Chemical and Biomolecular Engineering

https://engineering.lehigh.edu/chbe

The Chemical and Biomolecular Engineering Department offers a Bachelor of Science degree in chemical engineering to undergraduate students and offers graduate programs leading to the master of science, master of engineering, and doctor of philosophy degrees in Chemical Engineering, and master of engineering degrees in Biological Chemical Engineering and Chemical Energy Engineering.

Modern chemical engineering is built around the fundamental enabling sciences of biology, chemistry, physics, and mathematics. Its curriculum encompasses three basic organizing principles: Molecular Transformations, Multi-scale Analysis, and System Approaches. Chemical engineers serve a wide variety of technical and managerial functions within the chemical processing industry. For a lifetime of effectiveness they need a sound background in the fundamental sciences of chemistry and physics; a working capability with mathematics, numerical methods, and application of computer solutions; and a broad education in humanities, social sciences, and managerial techniques. These bases are applied in a sequence of chemical engineering courses in which logic and mathematical manipulation are applied to chemical processing problems. With the resulting habits of precise thought coupled to a broad base in scientific and general education, Lehigh graduates have been effective throughout industry and in advanced professional education. No effort is made toward any specific industry, but adaptation is rapid and the fundamental understanding forms the base for an expanding career.

The program is also designed to prepare a student for graduate study in chemical and biomolecular engineering. Further study at the graduate level leading to advanced degrees is highly desirable if an individual wishes to participate in the technical development of the field. The increasing complexity of modern manufacturing methods requires superior education for men and women working in research, development, and the design fields or for teaching.

PHYSICAL FACILITIES

The Chemical and Biomolecular Engineering Department is the only engineering department located on Lehigh's 780 acres Mountaintop Campus. Here the department occupies approximately one-third of Iacocca Hall, the 200,000-square-foot flagship building that contains offices, classrooms, and laboratories. Additional plant facilities, and the undergraduate chemical processing laboratory occupy approximately 10,000-square-feet in the nearby Imbt building.

These facilities provide excellent support for a wide range of general and special laboratory equipment for undergraduate and graduate studies of the behavior of typical chemical processing units; bioengineering research; nanotechnology; energy; biochemical engineering; polymers; digital computation for process dynamics research; and study of thermodynamics, kinetics, heat transfer, and mass transfer.

The Chemical and Biomolecular Engineering department has established a senior design laboratory in Iacocca Hall featuring 35 PCs, which is dedicated to undergraduate process design courses.

UNDERGRADUATE PROGRAM

The mission of the undergraduate program is "to educate students in the scientific principles of chemical and biomolecular engineering and provide opportunities to explore their applications in the context of a humanistic education that prepares them to address technological and societal challenges."

PROGRAM EDUCATIONAL OBJECTIVES

To achieve its educational mission, the Department of Chemical and Biomolecular Engineering has established the following set of Program Educational Objectives: Graduates of the Undergraduate Program in Chemical Engineering will:

1. Apply their broad education in chemical engineering to pursue careers in industry, government agencies, consulting firms, educational institutions, financial institutions, business, law, and medicine.
2. Pursue graduate studies, research, or continuing education.
3. Be sensitive to the social, ethical, and technical implications of their work as it affects the environment, safety, and health of citizens worldwide.

In order to achieve these program educational objectives, the chemical engineering program ensures that the graduates are capable of the following Student Outcomes proposed by the accreditation organization ABET:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

CAREER OPPORTUNITIES

Chemical engineers play important roles in all activities bearing on the chemical process industry. These include the functions of research, development, design, plant construction, plant operation and management, corporate planning, technical sales, and market analysis.

The industries that produce chemical and/or certain physical changes in fluids, including petroleum and petrochemicals, rubbers and polymers, pharmaceuticals, bioengineering, metals, industrial and fine chemicals, foods, and industrial gases, have found chemical engineers to be vital to their success. Chemical engineers are also important participants in pollution abatement, energy resources, national defense programs, and more recently in the manufacture of microelectronic devices and integrated circuits.

SPECIAL PROGRAMS AND OPPORTUNITIES

Co-op Program

The department, in conjunction with the P.C. Rossin College of Engineering and Applied Science, operates a cooperative program that is optional for specially selected students who are entering their junior year. This program offers early exposure to industry and an opportunity to integrate an academic background with significant periods of engineering practice. Our program is unique in offering two work experiences and still allowing the co-op students to graduate in four years with their class.

OSI Program

The Opportunities for Student Innovation (OSI) program seeks to develop students' propensities for critical assessment and innovative solution of meaningful problems. The OSI program offers selected seniors an opportunity to experience team research leading toward technological benefits. Some projects are hosted by industrial companies and carried out under the supervision of a Lehigh faculty members.

Minors and Specializations

Technical minors are available in biotechnology, energy engineering, computer science, environmental engineering, manufacturing systems, materials science and engineering, and polymer science and engineering. Minors are also available from the Business College and the College of Arts and Sciences.

Minor in Biotechnology

The department of Chemical and Biomolecular Engineering encourages engineering students to broaden their education by taking a minor. In this regard, a Biotechnology Minor is offered to students majoring in Engineering College. The Biotechnology minor requires 16 credit hours. A detailed listing of the required courses for the Biotechnology Minor can be obtained from the Chemical and Biomolecular Engineering Department.

Minor in Chemical Engineering

Minoring in Chemical Engineering provides students both bio-molecular and chemical engineering knowledge that they do not acquire in their major, such as knowledge of bio-chemical systems, transport phenomena, reaction engineering. This will widen their skills and help to increase the cooperation between the disciplines, which will lead to increased possibilities for employment. For further information please contact the department.

Concentrations

Chemical and Biomolecular Engineering offers five concentration areas, students majoring in Chemical Engineering can take three courses to have a certificate in a specific concentration. These courses may also be used to satisfy other elective requirements for their major.

