Department of Chemical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

06-100 Introduction to Chemical Engineering

Fall and Spring: 12 units
We equip students with creative engineering problem-solving techniques and fundamental chemical engineering material balance skills. Lectures, laboratory experiments, and recitation sessions are designed to provide coordinated training and experience in data analysis, material property estimation for single- and multi-phase systems, basic process flowsheet, reactive and non-reactive mass balances, problem solving strategies and tools, and team dynamics. The course is targeted for CIT First Year students.

06-150 First Year Research Project

Fall and Spring: 6 units
Research projects conducted by first year undergraduate students under the supervision of a Chemical Engineering faculty member. The nature of the project and the criteria for grading are to be determined between the student and the faculty supervisor. A final written report or an oral presentation of the results may be required. A commitment of six hours effort on the project per week is expected. Registration will be by permission only.

06-200 Sophomore Research Project

Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-222 Sophomore Chemical Engineering Seminar

Fall: 1 unit
This course provides an overview of the chemical engineering profession. It discusses the rationale for the curriculum, career paths, resume writing, written communication skills, and ethics, and also involves a project on the use and manufacture of chemicals.

06-223 Chemical Engineering Thermodynamics

Fall: 12 units
This course introduces students to thermodynamic state variables and the analysis of phase and chemical equilibrium in single- and multi-component chemical systems. Key topics include application of mass, energy and entropy balance equations to analyze processes with change of state and interconversion of energy between heat and work in open or closed systems; state property changes associated with phase change; equations of state to represent the pressure-volume-temperature relationship for pure materials and mixtures; Gibbs phase rule; phase equilibrium criteria; ideal and non-ideal mixtures; fugacity and prediction of pure liquid vapor pressure; fugacity and activity coefficients to predict multi-component vapor-liquid and liquid-liquid phase equilibrium; analysis of flash and other processes involving multi-component phase change; equilibrium constants and equilibrium conversions in chemically reacting systems.
Prerequisites: 06-100 and (33-141 or 33-151 or 33-121)

06-261 Fluid Mechanics

Spring: 9 units
The principles of fluid mechanics as applied to engineering, including unit operations, are discussed; examples include flow in conduits, process equipment, and commercial pipes, flow around submerged objects, and flow measurement. Microscopic mass and momentum balances are described, including the continuity and Navier-Stokes equations, and modern solution techniques will be explored. Microscopic flow structures will be determined for flow visualization. Boundary layer theory, turbulence, and non-Newtonian fluids are also discussed. A case-study project based on new technological advancements is also required.
Prerequisites: 21-254 and (33-151 or 33-121 or 33-141) and 06-223

06-262 Mathematical Methods of Chemical Engineering

Spring: 12 units
Mathematical techniques are presented as tools for modeling and solving engineering problems. Modeling of steady-state mass and energy balance problems using linear and matrix algebra, including Gaussian elimination, decomposition, and iterative techniques. Modeling of unsteady-state engineering problems using linear and nonlinear differential equations. Analytical techniques, including Laplace transforms, and numerical techniques for the solution of first-and higher-order differential equations and systems of differential equations arising in engineering models. Finally, the modeling of processes affected by chance and subject to experimental error; statistical and regression techniques within the context of experimental design and analysis of experimental data.
Prerequisites: 21-254 and 06-223

06-300 Junior Research Project

Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-310 Molecular Foundations of Chemical Engineering

Fall: 9 units
Students will learn to use the tools of molecular engineering that define the modern development of chemical engineering, using a combination of theory and computation. The theme throughout the course is the use of molecular engineering tools to specify alternative compositions and conditions for chemical engineering design. Applications will include the prediction of macroscopic transport properties and equations of state, and the ability to tune them via judicious specification of system composition; rate laws and rate constants for complex reacting systems, including multi-step heterogeneous and homogeneous reactions; and principles of non-covalent association and self-assembly in the context of sustainable chemical engineering product design. Students will investigate contemporary molecular engineering case studies focused on renewable energy, human health or solutions to environmental problems.
Prerequisites: 09-106 and 06-223

06-322 Junior Chemical Engineering Seminar

Fall: 2 units
This course discusses career choices for chemical engineers, professional practice, including alternate career paths, global industry, and graduate studies. It also emphasizes writing, interview skills, and oral presentations. Safety, environmental and ethical issues are illustrated in projects and via invited lectures.

