Department of Chemical Engineering

Professor Irven H. Rinard, Chair • Department Office: Steinman 322 • Tel: 212-650-7232

GENERAL INFORMATION

The City College offers the following master's degrees in Chemical Engineering:

M.E. (Ch.E.) (Professional Master's Degree)

M.S. (Engineering)

DEGREE REQUIREMENTS

Professional Master's Degree Engineering Core Courses: 6

ChE I3300: Advanced Chemical Reaction Engineering (3 cr.)
ChE I4100: Chemical Process Economics (3 cr.)

Engineering Management 6

Two of the following:
ENGR F3800: Management Concepts for Engineers (3 cr.)
ENGR G7600: Engineering Law (3 cr.)
ENGR I8000: Decision and Planning Techniques for Engineers (3 cr.)

Focus Areas in Chemical Engineering 9

Three courses in *one* of the following focus areas:

A. Polymers and Materials
- ChE I5500: Interfacial Phenomena (3 cr.)
- ChE I5700: Advanced Materials (3 cr.)
- ChE I6100: Polymer Science and Engineering (3 cr.)
- ChE I6200: Polymer Surfaces and Interfaces (3 cr.)
- ChE I6300: Thin Organic Films and their Analysis (3 cr.)
- ChE I6400: Rheology of Soft Materials (3 cr.)
- ChE I6500: Mechanics of Polymer Melt Processing (3 cr.)
- ChE I8900: Nanotechnology (3 cr.)
- ChE I9100: Mass Transfer (3 cr.)
- ChE I9200: Soft Materials Lab (3 cr.)

B. Solids Processing
- ChE I5200: Powder Science and Technology (3 cr.)
- ChE I6500: Mechanics of Polymer Melt Processing (3 cr.)
- ChE I8100: Fluid-Particle Systems (3 cr.)

C. Systems Engineering
- ChE I3000: Chemical Process Simulation (3 cr.)
- ChE I4000: Energy Systems Engineering for Global Sustainability (3 cr.)
- ChE I5800: Molecular Simulation (3 cr.)
- ChE I7700: Process Dynamics and Control (3 cr.)
- ChE I8600: Equilibrium Staged Separations (3 cr.)
- ChE I8800: Bioseparations (3 cr.)
- ChE I9000: Bioprocess Engineering (3 cr.)

Technical Electives 9

Any other three courses in Chemical Engineering. Courses in other areas by approval of the department.

Report 0

ChE I9700: Report (0 cr.)

M.S. (Engineering) Degree in Chemical Engineering: Required Courses 18-19

ENGR I1100: Introduction to Engineering Analysis (3 cr.)
ChE I0000: Seminar (1 cr.)
ChE I2800: Advanced Chemical Thermodynamics (3 cr.)
ChE I3300: Advanced Chemical Reaction Engineering (3 cr.)

Two of the following three courses*:*
ENGR I0800: Foundations of Fluid Mechanics (3 cr.)
ME I3700: Convection Heat Transfer
ChE I9100: Mass Transfer

Elective Courses 9-15

Three to five additional courses in Chemical Engineering.
One of the following:
ChE I9700: Report (0 cr.)
ChE I9900: Thesis Research (3-6 cr.)
ChE I9800: Master's Project (3 cr.)

Total Credits 30

Additional Requirements
All full-time graduate students are expected to engage in research.
Thesis: Optional. Requires prior departmental approval.

ADVISEMENT

Masters Program: Professor G. Tardos and J. Lee

Doctoral Program: Professor D. Rumschitzki

DEPARTMENT FACILITIES

In addition to the laboratories operated by the Grove School of Engineering in Steinman Hall, the Department of Chemical Engineering provides separate teaching laboratories for the study of powder technology and soft materials. In addition, it has facilities for a number of advanced experiments in materials science, a work-station based computation center as well as numerous laboratories for advanced research.