Biomolecular Engineering

- **CHE/ BIOE 345** - Quantitative Biology (3 cr)
- **CHE 306** - Intro to Biomedical Engineering (3 cr)
- **CHE 321** - Biomolecular and Cellular mechanics (3 cr)
- **CHE/ BIOE 341** - Biotechnology I (3 cr)
- **CHE/ BIOE 342** - Biotechnology II (3 cr)
- **CHE/ BIOE 344** - Molecular Bioengineering (3 cr)
- **CHE 339** - Neuronal Modeling and Computation (3 cr)
- **CHE 396** - Engineering in Medicine (3 cr)
- **CHM 371** - Biochemistry I (3 cr)

Computational Methods in Engineering

- **CHE 339** - Neuronal Modeling and Computation (3 cr)
- **CHE 363** - Numerical Methods for Scientists and Engineers (3 cr)
- **CHE 365** - Molecular Modeling and Simulation (3 cr)
- **CHE 396** - Data Driven Modeling (2 cr)
- **CSE 002** - Fundamentals of Programming (2 cr)
- **CSE 017** - Programming and Data Structures (3 cr)
- **CSE 160** - Intro to Data Science (3 cr)
- **CSE 262** - Programming Languages (3 cr)
- **ISE 172** - Algorithms in System Engineering (4 cr)

Energy and Environment

- **CHE 376** - Energy: issues & technology (3 cr)
- **CHE 377** - Electrochemical Engineering (3 cr)
- **CEE 170** - Intro to Environmental Engineering (3 cr)
- **CHE/ CEE 373** - Fundamentals of Air Pollution (3 cr)
- **CHE/ CEE 375** - Environmental Engineering Processes (3 cr)
- **ME 360** - Nuclear Reaction Engineering (3 cr)
- **CHE 374** - Environmental Catalysis (3 cr)
- **CHE 398** - Advanced porous Material (3 cr)

Entrpreneurship

- **ENTP 101** - Introduction to Entrepreneurship (3 cr)
- **ENTP/ IR/ SDEB 307** - International Social Entrepreneurship (4 cr)
- Approved **Internship**
- Approved **Mountaintop Experience**
- Approved **Study Abroad**
- Approved **Research in the Department**

Polymer/ Functional Materials

- **CHE 392** - Introduction to Polymer Science (3 cr)
- **CHM (CHE) 391** - Colloid and Surface Chemistry (3 cr)
- **CHE 317** - Soft Materials: Rheology and Characterization (3 cr)
- **CHM 394** - Organic Polymer Science (3 cr)
- **MAT 204** - Processing and Properties of Polymeric Mats (3 cr)
- **MAT 386** - Polymer Nanocomposites (3 cr)
- **CHE (CHM) 393** - Physical Polymer Science (3 cr)
- **CHE 398** - Characteristics of Advanced Functional Materials (3 cr)

Overseas

Study abroad is available in exchange programs that have been established by the department for the junior year at the University of Nottingham (United Kingdom) and for the summer following the junior year at the University of Dortmund (Germany). Please visit http://www.aaa.tu-dortmund.de/cms/en/International_Students/International_Summer_Program__ISP_/index.html (http://www.aaa.tu-dortmund.de/cms/en/International_Students/International_Summer_Program__ISP_/)

Requirements of the Major

131 credit hours are required for graduation with the degree of bachelor of science in chemical engineering.

First Year			
First Semester	Credits	Second Semester	Credits
WRT 001	3	WRT 002	3
MATH 021	4	MATH 022	4
ENGR 005	2	ENGR 010 or ECO 001	3-4
ENGR 010 or ECO 001	3-4	Select one of the following:	4-5
Select one of the following:	4-5	CHM 030 (4 CR)[1]	-
CHM 030 (4 CR)[1]	-	PHY 011 & PHY 012[1]	-
PHY 011 & PHY 012[1]	-		
	16-18		**14-16**
Second Year			
First Semester	Credits	Second Semester	Credits
CHE 031	3	CHE 144	3
CHM 031	4	CHE 210	3
PHY 021 & PHY 022	5	MATH 205	3
MATH 023	4	Electives	7
CHE 179	1		
	17		**16**
Third Year			
First Semester	Credits	Second Semester	Credits
CHE 151	3	CHE 244	3
CHE 201	4	CHE 211	3
CHM 110 & CHM 111	4	CHM 112	3
CHE 212	3	CHM 343	2
Electives	4	Electives	7
	18		**18**
Fourth Year			
First Semester	Credits	Second Semester	Credits
CHE 202	3	CHE 203	3
CHE 233	3	CHE 234	3
CHE 242	3	Electives	11
Electives	6		
	15		**17**

Total Credits: 131-135

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Required natural science courses, one taken fall semester and the other taken in spring

There are six types of electives:

1. Humanities/Social Sciences: See the requirements (http://catalog.lehigh.edu/coursesprogramsandcurricula/engineeringandappliedscience/) set by the P.C. Rossin College of Engineering and Applied Science. Note that ECO 001 is required, as well as First-Year Writing.
2. Bio-Elective: Students must have AP BIOS credits or must pick one from BIOS 041, BIOE 321, BIOE 349, CHE 341, CHE 345, or CHM 371.
3. Three credit hours from approved courses in other engineering departments (BioE, CEE, CSE, ECE, ISE, MEM, MSE).
4. Chemical and Biomolecular Engineering: CHE 001 or 3 credit hours of CHE 300-level or higher.
5. Chemical and Biomolecular Engineering OR Chemistry: 3 credit hours of CHM 300-level or higher OR 3 credit hours of CHE 300-level or higher.
6. Chemical and Biomolecular Engineering:: 3 credit hours of CHE 300 level or higher.
7. Free electives: 6 credit hours in any subject area.

Electives in (2) to (6) above can be combined with any technical minor in RCEAS.

GRADUATE PROGRAMS

The Department of Chemical and Biomolecular Engineering offers graduate programs leading to the master of science, master of engineering, and doctor of philosophy degrees in Chemical Engineering and master of engineering degree in Chemical Engineering, Biological Chemical Engineering and Chemical Energy Engineering. The programs are all custom tailored for individual student needs and professional goals. These individual programs are made possible by a diversity of faculty interests that are broadened and reinforced by cooperation between the department and several research centers on the campus.

A free flow of personnel and ideas between the centers and academic departments ensures that the student will have the widest choice of research activities. The student is also exposed to a wide range of ideas and information through courses and seminars to which both faculty and center personnel contribute. In addition, strong relationships with industry are maintained by the department and the research centers, some of which operate industrially-sponsored liaison programs whereby fundamental non-proprietary research is performed in areas of specific interest to participating sponsors.

In addition to interacting with the centers, the department originates and encourages programs that range from those that are classical chemical engineering to those that are distinctly interdisciplinary. The department offers active and growing programs in adhesion and tribology; emulsion polymerization and latex technology; bulk polymer systems; process control; process improvement studies; rheology; computer applications; environmental engineering; thermodynamics; kinetics and catalysis; enzyme technology; data science; and biochemical engineering.

Career Opportunities

Master of science, master of engineering, and doctor of philosophy graduates in the chemical engineering area are sought by industry for activities in the more technical aspects of their operations, especially design, process and product development, and research. Many of these graduates also find opportunities in research or project work in government agencies and in university teaching and research.

