

# CHEMICAL ENGINEERING

College of Engineering

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## Career Possibilities

Chemical Engineer • Process Engineer • Automation Control Engineer • Chemical Research Engineer • Chemical Test Engineer • Biochemical Engineer • Biomedical Engineer • Technical Sales • Management • Technical Writer • Quality Control Specialist • Consultant • Safety Engineer • Environmental Engineer • (Some of these careers require additional education or experience. For more information, see [www.careers.csulb.edu](http://www.careers.csulb.edu).)

## Introduction

Chemical engineering is a major that opens the way for many career opportunities. As the name implies, chemical engineers must build a foundation on engineering, science, and math while specializing in the application of chemistry to engineering systems. This is a versatile major that also encourages students to take courses from the other engineering disciplines as well as the biological sciences. In general, chemical engineers integrate their broad knowledge and analytical skills to design, implement and optimize chemical processes that convert raw materials into valuable products in a sustainable manner. Chemical engineers ensure that processes are operated safely and economically with minimum energy consumption and waste emission. Many of our graduates find career opportunities in traditional industries such as petroleum refining, energy production, chemical manufacturing and pharmaceuticals. Because of their diverse technical skill set, our graduates are increasingly finding employment in emerging industries such as alternative energy, biomedical engineering, environmental engineering, semiconductors, materials, and nanotechnology.

## Program Educational Objectives

The Chemical Engineering bachelor degree program's educational objective statement is directed towards the career accomplishments and expectations of the alumni. The objectives of the program are that recent alumni become successful in their professional careers, and that they continue on a path of professional development. Specific educational objectives of the program are to:

- Prepare graduates with broad knowledge in process design, simulation and optimization; and research and development for new chemical products.
- Prepare graduates who communicate effectively and work collaboratively in multidiscipline teams.

- Prepare graduates to be productive professionals in technical careers with the highest level of professional ethics.
- Prepare graduates with the ability to continue to learn and adapt to future changes in the technical work environment.

The faculty members of the Department of Chemical Engineering strive to continuously improve the program and the curriculum as well as laboratory facilities to ensure the professional career success of our recent graduates. The goal is to prepare students for a wide range of career routes that use chemical engineering principles with a solid foundation in engineering, math, science, and societal awareness. The scope of this program is broadened by courses from general education as well as specialized technical elective courses in chemical engineering and other engineering disciplines. Students develop teamwork skills and gain interdisciplinary experience particularly in laboratory courses, lecture courses with laboratory components, and the capstone design class that require team projects. This program provides ample opportunities for students to develop communication skills such as oral and poster presentations as well as written technical reports. Students are encouraged to participate in life-long learning activities such as professional meetings on or off campus and field trips. The goal is to have a comprehensive, student-centered program that can allow us to meet the educational objectives.

## Chemical Engineering Advisory and Development Council

The Department of Chemical Engineering Advisory and Development Council, consisting of outstanding engineers and executives from industry and government in Southern California, provides guidance to our program. Its mission is to advise and assist in developing the Department and to support its efforts to serve students, the community, and industry. This liaison between the University and industry ensures that industry concerns are addressed in our curricula and provides career guidance for our graduates.

## Accreditation

The Bachelor of Science in Chemical Engineering is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

## Other Related Programs

Students interested in obtaining a Minor in Environmental Engineering should refer to the College of Engineering section of this catalog. Students who take required Chemistry courses are most likely eligible for Minor in Chemistry degree. See the College of Natural Science and Mathematics section of this catalog.

Students wishing to pursue advanced study may be interested in the College of Engineering's Master of Science in Engineering (MSE) degree. Thesis work may be supervised by chemical engineering faculty. For detailed MSE requirements, see the College of Engineering section of this catalog.

## Grade Requirements

In addition to other University requirements, all students must obtain a grade of "C" or better in each prerequisite for any chemical engineering course. Also, required Written English (GE A1), Speech (GE A2), and Interdisciplinary (IC) courses must be taken for a letter grade, not Credit/No Credit.