06-323 Heat and Mass Transfer

Fall: 9 units
This course presents the fundamentals of heat and mass transfer, including steady-state and transient heat conduction and molecular diffusion, convection of heat and mass, and thermal radiation, with application to heat and mass transfer processes. Development of dimensionless quantities for engineering analysis is emphasized.
Prerequisites: 06-261 and (06-262 or 21-260) and (33-122 or 33-142 or 33-152)

06-325 Numerical Methods and Machine Learning for Chemical Engineering

Fall: 6 units
This course will focus on applying numerical methods and machine learning to chemical engineering problems. Students will learn how modern programming environments (on laptops and in the cloud) can run python code. Programming concepts such as defining functions and plotting quantities will be reviewed. Students will learn how to apply and debug numerical integration techniques to systems of ODEs. Solving systems of nonlinear equations and black-box optimization will be covered. Machine learning will be introduced starting with the statistics of linear and non-linear regression with regularization. Polynomial fitting and interpolation will be covered. With this base, students will learn how to apply machine learning techniques such as gaussian process regression and neural networks to regression tasks. A small project will be included near the end to encourage creative applications to chemical engineering problems.
Prerequisites: 06-262 and (15-112 or 15-110)

06-326 Optimization Modeling and Algorithms

Fall: 6 units
Formulation and solution of mathematical optimization problems with and without constraints. Objective functions are based on economics or functional specifications. Both discrete and continuous variables are considered.
Prerequisite: 06-262

06-361 Unit Operations of Chemical Engineering

Spring: 9 units
This course comprises many of the standard operations in chemical plants such as gas absorption, heat exchange, distillation and extraction. The design and operation of these devices is emphasized. A project dealing with a novel unit operation is also investigated.
Prerequisite: 06-323

06-363 Transport Process Laboratory

Spring: 9 units
Develop skills for proposing, designing, planning, implementing, interpreting, and communicating the results of experiments in fluid flow and heat and mass transfer. Oral and written reports are required.
Prerequisites: 06-261 and 06-323

06-364 Chemical Reaction Engineering

Spring: 9 units
Fundamental concepts in the kinetic modeling of chemical reactions, the treatment and analysis of rate data. Multiple reactions and reaction mechanisms. Analysis and design of ideal and non-ideal reactor systems. Energy effects and mass transfer in reactor systems. Introductory principles in heterogeneous catalysis.
Prerequisites: 06-323 and 06-310

06-400 Senior Research Project

Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-421 Chemical Process Systems Design

Fall: 12 units
Screening of processing alternatives. Computational strategies for preliminary material and energy balances in large chemical processes. Preliminary sizing of process equipment. Cost estimation, economics, and evaluation for chemical plants. Strategies for synthesizing energy networks and separation sequences. Preliminary design of a large industrial project.
Prerequisites: 06-364 and 06-361

06-423 Unit Operations Laboratory

Fall: 9 units
Open-ended laboratory projects illustrate the principles of unit operations in Chemical Engineering. In this course students select, with course staff review, current societal problems to which chemical engineering subject knowledge can be applied. Students work in teams to design and implement an experimental plan to evaluate proposed solutions. Teams must work together to identify constraints and relationships between the unit operations they work on. Students must document implementation feasibility (cost, scheduling, analytic capability, etc.) and clearly identify the criteria and methods for assessing experimental results. Oral and written reports are required.
Prerequisites: 06-361 and 06-364

06-426 Experimental Colloid Surface Science

Fall: 9 units
Laboratory exercises will deal with preparation and stabilization of colloids, flocculation, micellar aggregates, surface tension, contact angle, spreading and adsorption. Basic concepts will be related to practical problems of wetting, lubrication, foaming, adhesion, coatings and corrosion.
Prerequisites: 09-221 and 06-607