Physical Facilities

The department is well equipped for research in bioengineering, nanotechnology, energy, colloids and surface science, adhesion and tribology, polymer science and engineering, catalysis and reaction kinetics, thermodynamic property studies, fluid dynamics, heat and mass transfer, process dynamics and control, and enzyme engineering and biochemical engineering.

The departmental and university computing facilities include PCs and workstations, connected by a university-wide high speed network, which in turn provides worldwide networking via the Internet.

All of these facilities can access a wide variety of general purpose, and scientific and engineering software via the university and local networks, including software specifically for the steady state and dynamic simulation of chemical engineering systems.

Special Programs

Polymer Science and Engineering. The polymers activity includes work done in the Department of Chemical and Biomolecular Engineering as well as the Departments of Chemistry, Materials Science, and Physics, the Materials Research Center, the Center for Polymer Science and Engineering, and the Emulsion Polymers Institute. More than 20 faculty members from these organizations or areas have major interests in polymers and cooperate on a wide range of research projects. For students with deep interest in the area, degree programs are available leading to the master of science, master of engineering, and doctor of philosophy degrees in polymer science and engineering.

Distance Education

Delivered online through the Office of Distance Education, these programs are convenient for the part-time student and courses are the same level of quality of instruction that is available to our on-campus students. Choose from the following engineering programs; Master of Engineering degree in Chemical Engineering, Biological Chemical Engineering, Chemical Energy Engineering and Certificate in Chemical and Biomolecular Engineering. To learn more, visit the Office of Distance Education Online Programs (https://distance.lehigh.edu/online-programs/).

Major Requirements

All Ph.D. students must complete eight courses in consultation with his/her committee, although CHE 400, CHE 410, CHE 415 and CHE 452 are required. In addition to approved courses, all Ph.D. students must pass a qualification examination given during the second year of residence.

Candidates for Master of Science degree are required to complete 30 credits hours of course work which must include CHE 400, CHE 410, CHE 415 and CHE 452, and a research report or thesis for which six hours of graduate credits are earned.

Candidates for the Master of Engineering degrees do not do research; all 30 credit hours are fulfilled by course work. Course selection is done individually for each student within the University requirements for a master's degree.

The requirements for each of the Master degrees is slightly different. For more information on all of our Master degrees, please visit the Graduate Chemical and Biomolecular Engineering page at https://engineering.lehigh.edu/chbe/graduate (http://www.lehigh.edu/~incheme/stu_graduate_thesis_progreq.html)

Courses

CHE 001 Coffee and Cosmetics 3 Credits

This course will focus on developing processes for creating coffee and cosmetics that overlap with core principles of chemical engineering. Coffee will introduce students to basic concepts of process design and scale-up and the ideas of "unit operations" that that are performed such as roasting, grinding, and filtration. Cosmetics will introduce the basic principles of rheology, surface energy, and other concepts that surround "squishy" materials. These everyday goods will bring new light to the interface of engineering and consumer products.

CHE 031 Material and Energy Balances of Chemical Processes 0,3 Credits

Material and energy balances with and without chemical reaction. Introduction to phase equilibrium calculations. Applications in chemical process calculations and in design of staged separations: binary distillation, liquid-liquid extraction.
Prerequisites: ENGR 010 and (CHM 030 or CHM 040)
Can be taken Concurrently: ENGR 010, CHM 030, CHM 040

CHE 044 Fluid Mechanics 0,3 Credits
Fluid mechanics and its applications to chemical processes. Momentum and energy balances in fluid flow. Dimensional analysis. Fluid flow in pipes, packed and fluidized beds. Mixing and agitation. Filtration and sedimentation.

CHE 085 Undergraduate Research 1 Credit
Independent study of a problem involving laboratory investigation, design, or theoretical studies under the guidance of a faculty. Consent of the department chair.
Repeat Status: Course may be repeated.

CHE 144 Fluid Mechanics 0,3 Credits
Fluid mechanics and its applications to chemical processes. Momentum and energy balances in fluid flow. Dimensional analysis. Fluid flow in pipes, packed and fluidized beds. Mixing and agitation. Filtration and sedimentation. Credit will not be granted for both CHE 044 and CHE 144.

CHE 151 Heat and Mass Transfer 0,3 Credits
Fundamental principles of heat and mass transfer. The three modes of heat transfer are taught: conduction, convection and radiation. The physical principles of mass transfer are taught including diffusion and convection. Parallels and relationships between heat and mass transfer are highlighted. Fundamental principles of heat and mass transfer are applied to the analysis and design of unit operations including heat exchangers and mass separators.
Prerequisites: CHE 031 and CHE 044 and CHE 210

CHE 171 (EMC 171) Fundamentals of Environmental Technology 4 Credits
Introduction to water and air quality, water, air and soil pollution. Chemistry of common pollutants. Technologies for water purification, wastewater treatment, solid and hazardous waste management, environmental remediation, and air quality control. Global changes, energy and environment. Constraints of environmental protection on technology development and applications. Constraints of economic development on environmental quality. Environmental life cycle analysis and environmental policy. Not available to students in RCEAS.

CHE 179 Professional Development 1 Credit
Elements of professional growth, registration, ethics, and the responsibilities of engineers both as employees and as independent practitioners. Proprietary information and its handling. Patents and their importance. Discussions with the staff and with visiting Lecturers. A few plant trips.

CHE 185 Undergraduate Research I 1-3 Credits
Independent study of a problem involving laboratory investigation, design, or theoretical studies under the guidance of a faculty member.
Repeat Status: Course may be repeated.