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## Undergraduate Programs

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### Bachelor of Science In Chemical Engineering (128 units)

#### Degree Progress

Students must complete the following requirements within one calendar year of declaring the major. Some students may need to take courses during Summer Session to meet these requirements. At the end of the year, students who have not met the requirements must either declare another major or meet with an Academic Advisor to determine if the student's performance in the courses merits an additional semester to complete.

First-time Freshmen: A grade of "C" or better must be achieved in MATH 122 within one calendar year.

Transfer Students: A grade of "C" or better must be achieved in MATH 123 and PHYS 151 within one calendar year.

#### Requirements

A grade of "C" or better must be achieved in all required courses listed below.

Lower Division:

Take all the following courses:

CH E 200 Chemical Engineering Fundamentals (3)  
Prerequisites: CHEM 111A, MATH 122, PHYS 151 all with a grade of "C" or better.  
Corequisite: CHE 210.

CH E 210 Computer Methods in Chem Engineering (3)  
Corequisite: CHE 200

CH E 220 Chemical Engineering Thermodynamics I (3)  
Prerequisite: CH E 200 with a grade of "C" or better.

CHEM 111A General Chemistry (5)  
Prerequisites: A passing score on the Chemistry Placement Examination . (Credit in Chem 101 does not substitute for a passing score on the Chemistry Placement Examination) and a "C" or better in MATH 113 or 117 or 119A or 122. One year of high school chemistry is strongly recommended. (Recommended for students who intend to pursue careers in science or engineering).

CHEM 111B General Chemistry (5)  
Prerequisite: CHEM 111A with a grade of "C" or better.

C E 205 Analytical Mechanics I (Statics) (3)  
Prerequisite: PHYS 151 with a grade of "C" or better.  
Prerequisite/Corequisite: MATH 123.

ENGR 101 Introduction to Engineering Profession (1)  
Prerequisite/Corequisite: MATH 111 or MATH 113 or MATH 122

ENGR 102 Academic Success Skills (1)  
Prerequisite: ENGR 101 with a grade of "C" or better.

CH E 100 Introduction to Chemical Engineering (1)  
Prerequisite: None.

MATH 122 Calculus I (4)

Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

MATH 123 Calculus II (4)

Prerequisite: A grade of "C" or better in MATH 122.

MATH 224 Calculus III (4)

Prerequisite: A grade of "C" or better in MATH 123 or 222.

PHYS 151 Mechanics and Heat (4)

Prerequisite/Corequisite: MATH 122.

Take one of the following choices:

PHYS 152 Electricity and Magnetism (4)

Prerequisite: PHYS 151; Prerequisite/Corequisite: MATH 123.

or both of the following:

EE 210 Electro-Magnetic Foundations in EE (3)

Prerequisite: PHYS 151 with a grade of "C" or better.  
Corequisites: MATH 123, EE 210L.

EE 210L Electro-Magnetic Foundations in EE Lab (1)

Corequisite: EE 210.

Take one course from the following:

BIOL 200, CHEM 251, MICR 200

Upper Division:

Take all the following courses:

CH E 310 Chemical Engineering Thermodynamics II (3)

Prerequisites: CH E 210, 220 all with a grade of "C" or better.

CH E 320 Fluids (3)

Prerequisites: CH E 200, C E 205 all with a grade of "C" or better.

CH E 330 Separation Processes (4)

Prerequisite: CHE 310 all with a grade of "C" or better

CH E 420 Heat and Mass Transport (3)

Prerequisites: CHE 310, CHE 320 all with a grade of "C" or better.

CH E 430 Chemical Reactor Kinetics (3)

Prerequisites: CHEM 371A, (MATH 370A or CHE 480) all with a grade of "C" or better.  
Corequisite: CHE 420

CH E 440 Chemical Engineering Laboratory I (2)

Prerequisites: CHE 320, CHE 330 all with a grade of "C" or better.

CH E 450 Chemical Engineering Laboratory II (2)

Prerequisites: CHE 420, 430, 440 all with a grade of "C" or better.  
Corequisite: CHE 460

CH E 460 Chemical Process Control (3)

Prerequisites: CHE 420, CHE 430, and (MATH 370A or CHE 480) all with a grade of "C" or better

CH E 470 Chemical Engineering Design (4)

Prerequisites: CHE 330, CHE 420, CHE 430 all with a grade of "C" or better.