Powder Science and Technology Laboratory

This laboratory is attached to the course with the same name (ChE-I052) and is given together with it as demonstration of theoretical principles presented in class. The students are first introduced to powder characterization such as particle size, size distribution (using standard sieves and a light scattering instrument) and shape and surface structure using optical and electron microscopes. Instruments to measure powder specific surface area and pore volume using gas adsorption (BET and gas pycnometry) and mercury intrusion are also presented. Characterization of bulk powders properties is achieved in the Jenike Shear Cell used to measure powder-yield loci at different initial compression levels. This is a special instrument, characteristic of powder engineering, used to determine powder flowability as well as for the design of powder storage vessels such as hoppers and bins. Finally, the MikroPul Hosokawa Micron Powder Characteristics Tester provides six mechanical measurements with one easy-to-use instrument, including 1) angle of repose, 2) compressibility, 3) angle of spatula, 4) cohesiveness, 5) angle of fall and 6) disperse-ability. Measuring such properties has great importance in the design of storage hoppers, feeders, conveyors and other powder processing equipment. The laboratory also has a significant research component dedicated to the measurement of dry powder flows in different geometries and the study of powder granulation (size-enlargement). Principles of these processes are also demonstrated to students using the existing research equipment.

Interfacial Chemistry Laboratory

The course provides students with exposure to some surface modification chemistry and the standard techniques used for the characterization of surface properties. Written and verbal reports are required. In addition to use of instrumentation, students will familiarize themselves with surface preparation and modification techniques, including self-assembly, evaporation, spin coating, and Langmuir-Blodgett techniques. The modules currently available are:

Contact angle goniometry will be used to measure the surface energy for various materials. Students will compare the surface properties of hydrophilic and hydrophobic surfaces and mixed surfaces prepared via self-assembly and Langmuir-Blodgett transfer techniques and/or plasma or corona treatment.

Air-liquid and liquid-liquid interfacial tension measurement using shape characterization (pendant drop and bubble techniques) and the interfacial balance (Kahn Balance). The effects of surfactants present at these interfaces will be investigated, as well as surfactant transport to the interfaces.

Fluorescence imaging and Brewster Angle Microscopy (BAM) investigation of surfactant phase behavior at fluid-fluid interfaces and its effect on the interfacial properties of the system.

Spectroscopy (reflection infrared spectroscopy) will be used to determine the surface coverage and ordering of surfaces prepared by the students.

Ellipsometric measurement of thin films fabricated by the students via evaporation, spin coating, Langmuir-Blodgett films, and self-assembly.

Students will utilize atomic force microscopy (AFM) characterization of surfaces, and compare the constant force, lateral force, and tapping modes.

Colloidal particle size distribution measurement and particle stability using light backscattering.

Materials Science

State-of-the-art equipment is available for advanced materials science laboratory experiments. These include two Fourier-Transform Infra-Red spectrometers, a Differential Scanning Calorimeter, a Thermal Mechanical Analyzer, an Atomic Force Microscope, Single-wavelength Ellipsometer, three Langmuir-Blodgett Troughs, Flouroscence Microscope, High-Speed Video Camera (1000 fps), three high resolution optical microscopes with image analysis capabilities, Contact Angle Goniometer, Argon Plasma Cleaner, Light Scattering, UV-spectrometer, Atomic Absorption Spectrometer, Refractometer, conFocal Microscope, and an Electron Micrpscope.

The A.X. Schmidt Computer Laboratory

The Chemical Engineering Department is equipped with a network of 30 PC workstations, half of which are designated for student's coursework. All students have access to the Internet and E-mail. Application software available on the network includes ASPEN, Mathematica, Matlab, and Visio, Super-Pro Designer. Many courses make use of the computer network and software. The laboratory is available for unlimited student use. All students are expected to become proficient in its use.

COURSE DESCRIPTIONS

F6700: Polymer Science and Engineering

The chemistry and physics of polymeric materials. The kinetics and control of polymerization reactions. Analysis of the mechanical, thermal and flow behavior of polymeric solids and melts. Prereqs: Chem 34200, Chem 26300, ChE 32800, ChE 43000, ChE 43200. This course is not open to students who have taken ChE 46700 or its equivalent. 3 HR./WK.; 3 CR.