CHE 186 Undergraduate Research II 1-3 Credits
A continuation of the project begun under CHE 185. Consent of department chair.
Repeat Status: Course may be repeated.
Prerequisites: CHE 185

CHE 201 Methods of Analysis in Chemical Engineering 0,4 Credits
Analytical and numerical methods of solution applied to dynamic, discrete and continuous chemical engineering processes. Laplace Transforms. MATLAB based computations. Methods of analysis applied to equilibrium, characteristic value and non-linear chemical engineering problems.
Prerequisites: CHE 044 and CHE 210 and MATH 023 and MATH 205
Can be taken Concurrently: MATH 205

CHE 202 Chemical and Biomolecular Engineering Laboratory I 0,3 Credits
The laboratory study of chemical engineering unit operations and the reporting of technical results. One three-hour laboratory and one lecture period per week. Independent study and both group and individual reporting.
Prerequisites: CHE 151 and CHE 211 and CHE 244

CHE 203 Chemical and Biomolecular Engineering Laboratory II 3 Credits
Laboratory experience with more complex chemical processing situations including processes involving chemical reactions and those controlled automatically.
Prerequisites: CHE 202

CHE 210 Chemical Engineering Thermodynamics 0,3 Credits
Energy relations and their application to chemical engineering. Consideration of flow and nonflow processes. Evaluation of the effects of temperature and pressure on the thermodynamic properties of fluids. Heat effects accompanying phase changes and chemical reactions. Determination of chemical and physical equilibrium.
Prerequisites: CHE 031 and MATH 023

CHE 211 Chemical Reactor Design 0,3 Credits
The theory of chemical kinetics to the design and operation of chemical reactors. Plug flow and continuous stirred tank reactors. Homogeneous and heterogeneous reaction kinetics. Design of isothermal and adiabatic reactors.
Prerequisites: CHE 210

CHE 212 Physical Chemistry for Engineers 0,3 Credits
Thermodynamics of phase and reaction equilibria. Quantum theory and molecular spectroscopy. Reaction kinetics in homogeneous and heterogeneous systems. Fundamentals of Electrochemistry. Physical chemistry of colloidal systems.
Prerequisites: CHE 210 or ME 104

CHE 231 Biomolecular Engineering 3 Credits
Application of quantitative chemical engineering concepts to biological systems. Topics include kinetic and thermodynamic contributions to protein-ligand binding, enzyme kinetics, gene expression, protein trafficking, and cell growth.
Prerequisites: CHE 031 and (CHE 210 or BIOE 246 or MAT 205 or ME 104)

CHE 233 Process Design I 0,3 Credits
Design of chemical plants incorporating traditional elements of engineering economics and synthesis of steady-state flowsheets with (1) both heuristic and rigorous optimization methods and (2) consideration of dynamic controllability of the process. Economic principles involved in the selection of process alternatives and determination of process capital, operating costs, and venture profitability. Energy conservation, pinch techniques, heat exchanger networks, and separation sequences. Considerations of market limitations, environmental and regulatory restrictions, and process safety. Use of modern computer aided software for steady-state and dynamic simulation and optimization. Group design projects.
Prerequisites: (CHE 211 and CHE 242 and CHE 244)
Can be taken Concurrently: CHE 242

CHE 234 Process Design II 0,3 Credits
Continuation of CHE 233.
Prerequisites: CHE 233
Can be taken Concurrently: CHE 233

CHE 242 Introduction to Process Control and Simulation 0,3 Credits
Dynamic simulation of chemical processes. Transfer functions and block diagrams. Introduction to process control equipment. Open-loop and closed-loop stability analysis using root locus and Nyquist techniques. Design of control systems.
Prerequisites: CHE 201 and CHE 151 and ENGR 010

CHE 244 Separation Processes 0,3 Credits
Staged and continuous separations. Phase equilibrium. Binary and Multicomponent Distillation. Liquid-liquid extraction. Review of applied diffusion processes, atmospheric dispersion, jets and plumes. Membranes in gas and liquid systems. Adsorption and Ion Exchange Separations. Chromatographic Separations. Introduction to Bioseparations. Introduction to Aspen Programming.
Prerequisites: CHE 031 and CHE 044 and CHE 210 and CHE 151

CHE 280 Unit Operations Survey 3 Credits
The theory of heat, mass and momentum transport. Laminar and turbulent flow of real fluids. Heat transfer by conduction, convection and radiation. Application to a wide range of operations in the chemical and metallurgical process industries.

CHE 281 Chemical Engineering Fundamentals I 4 Credits
Fundamentals of material balances, fluid mechanics and heat transfer. Must have undergraduate degree in a scientific or engineering discipline or one semester undergraduate level general chemistry, one semester undergraduate level physics (statics and dynamics), and two semesters undergraduate calculus. Consent of department required.

CHE 282 Chemical Engineering Fundamentals II 4 Credits
Fundamentals of heat and mass transfer, process energy balances and unit operations. Consent of department required.
Prerequisites: CHE 281

CHE 300 Apprentice Teaching 1-4 Credits
Repeat Status: Course may be repeated.

CHE 306 Introduction to Biomedical Engineering and Mathematical Biology 3 Credits
Study of human physiology, including the cardiovascular, nervous and respiratory systems, and renal physiology. Mathematical analysis of physiological processes, including transport phenomena. Mathematical models of excitation and propagation in nerve. Biomechanics of the skeletal muscle system. Mathematical models in population dynamics and epidemiology. Independent study projects.
Prerequisites: MATH 205

CHE 318 (BIOE 318, MAT 318) Soft Materials: Rheology and Characterization 3 Credits
Characterization of soft materials using rheological techniques. Fundamentals of rheology and rheological characterization applied to materials such as polymers, glassy liquids and polymeric gels. Closed to students who have taken CHE/BIOE/MAT 418. Instructor permission or graduate status required.

CHE 321 Biomolecular & Cellular Mechanics 3 Credits
Mechanics and physics of the components of the cell, ranging in length scale from fundamental biomolecules to the entire cell. Thecourse covers the mechanics of proteins and other biopolymers in 1D, 2D, and 3D structures, cell membrane structure and dynamics, and the mechanics of the whole cell.
Prerequisites: MATH 205 and MATH 231 and PHY 022 and (PHY 013 or PHY 021)

CHE 331 Separation Processes 3 Credits
Industrial separation chemistry and processes. Computer solutions for simple and complex multicomponent distillation columns. Azeotropic and extractive distillation. Adsorption, ion exchange and chromatography in packed beds, moving beds and cyclic operation. Synthesis of polymer membrane and its applications to industrial separation processes.

CHE 334 (MAT 334) Electron Microscopy and Microanalysis 4 Credits
Fundamentals and experimental methods in electron optical techniques including scanning electron microscopy (SEM), conventional transmission (TEM) and scanning transmission (STEM) electron microscopy. Specific topics covered will include electron optics, electron beam interactions with solids, electron diffraction and chemical microanalysis. Applications to the study of the structure of materials are given. Consent of department required.

