kidney as an example; and drug delivery and pharmacokinetics. Prerequisite(s): Previous experience with transport phenomena concepts will be helpful but is not required. Knowledge in vector calculus and differential equations is imperative for this course.

EN.545.606. Chemical & Biomolecular Separation. 3 Credits.
This course covers staged and continuous-contacting separations processes critical to the chemical and biochemical industries. Separations technologies studied include distillation, liquidliquid 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. Course Note(s): Only with permission of the instructor. Colisted with 540.306.

EN.545.614. Computational Protein Structure Prediction and Design. 3 Credits.
The prediction of protein structure from the amino acid sequence has been a grand challenge for more than 50 years. With recent progress in research, it is now possible to blindly predict many protein structures and even to design new structures from scratch. 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, and design of protein interfaces. Classes will consist of lectures and handson computer workshops. Students will learn to use molecular visualization tools and write programs with the PyRosetta protein structure software suite, including a computational project. Prerequisite(s): Programming experience is helpful but not required.

EN.545.615. 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 interface 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.

EN.545.619. Project in Design: Alternative Energy. 3 Credits.
This course is a group design project (i.e., not a lecture course). In the class, student groups research the various forms of alternative energy and then model a real-world alternativeenergy process. 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 factor in the process design and/or operation. This design project is focused on the role of 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 meets separately each week with the instructor. Hence, there are 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. Prerequisite(s): 540.202 Introduction to Chemical & Biological Process Analysis; 540.203 Engineering Thermodynamics; 540.301 Kinetic Processes; and 540.305 Modeling and Statistical Analysis of Data for Chemical and Biomolecular Engineers. Course Note(s): Graduate Level. Meets with 540.401 Projects in Design: Alternative Energy.

EN.545.621. Project in Design: Pharmacodynamics. 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 and 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 are 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.

EN.545.622. Introduction to Polymeric Materials. 3 Credits.
Polymeric materials are ubiquitous in our society, from naturemade 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 focus 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.

EN.545.628. 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 have a deeper understanding of current challenges in translating nanoscience and nanotechnology into medical therapies.

EN.545.630. Thermodynamics and Statistical Mechanics. 3 Credits.
In this course we will aim for understanding the thermodynamics of chemical and biomolecular 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. Registration by instructor permission only.

EN.545.637. 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.

EN.545.639. Advanced Topics in Pharmacokinetics and Pharmacodynamics. 3 Credits.
This course involves a semester-long project in pharmacodynamics. Topics are chosen in consultation with instructor.

EN.545.640. Micro- and Nanotechnology. 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 and 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.

EN.545.652. Advanced Transport Phenomena. 3 Credits.
This lecture course introduces students to the application of engineering fundamentals from transport and kinetic processes to vascular biology and medicine. The first half of the course addresses the derivation of the governing equations for Newtonian fluids and their solution in the creeping flow limit. The second half of the course considers how these concepts can be used to understand the behavior of a deformable cell near planar surfaces. Prerequisite(s): Undergraduate Transport Phenomena preferred.

EN.545.660. 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.

EN.545.662. Polymer Design and Bioconjugation. 3 Credits.
This course will focus on conventional to most recent inventions on polymer and conjugation chemistry. 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 and about process design and product development. Prerequisite(s): Preliminary knowledge of organic chemistry is expected. No prerequisites for graduate students.

EN.545.665. 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 selfassembly; chemical and physical characteristics of delivery molecules and assemblies (polymer based, lipid based); significance of biodistributions and pharmacokinetic models; toxicity issues; and immune responses.

EN.545.668. 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. Emphasis will be placed on the geometric/visual computer-aided description and understanding of dynamics and chaos. Prerequisite(s): Knowledge of linear algebra and ordinary differential equations (at an undergraduate level); some computing experience is desirable.

EN.545.671. Advanced Thermodynamics in Practice. 3 Credits.
In this graduate-level course, we will cover important principles in thermodynamics and kinetics along with examples relevant to engineering practice. After a short review of the first and second laws of thermodynamics, we will move on to their application in engines and refrigeration. We will discuss the thermodynamic properties of systems consisting of pure species and mixtures and address phase equilibria. With the key thermodynamic concepts in place, we will discuss topics in kinetics, including the fundamentals of reaction rates, rate laws, multiple reactions, and nonelementary reaction kinetics. Finally, we will address how reactor type and properties, transport limitations, and phase equilibria influence reaction rate.

EN.545.672. Green Engineering, Alternative Energy and CO2 Capture/ Sequestration. 3 Credits.
This course inherently combines green engineering, alternative energy and CO2 capture and storage into a concentrated semester lecture. Green Engineering applies the cost-effective design, commercialization, and use of chemical processes in ways that minimize pollution at the source, and reduce impact on human activities and the environment. After general discussion of applying environmental principles into various chemical processes, this course will switch the gear to apply these green engineering ideas into the energy production that has increasing and critical importance to our modern world, how to minimize the pollution and CO2 emission. There are two ways to follow: 1. Alternative Energy, which uses alternative resources rather than the current dominant fossil fuel for energy production. Alternative energy includes solar, hydro, bioenergy, geothermal, tidal, nuclear energy and et al. The detailed production processes, the long term perspective, policy and advantages/ disadvantages over their counterpart, fossil fuel, will be discussed. 2. Fossil fuel with CO2 Capture and Storage. CO2 capture methods such as chemical solvents/chemical looping, membrane, oxy fuel combustion will be discussed and their technical benefits/limitations will be studied. The storage will cover geological methods (coal bed and saline aquifer), enhanced oil recovery, ocean storage, terrestrial and others. The technical details, cost, future trends and national/international policy (carbon taxes/markets) will be discussed in this course.

EN.545.673. 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 students aware of the needs and opportunities for chemical reaction engineering in industry.

EN.545.691. Chemical Engineering Modeling and Design for Graduate Students. 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 Chemical and Biomolecular Engineering master's program. This course guides the student through the complex process of new product design. Product designconcerns 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 on their accomplishments, both orally and in writing. Time is allowed so that laboratory tests can be performed and/ or prototypes can be built.

EN.545.800. Independent Study. 0 - 0 Credits.
Permission of instructor required.

EN.545.801. Indep Study Chem Engr. 0 - 0 Credits.
Permission of instructor required.