06-463 Chemical Product Design

Spring: 9 units
Computer-aided design of a chemical product. Course involves design of molecular structure, microstructure, or devices/processes that effect chemical change. This is a project-based course, for which an extensive report must be submitted.
Prerequisite: 06-421

06-464 Chemical Engineering Process Control

Spring: 9 units
This course presents basic concepts of process dynamics and feedback control. Included are selection of measurements and manipulated variables, definition of transfer functions, creation of block diagrams and closed loop configurations. The course also covers concepts of open loop and closed loop stability, and tuning of PID controllers.
Prerequisite: 06-325

06-466 Experimental Polymer Science

Spring: 9 units
Macromolecular behavior in bulk and in solution will be explored in experiments on tensile strength, elasticity, swelling of networks, solution viscosity, melt flow, and polymerization reactions. Particular reference will be made to aspects affecting production and fabrication of polymeric materials.
Prerequisites: 09-221 and (06-609 or 09-509)

06-606 Computational Methods for Large Scale Process Design & Analysis

Spring: 9 units
This course deals with the underlying computer-aided design techniques for steady-state and dynamic simulation, numerical solution and decomposition strategies for large systems of sparse nonlinear algebraic equations, stiff ordinary differential equations, strategies for mixed algebraic/differential systems and computer architectures for flowsheeting systems.
Prerequisites: 06-262 and 06-361

Course Website: http://numero.cheme.cmu.edu/course/06606.html

06-607 Physical Chemistry of Colloids and Surfaces

All Semesters: 9 units
Thermodynamics of surfaces; adsorption at gas, liquid, and solid interfaces; capillarity; wetting, spreading, lubrication and adhesion; properties of monolayers and thin films; preparation and characterization of colloids; colloidal stability, flocculation kinetics, micelles, electrokinetic phenomena and emulsions.

06-609 Physical Chemistry of Macromolecules

Fall: 9 units
This course develops fundamental principles of polymer science. Emphasis is placed on physio-chemical concepts associated with the macromolecular nature of polymeric materials. Engineering aspects of the physical, mechanical and chemical properties of these materials are discussed in relation to molecular structure. Topics include an introduction to polymer science and a general discussion of commercially important polymers; molecular weight; condensation and addition synthesis mechanisms with emphasis on molecular weight distribution; solution thermodynamics and molecular conformation; rubber elasticity; and the rheological and mechanical properties of polymeric systems. Students not having the prerequisite listed may seek permission of the instructor.

06-610 Rheology and Structure of Complex Fluids

Fall: 9 units
This course will cover the basic concepts of rheology and mechanical behavior of fluid systems. Both the experimental and theoretical aspects of rheology will be discussed. The basic forces influencing complex fluid rheology and rheology will be outlined and discussed; including excluded volume, van der Waals, electrostatic and other interactions. Methods of characterizing structure will be covered including scattering techniques, optical polarimetry and microscopy. Examples will focus on several types of complex fluids including polymer solutions and melts, gelling systems, suspensions and self-assembling fluids.

06-612 Formulation Engineering

Intermittent: 12 units
Students will learn the scientific and design principles needed for careers in complex fluid formulation-based industries such as consumer products, pharmaceuticals, paints, agrochemicals or lubricants. The essential science and engineering principles of colloids, surfactants, interfaces and polymer solutions will be introduced. Students will learn to use these principles in combination with experimental measurements and statistical design of experiments tools to design effective liquid product formulations within specified economic, material and even aesthetic constraints. The lecture portion of the course is complemented by weekly lab sessions where student teams will design, prepare, test and improve their own formulations for a commercial complex fluid product, such as a detergent or an ink, that meets performance goals within specified constraints.