CHE 339 Neuronal Modeling and Computation 3 Credits
Neuroscience in a computational, mathematical, and engineering framework. Literature surveys and case studies with simulations. Computational aspects of information processing within the nervous system by focusing on single neuron modeling. Single neurons and how their biological properties relate to neuronal coding. Biophysics of single neurons, signal detection and signal reconstruction, information theory, population coding and temporal coding.
Prerequisites: ENGR 010 and MATH 205

CHE 341 (BIOE 341) Biotechnology I 3 Credits
Applications of material and energy balances; heat, mass, and momentum transfer; enzyme and microbial kinetics; and mathematical modeling to the engineering design and scale-up of bio-reactor systems. Closed to students who have taken CHE 441 (BIOE 341 and BIOE 441).
Prerequisites: MATH 205 and CHE 031 and (CHM 031 or CHM 041)

CHE 342 (BIOE 342) Biotechnology II 3 Credits
Engineering design and analysis of the unit operations used in the recovery and purification of products manufactured by the biotechnology industries. Requirements for product finishing and waste handling will be addressed. Closed to students who have taken CHE 442 (BIOE 342 and BIOE 442).
Prerequisites: MATH 205 and CHE 031 and (CHM 031 or CHM 041)

CHE 344 (BIOE 344) Molecular Bioengineering 3 Credits
Kinetics in small systems, stochastic simulation of biochemical processes, receptor-mediated adhesion, dynamics of ion-channels, ligand binding, biochemical transport, surface Plasmon resonance, DNA microarray design, and chemical approaches to systems biology. Senior standing in ChE.
Prerequisites: MATH 205 and MATH 231

CHE 345 (BIOE 345) Quantitative Biology 3 Credits
Basic concepts in molecular and cellular biology as well as biochemistry. Connects these to engineering principles to (1) develop a quantitative understanding of biological systems and (2) understand how modern engineering uses applications of methods and principles in biology. Topics include quantity and length scales in biology, use of statistical mechanics to describe phenomena such as microstates and ligand receptor binding, and application of chemical reaction kinetics to describe biochemical reactions. Closed to students who have taken BIOE 445.
Prerequisites: MATH 205

CHE 346 Biochemical Engineering Laboratory 0,3 Credits
Laboratory and pilot-scale experiments in fermentation and enzyme technology, tissue culture, and separations techniques. Consent of instructor required. Closed to students who have taken CHE 446.
Prerequisites: CHE 341
Can be taken Concurrently: CHE 341

CHE 350 Special Topics 1-3 Credits
A study of areas in chemical engineering not covered in courses presently listed in the catalog.
Repeat Status: Course may be repeated.

CHE 363 (BIOE 363) Numerical Methods for Scientists and Engineers 3 Credits
Introduction to numerical methods in science and engineering. Expose students to the numerical solution of a variety of commonly encountered problems, enhance their numerical programming skills, and provide a broad base on which to build more specialized knowledge of computational methods. Topics include solution of linear and nonlinear sets of algebraic equations, linear and logistic regression, ordinary differential equations, Fourier analysis, eigenvalues, partial differential equations by finite difference and finite element methods.
Prerequisites: MATH 205

CHE 365 Molecular Modeling and Simulation 3 Credits
Introduction to molecular modeling and simulation techniques. Expose students to programming environments and give a broad overview of molecular simulation methods used in chemical engineering. Topics include density functional theory including periodic systems, molecular dynamics, Monte Carlo techniques, review of statistical mechanics and ensembles, biased sampling and free energy methods, and microkinetic modeling. Student will use existing software as well as develop their own computer codes in this class.

CHE 367 (BIOE 367) Engineering in Medicine 3 Credits
Introduction to the physical basis of disease. Discussion of biomolecular strategies to overcome these changes. Topics include drug delivery, targeting, and tissue engineering, with a focus on infectious disease, cancer, cardiovascular disease, and neurodegenerative disease. Closed to students who have taken CHE 467 (BIOE 367 and BIOE 467).

CHE 369 (BIOE 369) Advanced Topics in Regulatory Affairs 3 Credits
Regulatory requirements for the development and manufacture of 21st century medical products. Current challenges and innovative technologies in pharmaceuticals and medical devices. Topics include combination products, biosimilars, cell therapeutics, mobile medical applications, 3D-printed products, big data in healthcare, new approaches to process validation. Closed to students who have taken BIOE/CHE 469.
Prerequisites: BIOE 225

CHE 370 (BIOE 370) The Engineering of Brewing, Winemaking, and Distilling 0,3 Credits
An open-ended and experiential exploration of the engineering principles required for the brewing of beer, winemaking, and distilling of spirits.
Prerequisites: (BIOE 341 or CHE 211) and (BIOE 246 or CHE 212)

CHE 373 (CEE 373) Fundamentals of Air Pollution 3 Credits
Introduction to the problems of air pollution including such topics as: sources and dispersion of pollutants; sampling and analysis; technology of economics and control processes; legislation and standards. Must have senior standing in the College of Engineering and Applied Science.

CHE 374 Environmental Catalysis 3 Credits
Pollution emissions in the USA (NOx, SOx, NH3, CO, VOCs, PM, heavy metals and persistent bioaccumulative chemicals) and their sources and fate. Fundamental concepts of catalysis (surface and their characterization, physical adsorption, surface reaction mechanisms and their kinetics). Application of catalysis to a wide range of environmental issues (catalytic combustion of VOCs, automotive catalytic converter, selective catalytic conversion of NOx, etc.) Must have senior standing. Consent of instructor required.

CHE 375 (CEE 375) Environmental Engineering Processes 3 Credits
Fundamental physical, chemical and microbiological processes applied in environmental engineering for air pollution control, treatment of drinking water, municipal wastewater, industrial wastes, hazardous/toxic wastes, and environmental remediation. Kinetics, reactor theory, mass balances, application of fundamental physical, chemical and microbiological principles to analysis and design.
Prerequisites: CEE 170 and CHM 031

CHE 376 (ME 376) Energy: Issues & Technology 3 Credits
Energy usage and supply, fossil fuel technologies, renewable energy alternatives and environmental impacts. The scope will be broad to give some perspective of the problems, but in-depth technical analysis of many aspects will also be developed.
Prerequisites: CHE 210 or ME 104 or CHM 342 or MAT 205

CHE 377 Electrochemical Engineering 3 Credits
Fundamental concepts of electrochemistry, covering the thermodynamics, kinetics, and transport phenomena that occur in both liquid and solid state electrochemical systems. This course draws upon concepts from physical chemistry, chemical engineering and materials science to address the phenomena that govern the performance of electrochemical devices, and that drive important engineering phenomena such as corrosion. The course will serve as a basis for a career in electrochemistry as it applies to energy issues. Prerequisites: Senior level in ChE or instructor approval.