G0000: Selected Topics in Chemical Engineering

Advanced topics selected for their current interest to graduate students. 3 HR./WK.; 3 CR.

G2400: Viscous Flow I

G2500: Viscous Flow II

G2900: Dynamics and Stability of Chemically Reacting Systems

G3600: Catalyst Design and Catalytic Reaction Engineering

I0000: Seminar

Invited speakers and reports of graduate student research. 1 HR./WK.; 1 CR.

I2300: Non-Newtonian Fluid Mechanics

Review of the general concepts of continuum mechanics and tensor analysis. The rheology of non-Newtonian fluids. Viscometric flows. Linear viscoelasticity. Constitutive equation theory and codeforming and corrotating formalisms. Applications include the treatment of particle motions in non-Newtonian fluids. Prereq: ENGR I0800. 3 HR./WK.; 3 CR.

I2800: Advanced Chemical Thermodynamics
Classical thermodynamics; batch and flow systems; homogeneous and heterogeneous systems, physical and chemical equilibria, energy effects. Correlation and approximation methods. Prereq: ChE 43000 or ME 33100. 3 HR./WK.; 3 CR.

I3000: Chemical Process Simulation
Steady-state simulation using ASPEN Plus for flow sheet calculations and economic evaluations. Dynamic simulation for process control studies, hazard analyses and batch process scheduling. Special purpose simulations of reactors and separation systems. Emphasis on the underlying numerical methods and sensitivity to modeling errors. 3 HR./WK.; 3 CR.

I3200: Statistical Mechanics I
Introduction to equilibrium statistical mechanics: Liouville's Theorem, ergodic hypothesis, ensembles, connection to classical thermodynamics. Distinguishable and indistinguishable particles, Boltzmann statistics, quantum gases, semi-classical limit. Real gases: cluster and virial expansions. Graphical methods. Prereq: ChE I2800 or ME I3300. 3 HR./WK.; 3 CR.

I3300: Advanced Chemical Reaction Engineering
The analysis of non-ideal chemical reactor systems. Both homogeneous and heterogeneous reactor systems. Industrial catalytic reactor design and troubleshooting. Prereq: ChE 43200. 3 HR./WK.; 3 CR.

I3500: Statistical Mechanics II
The liquid state and non-equilibrium statistical mechanics: distribution function theories, integral equation methods, hierarchies. Perturbation theories of liquids. Phase transition: mean field theory, scaling. Time dependent phenomena: dynamic light scattering, fluctuation-dissipation theorem, linear response theory, Green-Kubo relations. Boltzmann equation. Prereq: ChE I3200 or Phys 55300. 3 HR./WK.; 3 CR.

I4000: Energy Systems Engineering for Global Sustainability
This course is intended to provide students with the background and tools to analyze energy choices for the future. World energy supplies, demand, and trends. The politics of energy. The scientific basis for anthropogenic global warming and its impact on climate and planetary ecosystems. Characterization and analysis of conventional sources of energy and fuels production including refineries, fossil fuel fired power plants, and gas turbine combined-cycle systems from both thermodynamic and environmental points of view. Alternate sources of power including nuclear, wind farms, solar (both photovoltaic and thermal), and biomass. Energy consumption by the transportation, manufacturing, and space heating and cooling segments of the economy. The hydrogen economy. Social barriers such as denial, lock-in, and NIMBY. Prereq.: Undergraduate degree in engineering, or permission of the instructor. 3 HR./WK.; 3 CR.

I4100: Chemical Process Economics
Basic principles; break-even and shut-down studies; profitability criteria; plant location; market research; project analysis and optimization. 3 HR./WK.; 3 CR.

I5200: Powder Science and Technology
Powder metrology: Characterization of particles and particle assemblies; packing of granular solids; interparticle forces and tribology in particulate systems; continuum powder mechanics; design of hoppers; population balance modeling of mixing, segregation, agglomeration and comminution. Bulk Powder handling: conveying and storing. 3 HR./WK.; 3 CR.