Corequisite: CHE 460

CHEM 371A Physical Chemistry: Thermodynamics and Kinetics (3)

Prerequisites: CHEM 251, MATH 123, PHYS 152 (all with a grade of "C" or better), MATH 224 (may be taken concurrently).

MATH 370A Applied Mathematics I (3)

Prerequisites: MATH 123. Not open to Freshmen.

Take one of the following choices:

CHEM 320A and CHEM 320B

or

CHEM 322A and 323A and CHEM 322B and 323B

or

CHEM 327 and approved science laboratory

Take six units from the following courses:

CH E 300, 415, 431, 432, 433, 437, 445, 455, 465, 475, 480, 485, 490;

Take three units from the following courses:

EE 211, CE 406, approved ECON elective course, or approved Engineering elective course.

All students must show evidence of having registered for the FE Exam (also known as EIT Exam) prior to graduation. Those who pass the FE Exam before graduation can waive 3 units of elective course.

## Minor in Environmental Engineering

For requirements, see the description in the College of Engineering section of this catalog.

## Certificate in Safety Operations

Not accepting new students as of Fall 2012.

This interdisciplinary certificate is designed to prepare students for safety positions that require a strong background in the technology of safe industrial environments.

Please be aware that this program is not eligible for Financial Aid unless pursued concurrently with a degree program.

### Requirements

1. May be earned concurrently with or subsequent to the baccalaureate degree.
2. Open to all majors who have fulfilled the required prerequisites as stated below.
3. Requires a total of 24 units as specified below:
  - A. Completion of supporting technical courses chosen in consultation with an advisor.
  - B. 24 units are required from the following courses: ET 307, 309, 311, 319, 329, 329L, 409, 410.
4. Any deviation from this program requires the written permission of the program advisor.

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## Chemical Engineering Courses (CH E)

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### LOWER DIVISION

#### 100. Introduction to Chemical Engineering (1)

Chemical engineering as a profession. Nature of profession and career opportunities. Emerging frontiers of chemical engineering. (Lecture 1 hour) Letter grade only (A-F).

#### 200. Chemical Engineering Fundamentals (3) F

Prerequisites: CHEM 111A, MATH 122, PHYS 151 all with a grade of "C" or better.

Corequisite: CHE 210.

Dimensional analysis of units, steady and transient balances of mass, momentum and energy, the mathematical solution of chemical engineering problems.

(Lecture-problems 3 hrs) Letter grade only (A-F).

#### 210. Computer Methods in Chemical Engineering (3) F

Corequisite: CHE 200

Beginning programming and techniques of numerical analysis applied to typical problems in chemical engineering.

(Lecture-problems 2 hours, lab 3 hours) Letter grade only (A-F).

#### 220. Chemical Engineering Thermodynamics I (3) S

Prerequisite: CH E 200 with a grade of "C" or better.

Applications of the first and second laws of thermodynamics to chemical processes. Concepts of heat, work, and energy. Energy balances in batch and flow processes, with and without chemical reaction. Gas behavior, phase change, vapor pressure, humidity.

(Lecture-problems 3 hours) Letter grade only (A-F).

### UPPER DIVISION

#### 300. The Chemical Industry (3)

Prerequisite: CH E 200 with a grade of "C" or better.

Survey of industrial chemical processing techniques and the activities of engineers in this area, illustrated by field trips, speakers, professional society meetings, films, readings, etc.

(Lecture 3 hours) Letter grade only (A-F).

#### 310. Chemical Engineering Thermodynamics II (3) F

Prerequisites: CH E 210, 220 all with a grade of "C" or better.

Analysis and design of process equipment and systems using thermodynamics. Turbines, compressors, power plants, refrigeration cycles. Phase equilibria and nonideal solution behavior. Chemical reaction equilibria and heat effects.

(Lecture-problems 3 hours) Letter grade only (A-F). Not open for credit to students with credit in CHE 410.