CHE 379 Senior Thesis 3 Credits
Two-semester, independent study of a research problem under the guidance of a faculty advisor and thesis committee. Written thesis proposal and oral presentation required in first semester, and a written final thesis and oral presentation required at the end of the second semester. Students will receive a certificate upon graduation with the thesis title, signed by the advisor and department chair. Must have senior standing in Chemical and Biomolecular Engineering. Consent of department required.
Repeat Status: Course may be repeated.

CHE 380 Senior Research Project (OSI) 1-6 Credits
Independent study of a problem involving laboratory investigation, design, and theory, when possible involves one of the local communities or industries. Team work under the guidance of Faculty advisors. Experiential learning opportunity to bridge educational gap between conventional textbook learning and industrial approaches to real-world technical problem solving. Must have senior standing. Consent of department required.
Repeat Status: Course may be repeated.

CHE 383 Chemical Engineering Fundamentals III 4 Credits
Fundamentals of thermodynamics, reaction kinetics and reactor analysis, and applied mathematics. Consent of department required. Cannot apply towards a Chemical Engineering undergraduate degree.
Prerequisites: CHE 282

CHE 386 Process Control 3 Credits
Open-loop and closed-loop stability analysis using root locus and Nyquist techniques, design of feedback controllers with time and frequency domain specifications. Experimental process identification. Control of multivariable processes. Introduction to sampled-data control theory.
Prerequisites: CHE 242

CHE 387 (ECE 387, ME 387) Digital Control 3 Credits
Sampled-data systems; z-transforms; pulse transfer functions; stability in the z-plane; root locus and frequency response design methods; minimal prototype design; digital control hardware; discrete state variables; state transition matrix; Liapunov stability state feedback control (2 lectures and one laboratory per week).
Prerequisites: CHE 386 or ECE 212 or ME 343

CHE 388 (CHM 388, MAT 388) Polymer Characterization 3 Credits
Description of molecular weight measurements using dilute solutions (solution viscosity, size exclusion chromatography, osmotic pressure, and light scattering). Introduction to polymer thermal analysis techniques such as differential scanning calorimetry (DSC) , dynamic mechanical analysis (DMA), and thermomechanical analyzer (TMA). Discussion of structure and morphology of polymers and polymer blends using nuclear magnetic resonance (NMR), infrared spectroscopy (IR), Raman spectroscopy, UV analysis, transmission electron microscopy (TEM), scanning electron microscopy (SEM), atomic force microscopy (AFM). Crystallinity measurements using SANS, SAXS, and WAXS.
Prerequisites: MAT 033 or MAT 204 or MAT 392 or MAT 393

CHE 389 (ECE 389, ME 389) Control Systems Laboratory 2 Credits
Experiments on a variety of mechanical, electrical and chemical dynamic control systems. Exposure to state-of-the-art control instrumentation: sensors, transmitters, control valves, analog and digital controllers. Emphasis on comparison of theoretical computer simulation predictions with actual experimental data. Lab teams will be interdisciplinary.
Prerequisites: CHE 242 or ECE 212 or ME 343

CHE 391 (CHM 391) Colloid and Surface Chemistry 3 Credits
Physical chemistry of everyday phenomena. Intermolecular forces and electrostatic phenomena at interfaces, boundary tensions and films at interfaces, mass and charge transport in colloidal suspensions, electrostatic and London forces in disperse systems, gas adsorption and heterogeneous catalysis. Consent of instructor required.

CHE 392 (MAT 392) Introduction to Polymer Science 3 Credits
Introduction to concepts of polymer science. Kinetics and mechanism of polymerization, synthesis and processing of polymers, characterization. Relationship of molecular conformation, structure and morphology to physical and mechanical properties.

CHE 393 (CHM 393, MAT 393) Physical Polymer Science 3 Credits
Structural and physical aspects of polymers (organic, inorganic, natural). Molecular and atomic basis for polymer properties and behavior. Characteristics of glassy, crystalline, and paracrystal-line states (including viscoelastic and relaxation behavior) for single- and multi-component systems. Thermodynamics and kinetics of transition phenomena. Structure, morphology, and behavior. Available to graduate and undergraduate students (with senior level standing) in CHE, CHEM or MAT.

CHE 394 (CHM 394) Organic Polymer Science I 3 Credits
Organic chemistry of synthetic high polymers. Polymer nomenclature, properties, and applications. Functionality and reactivity or monomers and polymers. Mechanism and kinetics of step-growth and chain-growth polymerization in homogenous and heterogenous media. Brief description of emulsion polymerization, ionic polymerization, and copolymerization. Must have completed one year of physical chemistry and one year of organic chemistry.
Prerequisites: CHM 031 or CHM 041 or CHM 110 or CHM 112 or CHM 342 or CHE 210
Attribute/Distribution: NS, Q

CHE 400 Chemical Engineering Thermodynamics 3 Credits
Applications of thermodynamics in chemical engineering. Topics include energy and entropy, heat effects accompanying solution, flow of compressible fluids, refrigeration including solution cycles, vaporization and condensation processes, and chemical equilibria. Must have completed an introductory course in thermodynamics.

CHE 401 Chemical Engineering Thermodynamics II 3 Credits
A detailed study of the uses of thermodynamics in predicting phase equilibria in solid, liquid, and gaseous systems. Fugacities of gas mixtures, liquid mixtures, and solids. Solution theories; uses of equations of state; high-pressure equilibria.

CHE 410 Chemical Reaction Engineering 3 Credits
The application of chemical kinetics to the engineering design and operation of reactors. Non-isothermal and adiabatic reactions. Homogeneous and heterogeneous catalysis. Residence time distribution in reactors.

CHE 413 Heterogeneous Catalysis and Surface Characterization 3 Credits
History and concepts of heterogeneous catalysis. Surface characterization techniques, and atomic structure of surfaces and adsorbed monolayers. Kinetics of elementary steps (adsorption, desorption, and surface reaction) and overall reactions. Catalysis by metals, metal oxides, and sulfides. Industrial applications of catalysis: selective oxidation, pollution control, ammonia synthesis, hydrogenation of carbon monoxide to synthetic fuels and chemicals, polymerization, hydrotreating, and cracking.