06-614 Special Topics: Atmospheric Nanoparticles and Climate

Fall and Spring: 12 units
This course will examine the physicochemical properties of atmospheric nanoparticles and the chemical processes that form these particles. We will also cover basic techniques for characterizing atmospheric nanoparticles using fundamentals of aerosol physics and chemistry. The last portion of the course will explore how atmospheric nanoparticles affect the Earth's radiative budget and ultimately climate. Students will apply their atmospheric nanoparticle knowledge to determine the feasibility and effectiveness of various atmospheric geoengineering techniques proposed in literature. Though this course targets atmospheric nanoparticles, it is also broadly applicable to anyone interested applications of aerosolized nanoparticles. Prerequisites: undergraduate chemistry and physics

06-623 Mathematical Modeling of Chemical Engineering Processes

Fall: 12 units
Numerical approaches to solving problems relevant to chemical engineering applications. In this course, advanced mathematical topics relevant to chemical engineering will be used to solve complex problems. Topics include linear algebra, nonlinear equation solving, initial value and boundary value problems for solution of differential equations, numerical optimization, probability and stochastic methods. Significant focus will be placed on numerical rather than analytical solution to problems. Primary Software Package(s): Mathematical programming environment.

06-625 Chemical and Reactive Systems

Fall: 12 units
In this course process simulation software will be used to develop models of chemical and reactive systems. The models will be used to predict the performance of the system, as well as to probe how process modifications, e.g. process conditions, reactor types or sequences, etc. affect system performance. The effects of the underlying thermodynamic and kinetic databases of chemical properties on the performance predictions will be explored. Methods to incorporate new thermodynamic and kinetic data into chemical and reactive system simulations will be examined. Thermochemical and kinetic data for reactions will be estimated for use in process simulation software. Primary Software Package(s): Molecular modeling and process simulation software.

06-631 Air Quality Engineering

Fall: 12 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.
Prerequisites: 36-220 and 24-231 and 09-105

06-634 Drug Delivery Systems

Fall and Spring: 9 units
The body is remarkable in its ability to sequester and clear foreign entities - whether they be "bad" (e.g. pathogens) or "good" (e.g. therapeutic drugs). This course will explore the design principles being used to engineer modern drug delivery systems capable of overcoming the body's innate defenses to achieve therapeutic effect. Specifically, we will study the chemistry, formulation, and mechanisms of systems designed to deliver nucleic acids, chemotherapeutics, and proteins across a variety of physiological barriers. Scientific communication plays a prominent role in the course, and students will have several opportunities to strengthen their communication skills through journal club presentations, proposal writing and constructive feedback. This is a graduate level course that is also open to undergraduate seniors.

06-642 Data Science and Machine Learning in Chemical Engineering

Fall and Spring: 6 units
This class will examine topics related to data science and machine learning in chemical engineering. This includes topics in data visualization and modeling. The course will emphasize computational implementations of these topics with applications in chemical engineering. Students will need to be comfortable with scientific programming. Students who have taken 06-623 and/or 06-625 should have the skills needed in this class.

06-643 Creating Scientific Research Software

Fall and Spring: 6 units
This course will introduce students to topics in creating scientific research software. This will include using a shell, creating and using command-line utilities, using software editors, using version control systems, and creating and distributing software packages for scientific research.

06-663 Analysis and Modeling of Transport Phenomena

Spring: 12 units
Students will learn the basic differential equations and boundary conditions governing momentum, heat, and mass transfer. Students will learn how to think about these equations in dimensionless terms and will apply them to model physical and chemical processes. The primary mode for solving them will be numerical. Analytical results for classical problems of high symmetry also will be presented to serve as a basis for comparison and validation. Software: A finite element and computational transport tool.

06-665 Process Systems Modeling

Spring: 12 units
Simulation and optimization of complex flowsheets, synthesis of separation systems, planning and enterprise-wide optimization, process control and molecular design. Primary Software Package(s): Process Simulation software. Target Audience: first year masters students in chemical engineering Prerequisite skills: analytical and mathematical skills typical of an undergraduate engineering degree or technical degree.