I5500: Interfacial Phenomena
Interfacial thermodynamics. The theory of the electrical double layer. Interfacial statics and the Young-Laplace equation. Interfacial fluid mechanics and stability. Applications such as surface waves and Marangoni flows are included. 3 HR./WK.; 3 CR.

I5700: Advanced Materials Engineering
Microscopic level interactions in solid materials. The geometric structure of materials: metals, semiconductors, ceramics, and polymers. Structure determination. The thermodynamic foundation of phase diagrams. Material properties: thermal, electrical, and optical. Surface properties. Synthesis and characterization of "high tech" materials with emphasis on nanoscale technology. Prereq: ChE 31000 or permission of instructor. 3 HR./WK.; 3 CR.

I5800: Molecular Simulation
Theory and practice of numerical techniques for the simulation ofA0 material properties and transport phenomena at the molecular level. Introduction to *ab initio* and empirical force fields, theoretical background on MonteA0Carlo, molecular dynamics, and related methods.A0 Introduction to biased and accelerated methods, simulation of fluid flows, long-range interactions, phase equilibriums and other topics of current interest.A0Exercises will emphasize computational practice, writing code for particular applications, and the analysis of numerical results. Prereq: ChE I3200 or permission of the instructor. 3 HR./WK.; 3 CR.

I6100: Polymer Science and Engineering
Statistical mechanics of polymer chains. Polymer rheology. Scaling concepts in polymer solutions. Behavior of polymer blends, interpenetrating polymer networks, and polymer/mixed solvent systems. Polymer/particle interactions. Prereq: ChE 46700, ChE F6700, or permission of instructor. 3 HR./WK.; 3 CR.

I6200: Polymer Surfaces and Interfaces
This course introduces the students to surface phenomena related to polymers. Topics covered are: Statistical Nature of Polymers, Polydispersity & Branching; Molecular Weight and its Distribution; Flexibility; Global versus Local Properties; Average Dimensions of Polymer; Polymer Structure and Physical Properties; Diffusion Modes-Reconfiguration and Center of Mass Transport; Interfacial Thermodynamics; Molecular Interactions in Polymers (Van der Waals Forces, Additivity and Fractional Contributions of Various Types of Molecular Forces, Introduction to Mean-field and Monte Carlo approximation to polymer molecular configurations); Surface Energetics of Polymers (Measurement of Surface Tension, Calculation of Surface tension, Measurement of Solubility, Calculation of Solubility); Polymer-Liquid Interactions (Equilibrium Spreading Pressure, Polarity of Liquids, Contact Angle, Measurement and Prediction); Polymer-Polymer Interactions (Solubility of Polymers, Measurement of Solubility, Calculation of Solubility, Prediction of Interfacial Tension of Polymers, in the melt and solid state); Applications (Adhesion, Blending, Adsorption, Permeation). Prereq.: Undergraduate degree in engineering, or permission of the instructor. 3 HR./WK.; 3 CR.

ChE I6300: Thin Organic Films and Their Analysis
This courses introduces the students to the concepts of supported thin organic films and their analysis: Langmuir-Blodgett Films; Self-Assembled Monolayers; Polymer Films; Homopolymers; Block Copolymers; Polyelectrolytes (Layer by Layer); Optical Techniques (Ellispometry, Second Harmonic Generation); Electroanalytical Techniques (Surface Potential); Physocochemical Techniques (Wetting); Spectroscopic Techniques (Infrared Spectroscopy (FT-IR), Raman Spectroscopy, X-Ray Photoelectron Spectroscopy (XPS), Secondary Ion Mass Spectroscopy (SIMS)); Scanning Probe Microscopy (Atomic Force, Scanning Tunneling); Scattering Techniques (Neutron Scattering, X-Ray Scattering, X-Ray Diffraction, Light Scattering). Prereq.: Undergraduate degree in engineering, or permission of the instructor. 3 HR./WK.; 3 CR.