#### 320. Fluids (3) S

Prerequisites: CH E 200, C E 205 all with a grade of "C" or better.

Study of the deformation and flow of fluids, both liquids and gases, with applications to chemical engineering.

(Lecture-problems 3 hours) Letter grade only (A-F).

#### 330. Separation Processes (4) F

Prerequisite: CHE 310 with a grade of "C" or better.

Computation methods for predicting the separation of materials by distillation, absorption, extraction and other methods.

(Lecture-problems 3 hours, lab 3 hrs) Letter grade only (A-F).

#### 400./500. Chemical Processes (3)

Prerequisite: CH E 200 or 300 all with a grade of "C" or better or consent of instructor.

In depth study of chemicals and chemical manufacturing processes and related environmental problems and energy conservation issues.

Graduate students have additional assignments. (Lecture-problem 3 hours). Letter grade only (A-F).

#### 415./515. Occupational and Environmental Safety Engineering and Management (3)

Prerequisite: CHEM 327 all with a grade of "C" or better or consent of instructor.

Safety analysis and management, legislation, regulations and standards; toxicology and personal protective equipment; fire hazards; noise control; electrical safety; container and spill management; statistical analysis. Extra requirements for graduate students.

(Lecture-problems 3 hours) Letter grade only (A-F).

#### 420. Heat and Mass Transport (3) F

Prerequisites: CHE 310, CHE 320 all with a grade of "C" or better.

Heat exchange by conduction, convection and radiation. Diffusion in fluids and solids. Simultaneous heat and mass transport.

(Lecture-problems 2 hours, lab 3 hours) Letter grade only (A-F).

### **430. Chemical Reactor Kinetics (3) F**

Prerequisites: CHEM 371A, (MATH 370A or CHE 480) all with a grade of "C" or better.  
Corequisite: CHE 420

Homogeneous and heterogeneous reactions and application to reactor design, catalysts.

(Lecture-problems 2 hours, lab 3 hours) Letter grade only (A-F).

### **431./531. Heterogeneous Catalysts (3)**

Prerequisite: CHE 430 with a grade of "C" or better or consent of instructor.

Basic principles of solid catalysts and solid catalyzed reactions. Proper choice of catalysts and how to solve catalyst-related problems in chemical engineering. Development of chemical processes that utilize innovative catalysts. Graduate students will need to do more assignments.

Letter grade only (A-F). (Lecture-problems 3 hours).

### **432./532. Microfabrication and Microfluidics Technology (3)**

Prerequisites: CHE 320, CHEM 327, (MATH 370A or CHE 480) all with a grade of "C" or better or consent of instructor.

Fundamentals of major microfabrication techniques for device construction and microfluidics technology. Topics: photolithography, wet/dry etching, metal/dielectric deposition, soft lithography, diffusion/mixing/separation in microfluidic devices, and chip-to-world interfaces. Graduate students need to do more assignments.

Letter grade only (A-F). (Lecture-problems 3 hours).

### **433./533. Green Engineering I: Alternative Energy (3)**

Prerequisites: CHE 220. CHE 330, CHE 310 all with a grade of "C" or better or consent of instructor.

Aspects of green engineering. Sustainable liquid fuels: ethanol and biodiesel from renewable sources. Photovoltaic solar devices: semiconductor- and polymer-based solar cells. Solar array collectors: power cycles to convert heat to electrical power. Hydrogen fuel cells: electrochemical cells, and proton exchange membranes. Graduate students will submit final written reports.

Letter grade only (A-F). (Lecture-Problems 3 hours).

### **437./537. Materials Purification Processes (3)**

Prerequisite: CH E 330, 420 all with a grade of "C" or better or consent of instructor.

Rate-controlled separation processes such as membrane separations, pressure swing adsorption, molecular sieve separation, supercritical fluid extraction, reverse osmosis, and spray drying.

Additional projects required for CH E 537. (Lecture-problems 3 hours) Letter grade only (A-F).

### **440. Chemical Engineering Laboratory I (2) F**

Prerequisites: CHE 320, CHE 330 all with a grade of "C" or better.