CHE 415 Transport Processes 3 Credits
A combined study of the fundamentals of momentum transport, energy transport and mass transport and the analogies between them. Evaluation of transport coefficients for single and multicomponent systems. Analysis of transport phenomena through the equations of continuity, motion, and energy.
Prerequisites: CHE 461 or ENGR 452 or CHE 452

CHE 417 (BIOE 417, MAT 417) Soft Materials: Mechanics and Physics 3 Credits
Physical and mechanical behavior of soft materials such as gels, foams, rubbers, soft adhesives, and most biological tissue. Large strain kinematics, stress measures, constitutive relations from the molecular and continuum points of view, and application to problems such as cavitation, creasing, thin structures, fracture, adhesion, surface stress, and electroactive materials.
Prerequisites: CHE 452 or ENGR 452

CHE 418 (BIOE 418, MAT 418) Soft Materials: Rheology and Characterization 3 Credits
See the course description listed for CHE/BIOE/MAT 318. In order to receive 400-level credits, the student must do an additional, more advanced term project, as defined by the instructor at the beginning of the course. Closed to students who have taken CHE/BIOE/MAT 318.

CHE 421 (BIOE 421) Biomolecular & Cellular Mechanics 3 Credits
Mechanics and physics of cell components, from fundamental biomolecules to the entire cell. The mechanics of proteins and other biopolymers in 1D, 2D, and 3D structures, cell membrane structure and dynamics, and the mechanics of the whole cell. This course is a graduate version of ChE 321 (BioE/Phy 321). The lecture content will be the same as in ChE 321 (BioE/Phy 321), but students enrolled in ChE 421 (BioE 421) will have more advanced assignments. Closed to students who have completed ChE 321 (BioE/Phy 321). Must have graduate standing or consent of instructor.

CHE 428 Rheology 3 Credits
An intensive study of momentum transfer in elastic viscous liquids. Rheological behavior of solution and bulk phase polymers with emphasis on the effect of molecular weight, molecular weight distribution and branching. Derivation of constitutive equations based on both molecular theories and continuum mechanics principles. Application of the momentum equation and selected constitutive equations to geometries associated with viscometric flows. Consent of instructor required.
Prerequisites: CHE 461 or CHE 452

CHE 430 Mass Transfer 3 Credits
Theory and developments of the basic diffusion and mass transfer equations and transfer coefficients including simultaneous heat and mass transfer, chemical reaction and dispersion effects. Applications to various industrially important operations including continuous contact mass transfer, absorption, humidification, etc. Brief coverage of equilibrium stage operations as applied to absorption and to binary and multicomponent distillation.

CHE 433 (ECE 433, ME 433) Linear Systems and Control 3 Credits
This course covers the following topics in linear systems and control theory: review of fundamental concepts in linear algebra, state-space representation of linear systems, linearization, time-variance and linearity properties of systems, impulse response, transfer functions and their state-space representations, solution to LTI and LTV state equations, Jordan form, Lyapunov stability, input-output stability, controllability, stabilizability, observability, detectability, Canonical forms, minimal realizations, introduction to optimal control theory, Linear Quadratic Regulator (LQR), Algebraic Riccati Equation (ARE), frequency domain properties of LQR controllers.
Prerequisites: CHE 386 or ME 343 or ECE 212

CHE 434 (ECE 434, ME 434) Multivariable Process Control 3 Credits
A state-of-the-art review of multivariable methods of interest to process control applications. Design techniques examined include loop interaction analysis, frequency domain methods (Inverse Nyquist Array, Characteristic Loci and Singular Value Decomposition) feed forward control, internal model control and dynamic matrix control. Special attention is placed on the interaction of process design and process control. Most of the above methods are used to compare the relative performance of intensive and extensive variable control structures.
Prerequisites: CHE 433 or ME 433 or ECE 433

CHE 436 (ECE 436, ME 436) Systems Identification 3 Credits
The determination of model parameters from time history and frequency response data by graphical, deterministic and stochastic methods. Examples and exercises taken from process industries, communications and aerospace testing. Regression, quasilinearization and invariant-imbedding techniques for nonlinear system parameter identification included.

CHE 438 Process Modeling and Control Seminar 1 Credit
Presentations and discussions on current methods, approaches, and applications. Credit cannot be used for the M.S. degree.

CHE 439 (BIOE 439) Neuronal Modeling and Computation 3 Credits
This course is a graduate version of CHE 339 (BIOE 339). While the lecture content will be the same as the 300-level course, students in the 400-level class will be expected to complete an independent term project. Closed to students who have completed CHE 339 (BIOE 339). Must have graduate standing in Chemical Engineering or Bioengineering.

CHE 440 Chemical Engineering in the Life Sciences 3 Credits
Introduction of important topics in life sciences to chemical engineers. Topics include protein and biomolecule structures and characterization, recombinant DNA technology, immunoaffinity technology, combinatorial chemistry, metabolic engineering, bioinformatics. Must have Bachelor's degree in science or engineering.

CHE 441 (BIOE 441) Biotechnology I 3 Credits
See the course description listed for CHE 341 (BIOE 341). In order to receive 400-level credits, the student must do an additional, more advanced term project, as defined by the instructor at the beginning of the course. Closed to students who have taken CHE 341 (BIOE 341).

CHE 442 (BIOE 442) Biotechnology II 3 Credits
See the course description listed for CHE 342 (BIOE 342). In order to receive 400-level credits, the student must do an additional, more advanced term project, as defined by the instructor at the beginning of the course. Closed to students who have taken CHE 342 (BIOE 342).

CHE 444 Bioseparations 3 Credits
Separation techniques for biomolecule isolation and purification. Theory and problems of bioaffinity chromatography, electromigration processes, and aqueous two-phase polymer extraction systems. Engineering principles for scaling-up bioseparation processes. Consent of instructor required.

CHE 445 (BIOE 445) Quantitative Biology 3 Credits
This course is a graduate-level version of BIOE 345. While the lecture content will be the same as the 300-level course, students enrolled in BIOE 445 will have more advanced assignments. Closed to students who have taken BIOE 345.

CHE 446 Biochemical Engineering Laboratory 0,3 Credits
Laboratory and pilot-scale experiments in fermentation and enzyme technology, tissue culture, and separations techniques. Closed to students who have taken CHE 346.
Prerequisites: CHE 341 or CHE 444 or CHE 342
Can be taken Concurrently: CHE 342

CHE 447 (BIOE 447) Molecular Bioengineering 3 Credits
This course is a graduate version of CHE 344 (BIOE 344). While the lecture content will be the same as the 300-level course, students enrolled in CHE 444 will have more advanced assignments. Closed to students who have completed CHE 344 (BIOE 344).

CHE 448 Topics in Biochemical Engineering 3 Credits
Analysis, discussion, and review of current literature for a topical area of biotechnology. may be repeated for credit with the consent of the instructor. Consent of instructor required.
Repeat Status: Course may be repeated.