I6400: Rheology of Soft Materials
Rheological measurement. Linear and non-linear viscoelasticity. Rheology of polymers, liquid crystals, emulsions, gels, and other complex fluids and soft solids. Continuum and molecular theories of viscoelasticity. Prereqs.: Undergraduate degree in a physical science or engineering discipline, or permission of instructor. 3 HR./WK.; 3 CR.

I6500: Mechanics of Polymer Melt Processing
Fluid mechanics and heat transfer principles underlying the mechanics of polymer melt processing. Conservation principles. Non-Newtonian fluids. Coupled flow and heat transfer in extrusion. Pressure effects. Solution multiplicity. Lubrication theory for polymer processing. Injection and compression molding. Fiber spinning. Numerical simulation. Effects of viscoelasticity on processing. Stability and sensitivity. Prereq.: Undergraduate degree in engineering, or permission of the instructor. 3 HR./WK.; 3 CR.

I7700: Process Dynamics and Control
Dynamic Behavior and control of process equipment and flow systems. Behavior and stability of linear and non-linear systems with examples from chemical reactors, distillation columns and heat transfer equipment. Prereq.: ChE 47700 or EE 37100. 3 HR./WK.; 3 CR.

I8100: Fluid Particle Systems
Basic equations of multi-phase systems; transport processes of rigid and deformable particles; drag coefficients; heat and mass transfer rates; turbulence effects; transport properties of clouds of particles; pipe flow of a suspension; filtration of aerosols; industrial filters. 3 HR./WK.; 3 CR.

I8600: Equilibrium Staged Separations
Analysis, design and simulation of the major separation operations of distillation, absorption and extraction. Both staged and continuous countercurrent modes of operation are covered. Choice of vapor-liquid and liquid-liquid equilibria models, data regression and prediction methods. Process synthesis of sequences of separation operations; heat integration for efficient energy utilization. Introduction to column dynamics and control strategies. 3 HR./WK.; 3 CR.

I8800: Bioseparations
Modeling and simulation of the dynamic behavior of staged and plug flow separation operations. Batch distillation. Adsorption techniques including chromatographic separations and pressure swing adsorption. Membrane technologies such as reverse osmosis and gas separation. Separations involving solids including filtration and crystallization. Separations for biotechnology. 3 HR./WK.; 3 CR.

I8900: Nanotechnology
Introduction to nanotechnology and its applications in the development and synthesis of soft materials. Prereq.: ChE I2800 and Engr I9100. 3 HR./WK.; 3 CR.

I9000: Bioprocess Engineering: Mammalian Cell Biotechnology
Basics of biochemistry and cell structure with emphasis on eucaryotic cells. Introduction to recombinant DNA technology and protein engineering. Introduction to cell culture bioreactors. Production of glycosylated proteins. Biochemical engineering aspects of stem cells. Prereq.: ChE I2800 and Engr I9100. 3 HR./WK.; 3 CR.

I9100: Mass Transfer
Definitions of concentrations, velocities and mass fluxes. Conservation of species equation; multicomponent diffusion; Stefan-Maxwell equations. Transient diffusion in semi-infinite media. Definition of transfer coefficients with mass addition. Application of film, penetration and boundary layer theory. Diffusion with homogeneous and heterogeneous chemical reaction. Interphase transport. Prereq: Engr I0800. 3 HR./WK.; 3 CR.

I9200: Soft Materials Lab
The course provides students with exposure to some surface modification chemistry and the standard techniques used for the characterization of surface properties. In addition to use of instrumentation, students will familiarize themselves with surface preparation and modification techniques, including self-assembly, evaporation, spin coating, and Langmuir-Blodgett techniques. There are seven experimental modules: contact angle goniometry; air-liquid and liquid-liquid interfacial tension measurement; fluorescence imaging and Brewster Angle Microscopy; reflection infrared spectroscopic determination of surface coverage; ellipsometric measurement of thin films; atomic force microscopy (AFM) characterization of surfaces; and colloidal particle size distribution measurement and particle stability using light backscattering. Written and verbal reports are required. Prereq.: Undergraduate degree in engineering, or permission of the instructor. 3 HR./WK.; 3 CR.