Laboratory study of fluid mechanics, separation processes and thermodynamics. Experimental design and analysis and preparation of engineering reports.

(Laboratory 6 hours) Letter grade only (A-F).

### **445./545. Pollution Prevention (3)**

Prerequisite: CH E 330 with a grade of "C" or better.

Pollution prevention strategies in chemical industry. Hierarchical approach of waste minimization. Life cycle analyses of wastes. Identification of pollution source. Environmentally compatible materials. Unit operations for minimizing waste. Economics of pollution prevention. Extra requirement for graduate students.

(Lecture-problems 3 hours) Letter grade only (A-F).

### **450. Chemical Engineering Laboratory II (2) S**

Prerequisites: CHE 420, 430, 440 all with a grade of "C" or better.  
Corequisite: CHE 460

Laboratory study of heat and mass transport, chemical kinetics and control theory. Experimental design and analysis and preparation of engineering reports.

(Laboratory 6 hours) Letter grade only (A-F).

### **455./555. Environmental Compliance (3)**

Prerequisite: CHEM 327 with a grade of "C" or better or consent of instructor.

Physical and chemical properties of hazardous materials and wastes. Environmental hazards. An examination of environmental laws, regulations and standards dealing with storage, transportation, treatment and disposal of hazardous wastes. Emergency planning and preparedness. Extra requirement for graduate students: term papers or projects.

(Lecture-problems 3 hours) Letter grade only (A-F).

### **460. Chemical Process Control (3) S**

Prerequisites: CHE 420, CHE 430, and (MATH 370A or CHE 480) all with a grade of "C" or better.

Control theory and practice, instrumentation, system responses, transfer functions, feed-back control, and stability as applied to chemical engineering processes.

(Lecture-problems 2 hours, lab 3 hours) Letter grade only (A-F).

### **465./565. Biochemical Engineering (3)**

Prerequisite: CH E 200, 330, 430 all with a grade of "C" or better and life science course(s) with instructor's approval.

Review of basic science. Kinetics of enzyme-catalyzed reactions. Kinetics of substrate utilization, product formation and biomass production. Design and analysis of bioreactors. Product recovery operations. Applications to natural systems.

Extra requirements for graduate students. (Lecture-problems 3 hrs) Letter grade only (A-F).

### **470. Chemical Engineering Design (4) S**

Prerequisites: CHE 330, 420, 430 all with a grade of "C" or better.  
Corequisite: CHE 460

Design based upon economics and chemical engineering design and analysis.

(Lecture-problems 3 hours, problem-design session 3 hrs) Letter grade only (A-F).

### **475./575. Environmental Pollution (3)**

Prerequisite: CHEM 320A or 327 all with a grade of "C" or better or consent of instructor.

Application of chemistry to the problems of pollution. Graduate students have additional assignments.

(Lecture-problem 3 hours) Letter grade only (A-F).

### **480./580. Theoretical Methods in Chemical Engineering (3)**

Prerequisites: CH E 420, 430 all with a grade of "C" or better.

Simulation and optimization of chemical engineering processes by mathematical formulation and computer modeling.

Extra requirements for graduate students: term papers or projects. (Lecture-problems 3 hours) Letter grade only (A-F).

### **481./581. Advanced Theoretical Methods in Chemical Engineering (3)**

Prerequisites: MATH 370A, CH E 480, or 580 all with a grade of "C" or better or consent of instructor.

Solutions of problems encountered in models of chemical processes: boundary value ordinary differential equations and partial differential equations.

Graduate students have additional assignments. (Lecture-problem 3 hours). Letter grade only (A-F).

### **485./585. Air Pollution (3)**

Prerequisite: CH E 475 or CE 364 all with a grade of "C" or better or consent of instructor.

Air pollution chemistry; control strategies; origin of pollutants; meteorology; vapor dispersion models; control principles for particulates, sulfur dioxide, and nitrogen oxides.

Extra requirements for graduate students: term papers or projects. (Lecture-problems 3 hrs) Letter grade only (A-F).



### **490. Special Problems (1-3)**

Prerequisite: Consent of instructor.

Assigned topics in technical literature or laboratory projects and reports on same.

