

# Department of Chemical Engineering Courses

## Note on Course Numbers

Each Carnegie Mellon course number begins with a two-digit prefix which designates the department offering the course (76-xxx courses are offered by the Department of English, etc.). 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. xx-6xx courses may be either undergraduate senior-level or graduate-level, depending on the department. xx-7xx courses and higher are graduate-level. Please 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.

## 06-200 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.

## 06-221 Thermodynamics

Fall: 9 units

This course introduces students to the process thermodynamics of single component systems. Topics include equilibrium and thermodynamic state variables; heat and work; conservation of energy and the first law of thermodynamics; entropy balances and the second law of thermodynamics; reversibility; free energies; interconversion of heat and work via engines, refrigeration and power cycles; absolute temperature and the third law of thermodynamics; equations of state; principle of corresponding states; thermodynamic property relationships; changes of state; phase equilibrium and stability in single component systems; vapor pressure and phase transition.

Prerequisites: (33-106 and 06-100) or (06-100 and 33-141) or (33-151 and 06-100)

## 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.

## 06-261 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: 06-100 and 21-259 Min. grade C

## 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: 06-221 and 21-122 Min. grade C and 06-100

## 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.

## 06-321 Chemical Engineering Thermodynamics

Fall: 9 units

The objective of this course is to cover principles and solution techniques for phase and chemical equilibria in multicomponent systems. Topics include thermodynamic properties of ideal and non-ideal mixtures; criteria for equilibrium; chemical potential, fugacity and activity coefficients; flash calculations; Gibbs energy minimization; thermodynamics of chemical reactions including equilibrium conversions.

Prerequisite: 06-221

## 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 (21-260 or 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.

Prerequisites: 06-321 and 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: 06-323 and 06-261

Course Website: <http://tlab12.cheme.cmu.edu/>

## 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: 06-321 and 09-347 and 06-323

**06-365 Water Technology Innovation and Policy**

Spring: 9 units

Innovation in water technologies is necessary to confront profound water resource challenges facing countries around the world. Students successfully completing this course will be able to discuss the factors and conditions that drive innovation in the water sector. Students will begin by describing and classifying the historical drivers for innovation in water treatment, including technical, economic, and regulatory drivers. After an introduction to the fundamental principles of water treatment technologies, students will identify present day technology shortcomings and distill these into discrete design objectives. Students will then formulate and answer quantitative and qualitative questions that respond to these design objectives by leveraging their knowledge of engineering fundamentals, regulatory tools, and pricing policies. Comparing their own solutions with those proposed in the peer-reviewed academic literature in engineering and the social sciences, students will evaluate the technical feasibility, usability, and social desirability of proposed water innovations in developed and developing countries and summarize their findings in policy briefs.

Prerequisites: 19-101 or 19-201 or 12-100 or 06-100

**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 and 06-321

**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: 06-607 and 09-221

**06-462 Optimization Modeling and Algorithms**

Spring: 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: 06-421

**06-463 Chemical Product Design**

Spring: 6 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: 06-262

**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: 06-361 and 06-262

**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.

Prerequisites: 09-347 and 06-221

**06-608 Safety Issues in Science and Engineering Practice**

Fall: 3 units

Exposes the students to personal safety issues encountered in normal science and engineering practice. Topics covered include mechanical, electrical, chemical, radiation, and biological hazards, to provide an awareness of these hazards and appropriate action to be taken in the event of an accident.

**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.

Prerequisite: 09-347

**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.

Prerequisites: 09-509 or 06-609

**06-619 Semiconductor Processing Technology**

Spring: 9 units

This is an introductory course to the physical and chemical concepts involved in integrated circuit processing. The material focuses on basic principles in chemical reaction engineering and how they can be applied to integrated circuit process engineering. Students not having the prerequisites listed may seek permission of the instructor.

Prerequisites: 06-364 and 09-347

**06-620 Global Atmospheric Chemistry: Fundamentals and Data Analysis Methods**

Spring: 9 units

This course will explore global atmospheric chemistry through a series of case studies: Stratospheric Ozone, Global Methane and OH, and Urban and Regional Ozone. Each case will begin with a description of the chemistry and atmospheric physics fundamental to the particular problem. Students will formulate testable mathematical models incorporating that chemistry and physics, turning then to existing atmospheric data sets to test current understanding. The emphasis of this course is to develop an understanding of how to pose a testable hypotheses in a complex chemical environment such as the atmosphere, validate or refute those hypotheses, and then by extension predict how the system will respond to perturbations. A particular objective is to explore how to extend this methodology from the stratosphere and background troposphere (the first two cases), where it has been applied with success, to the much more complicated problem of urban and regional air quality. Students not having the prerequisites listed may seek permission of the instructor.

Prerequisites: 09-105 and 06-262

**06-622 Bioprocess Design**

Fall and Spring: 9 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.

Prerequisites: 42-621 or 06-621

**06-640 Principles and Applications of Molecular Simulation**

Fall and Spring: 9 units

This course will introduce modern concepts and methods for simulating physical and thermodynamics properties of materials from atomic-scales, with special emphasis on the gas and liquid states. Strengths and limitations of molecular simulation methods will be discussed. Topics will include basic statistical mechanics, interatomic potentials, Molecular Dynamics methods, Monte Carlo methods, computation of phase coexistence curves, and Brownian Dynamics.

Prerequisites: 06-262 and 06-321

**06-679 Introduction to Meteorology**

Fall: 12 units

to be determined by the department

**06-708 Advanced Process Dynamics and Control**

Spring: 12 units

Modeling and simulation of dynamic behavior of chemical processes. Theoretical and practical aspects of development of optimal and various regulatory control schemes for start-up and continuous process operation. Application of filtering techniques for noisy or estimated data. Process automation.

**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.

**06-720 Advanced Process Systems Engineering**

Spring: 12 units

A general background on problems, methods, and tools for solving analysis and synthesis problems in process engineering. Formulation and numerical solutions of steady-state and dynamic simulation and optimization problems will be discussed. Insights and solution methods are also covered, based on both heuristics and mixed-integer programming techniques for the synthesis of heat exchanger networks, separation processes, and total process systems.