06-679 Introduction to Meteorology

Fall and Spring: 12 units
Provide you with the basics of meteorology, with a focus on large-scale atmospheric motion. By the end of the class you will understand the basics of atmospheric dynamics, including horizontal and vertical motion, as well as the vertical structure of the atmosphere (atmospheric stability and boundary-layer dynamics). You will understand what makes weather happen and you will understand weather maps and charts. You will be able to critically watch the nightly weather forecast and you will be able to access available meteorological databases to make informed predictions of your own. Finally, you will understand atmospheric transport and boundary-layer dynamics, which will serve as a foundation for other coursework involving atmospheric transport and air-pollution if you are pursuing those topics more deeply.

06-685 Bioseparations and Bioprocess Analytical Technologies

Spring: 12 units
This course gives an introduction to key principles of bioseparations and process analytical technologies relevant to the manufacture of biopharmaceuticals. Transport modeling principles are applied to sedimentation/centrifugation, flocculation, and filtration of antibodies and plasmid DNA from raw cell culture. Polishing methods such as Protein A chromatography and size-exclusion chromatography are a particular focus. Chemical means to graft affinity ligands to commercial media are discussed along with in-line spectroscopic techniques. A molecular-level basis of light absorbance and fluorescence is established and the selection and conjugation of fluorophores to biomolecules of interest is presented. Means to assess the state of antibody aggregation and the proper folding of protein-based therapeutics are covered in the context of spectroscopic identification. Finally, the course will provide an overview of the diverse metrics needed for analysis of biomacromolecules as well as the variety of techniques used to analyze quality of produced materials by comparing cost, speed, accuracy and precision.

06-686 ST: Polymers for a Sustainable Future

Fall and Spring: 9 units
This course presents basic concepts of polymer science and discusses topics related to polymers and sustainability. Condensation, radical, ionic, emulsion, and ring-opening polymerizations, polymer behavior in solution and in the bulk will be explored in relation to material applications. We will touch on topics including chemistry of biomass and sustainable utilization of bio-based materials, along with polymers for sustainable technologies in renewable energy, water, and the environment.

06-702 Advanced Reaction Kinetics

Spring: 12 units
Advanced application of engineering and scientific principles to the study of complex chemical reaction systems. Catalytic and noncatalytic reactions in homogeneous and heterogeneous systems, fast reaction techniques, and isothermal and non-isothermal reaction design.

06-705 Advanced Chemical Engineering Thermodynamics

Fall: 12 units
Advanced application of the general thermodynamic method to chemical engineering problems. Second law consequences, estimation and correlation of thermodynamic properties, and chemical and phase equilibria.

06-707 Advanced Transport Phenomena

Fall and Spring: 12 units
An introduction to foundational concepts in mass, momentum, and energy transport. The governing equations for such transport phenomena in flowing fluids will be derived and then analyzed in a variety of scenarios, including unidirectional flows, lubrication theory, Stokes flow, and forced convection heat and mass transfer. The focus will be on problem formulation and solution using applied mathematical techniques. Throughout, the importance of developing a physical intuition for transport phenomena will be emphasized.

06-713 Mathematical Techniques in Chemical Engineering

Fall: 12 units
Selection, construction, solution, and interpretation of mathematical models applicable to the study of chemical engineering problems. Mathematical topics emphasized include divergence, curl and gradient operators, vector field theory, the solution of ordinary and partial differential equations by infinite series, separation of variables, Green's functions, regular and singular perturbations, and boundary-layer techniques.

06-714 Surfaces and Adsorption

Fall and Spring: 12 units
A survey of solid surfaces and gas-solid interactions. Topics include the structure and electronic properties of metal surfaces, the kinetics and thermodynamics of adsorption and desorption processes, and concepts in heterogeneous catalysis. The course emphasizes the application of recent experimental techniques in studying these problems.

06-722 Bioprocess Design

Fall and Spring: 12 units
This course is designed to link concepts of cell culture, bioseparations, formulation, and delivery together for the commercial production and use of biologically-based pharmaceuticals; products considered include proteins, nucleic acids, and fermentation-derived fine chemicals. Associated regulatory issues and biotech industry case studies are also included. A fair knowledge of cell culture and fermentation operations is assumed.