CHE 449 (BIOE 449) Metabolic Engineering 3 Credits
Quantitative perspective of cellular metabolism and biochemical pathways. Methods for analyzing stoichiometric and kinetic models, mass balances, flux in reaction networks, and metabolic control. Solving problems using advanced mathematics and computer programming. Closed to students who have completed BIOE 349. Must have graduate standing in Chemical Engineering or Bioengineering.

CHE 450 Special Topics 1-12 Credits
An intensive study of some field of chemical engineering not covered in the more general courses. Credit above three hours is granted only when different material is covered.

CHE 451 Problems In Research 1 Credit
Study and discussion of optimal planning of experiments and analysis of experimental data. Discussion of more common and more difficult techniques in the execution of chemical engineering research.

CHE 452 (BIOE 452, ENGR 452, ME 452) Mathematical Methods In Engineering I 3 Credits
Analytical techniques relevant to the engineering sciences are described. Vector spaces; eigenvalues; eigenvectors. Linear ordinary differential equations; diagonalizable and non- diagonalizable systems. Inhomogeneous linear systems; variation of parameters. Non-linear systems; stability; phase plane. Series solutions of linear ordinary differential equations; special functions. Laplace and Fourier transforms; application to partial differential equations and integral equations. Sturm-Liouville theory. Finite Fourier transforms; planar, cylindrical, and spherical geometries.

CHE 453 Teaching Apprentice 1 Credit
Students will work under the guidance of individual Faculty instructors to participate in some of the following teaching tasks: Development of the course syllabus, preparation and grading of homework and exams, holding a recitation and/or lecture section. Must have graduate standing in ChE department.
Repeat Status: Course may be repeated.

CHE 454 Seminar 0-3 Credits
Critical discussion of recent advances in chemical engineering.

CHE 455 Seminar 1-3 Credits
Critical discussion of recent advances in chemical engineering. Credit above one hour is granted only when different material is covered.

CHE 456 (BIOE 456) Stochastic Processes: Theory and Applications in Biology 3 Credits
Stochastic, or probabilistic, models of cellular processes and other biological systems to describe the inherent randomness of nature. Topics covered include theory and biological applications of Markov chains, the Master Equation, white noise and stochastic integrals, the Fokker-Planck Equation, and noise in gene expression. Some minimal experience in programming and/or Mathematica/Matlab.
Prerequisites: MATH 205

CHE 460 Chemical Engineering Project 1-6 Credits
An intensive study of one or more areas of chemical engineering, with emphasis on engineering design and applications. A written report is required.
Repeat Status: Course may be repeated.

CHE 463 (BIOE 463) Numerical Methods for Scientists and Engineers 3 Credits
See the course description listed for ChE 363 (BIOE 363). This course is graduate version of ChE 363 (BIOE 363). The lecture content will be the same as ChE 363 (BIOE 363), but students enrolled in ChE 463 (BIOE 463) will have more advanced assignments. Closed to students who have taken ChE 363 (BIOE 363). Must have graduate standing or consent of the instructor.

CHE 465 Molecular Modeling and Simulation 3 Credits
See the course description listed for ChE 365. This course is graduate version of ChE 365. The lecture content will be the same as ChE 365, but students enrolled in ChE 465 will have more advanced assignments. Closed to students who have taken ChE 365. Must have graduate standing or consent of the instructor.

CHE 467 (BIOE 467) Engineering in Medicine 3 Credits
See the course description listed for CHE 367 (BIOE 367). In order to receive 400-level credits, the student must do an additional, more advanced term project, as defined by the instructor at the beginning of the course. Closed to students who have taken CHE 367 (BIOE 367), or BIOE 467.

CHE 469 (BIOE 469) Advanced Topics in Regulatory Affairs 3 Credits
This course is a graduate version of BIOE 369 (CHE 369). While the lecture content will be the same as the 300-level course, students enrolled in BIOE 469 (CHE 469) will have more advanced assignments. Closed to students who have taken BIOE/CHE 369.

CHE 473 Environmental Separation and Control 3 Credits
Theory and application of adsorption, ion exchange, reverse osmosis, air stripping and chemical oxidation in water and wastewater treatment. Modeling engineered treatment processes.
Prerequisites: CEE 470

CHE 480 Research 3 Credits
Investigation of a problem in chemical engineering.

CHE 481 Research 3 Credits
Continuation of CHE 480.

CHE 482 (CHM 482, MAT 482) Mechanical Behaviors of Polymers 3 Credits
Mechanical behavior of polymers. Characterization of viscoelastic response with the aid of mechanical model analogs. Time-temperature superposition, experimental characterization of large deformation, and fracture processes, polymer adhesion. Effects of fillers, plasticizers, moisture, and aging on mechanical behavior.

CHE 483 (CHM 483, MAT 483, PSE 483) Emulsion Polymers 3 Credits
Examination of fundamental concepts important in the manufacture, characterization, and application of polymer latexes. Topics to be covered will include colloidal stability, polymerization mechanisms and kinetics, reactor design, characterization of particle surfaces, latex rheology, morphology considerations, polymerization with functional groups, film formation and various application problems.

CHE 485 (CHM 485, MAT 485, PSE 485) Polymer Blends 3 Credits
Synthesis, morphology, and mechanical behavior of polymer blends. Polymer/polymer miscibility and thermodynamics of mixing of polymer/solvent and polymer/polymer blends. Prediction of miscibility using various theoretical models and methods that can be used to help enhance miscibility (H bonding etc.). Methods to enhance the compatibility of polymer/polymer blends (e.g., block copolymers, ternary addition, IPNs), etc.). Types of polymer blends. Must have completed any introductory polymer course or equivalent.

CHE 486 Polymer Processing 3 Credits
Application of fundamental principles of mechanics, fluid dynamics and heat transfer to the analysis of a wide variety of polymer flow processes. A brief survey of the rheological behavior of polymers is also included. Topics include pressurization, pumping, die forming, calendering, coating, molding, fiber spinning and elastic phenomena.

CHE 490 Thesis 1-6 Credits

CHE 492 (CHM 492, MAT 492) Topics in Polymer Science 3 Credits
Intensive study of topic selected from areas of current research interest such as morphology and mechanical behavior, thermodynamics and kinetics of crystallization, new analytical techniques, molecular weight distribution, non-Newtonian flow behavior, second order transition phenomena, novel polymer structures. Credit above three hours is granted only when different material is covered.
Prerequisites: CHE 392 or CHE 392 or CHM 392 or CHM 392

CHE 499 Dissertation 1-15 Credits
Repeat Status: Course may be repeated.