I9700: Report
In-depth analysis by means of written reports of a number of technical papers, reports or articles on a specific topic of interest to chemical engineers. Topics to be chosen by the student after consultation with a professor in the department. An oral presentation of the written report may be required at the departmental seminar. Prereq: completion of 12 credits toward the master's degree in ChE. Not applicable for credit toward the Ph.D. 0 CR.

I9800: Master's Project
Theoretical or experimental project under the supervision of a faculty advisor. Student submits a written proposal, performs the required work, and submits a written final report. Prereq: written departmental approval. 3 CR.

I9900: Research for the Master's Thesis
VARIABLE CR., UP TO 6 CR.

J9900: Research for the Doctoral Dissertation
VARIABLE CR., UP TO 12 CR.

Other Engineering Courses

Other appropriate Engineering courses are listed under Graduate Engineering courses in the front section of the Grove School of Engineering.

I0800: Foundations of Fluid Mechanics I

I0900: Foundations of Fluid Mechanics II

I1100: Introduction to Engineering Analysis

I1200: Functions of a Complex Variable

I1300: Transform Methods in Engineering

I1400: Applied Partial Differential Equations

I1500: Introduction to Numerical Methods

I2200: Biofluid Mechanics

I2400: Turbulent Flows

I3600: Conduction Heat Transfer

I3700: Convection Heat Transfer

I3800: Radiation Heat Transfer

I8000: Decision and Planning Techniques for Engineering Management

I9100: Mass Transfer

J0100: Fluid Dynamic Stability

FACULTY

Alexander Couzis, Herbert G. Kayser Professor
B.S. (Ch.E.), National Technical Univ. (Greece); M.S., (Ch.E.) Univ. of Michigan, Ph.D (Ch.E.)

Morton M. Denn, Albert Einstein Professor
B.S.E. (Ch.E.), Princeton Univ.; Ph.D., Univ. of California (Davis)

M. Lane Gilchrist, Jr., Assistant Professor
B.Ch.E., Louisiana State Univ.; Ph.D., Univ. of California (Davis)

Leslie L. Isaacs, Professor
B.Sc.(Ch.E.), Columbia Univ.; Ph.D., M.I.T.

Ilona Kretzschmar, Assistant Professor
Diploma (Chemistry), Technical Univ. of Berlin

Jae W. Lee, Associate Professor
B.S. (Ch.E.), Seoul National Univ.; Ph.D., Carnegie Mellon Univ.

Charles Maldarelli, Professor
B.S. (Ch.E.), Columbia Univ., M.S.(Ch.E.), D.Eng.Sc.(Ch.E.)

Jeffrey Morris, Associate Professor
B.A., Georgia Institute of Technology; M.S., California Institute of Technology, Ph.D. (Ch.E.)

Irven Rinard, Professor and Chair
B.Ch.E., Univ. of Delaware; M.Sc., M.I.T., Sc.D. (Ch.E.)

David S. Rumschitski, Herbert G. Kayser Professor
B.S. (Math/Ch.E.), Cooper Union; M.S. (Ch.E.), Univ. of California (Berkeley), Ph.D. (Ch.E.)

Carol A. Steiner, Professor
B.S. (Chem.), M.I.T.; M.S. (Chem./Biochem. Engrg.), Univ. of Pennsylvania, Ph.D. (Ch.E.)

Gabriel Tardos, Professor
Dipl. Eng., Polytech. Bucharest, Roumania; M.Sc. (M.E.), Technion, Israel, D.Sc.

Raymond Tu, Professor
B.S. (Ch.E.), Univ. of Florida; Ph.D., Univ. of California (Santa Barbara)

PROFESSORS EMERITI

Andreas Acrivos, Albert Einstein Professor Emeritus
Robert A. Graff
Morris Kolodney
Harvey L. List
Robert Pfeffer
Reuel Shinnar
Herbert Weinstein