Letter grade only (A-F).

## **GRADUATE LEVEL**

### **500./400. Chemical Processes (3)**

Prerequisite: CH E 200 or 300 all with a grade of "C" or better or consent of instructor.

In depth study of chemicals and chemical manufacturing processes and related environmental problems and energy conservation issues.

Graduate students have additional assignments. (Lecture-problem 3 hours). Letter grade only (A-F).

### **515./415. Occupational and Environmental Safety Engineering and Management (3)**

Prerequisite: CHEM 327 all with a grade of "C" or better or consent of instructor.

Safety engineering and management, legislation, regulations and standards; toxicology and personal protective equipment; fire hazards; noise control; electrical safety; system safety analysis; container and spill management; use of computer systems and statistical methods.

Extra requirements for graduate students: term papers or projects. (Lecture-problems 3 hours) Letter grade only (A-F).

### **520. Advanced Transport Phenomena (3)**

Prerequisites: CH E 320, 420, 430 all with a grade of "C" or better.

Application of differential and integral mass, momentum and energy balances to chemical engineering processes. Analysis of fluid flow, heat transfer, diffusion and chemical reaction in various unit operations.

(Lecture-Problems 3 hours) Letter grade only (A-F).

### **521. Advanced Mass Transfer Operations of Chemical Engineering (3)**

Prerequisite: CH E 520 with a grade of "C" or better or consent of instructor.

Fundamental laws of diffusion and diffusion with chemical reaction in traditional and unconventional mass transfer operations.

(Lecture-problem 3 hours). Letter grade only (A-F).

### **530. Advanced Reactor Kinetics (3)**

Prerequisite: CH E all with a grade of "C" or better.

Modeling of chemical reactors; effects of multiple phases, mixing, adsorption, diffusion and catalysts on reactor performance.

(Lecture-Problems 3 hrs) Letter grade only (A-F).

### **531./431. Heterogeneous Catalysts (3)**

Prerequisite: CHE 430 with a grade of "C" or better or consent of instructor.

Basic principles of solid catalysts and solid catalyzed reactions. Proper choice of catalysts and how to solve catalyst-related problems in chemical engineering. Development of chemical processes that utilize innovative catalysts. Graduate students will need to do more assignments.

Letter grade only (A-F). (Lecture-Problems 3 hours).

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Prerequisites: CHE 320, CHEM 327, MATH 370A or CHE 480 all with a grade of "C" or better or consent of instructor.

Fundamentals of major microfabrication techniques for device construction and microfluidics technology. Topics: photolithography, wet/dry etching, metal/dielectric deposition, soft lithography, diffusion/mixing/separation in microfluidic devices, and chip-to-world interfaces. Graduate students need to do more assignments.

Letter grade only (A-F). (Lecture-Problems 3 hours).

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Prerequisites: CHE 220, CHE 330, CHE 310 all with a grade of "C" or better or consent of instructor.

Aspects of green engineering. Sustainable liquid fuels: ethanol and biodiesel from renewable sources. Photovoltaic solar devices: semiconductor- and polymer-based solar cells. Solar array collectors: power cycles to convert heat to electrical power. Hydrogen fuel cells: electrochemical cells, and proton exchange membranes. Graduate students will submit final written reports.

Letter grade only (A-F). (Lecture-Problems 3 hours).

### **537./437. Materials Purification Processes (3)**

Prerequisites: CH E 330, 420 all with a grade of "C" or better. or consent of instructor.

Rate-controlled separation processes such as membrane separations, pressure swing adsorption, molecular sieve separation, supercritical fluid extraction, reverse osmosis, and spray drying.

Additional projects required for CH E 537. (Lecture-problems 3 hours) Letter grade only (A-F).

### **545./445. Pollution Prevention (3)**

Prerequisite: CH E 330 with a grade of "C" or better.

Pollution prevention strategies in chemical industry; hierarchical approach waste minimization; life cycle analyses of wastes; identification of pollution source; environmentally compatible materials; unit operations for minimizing waste; economics of pollution prevention.

Extra requirement for graduate students. (Lecture-problems 3 hours) Letter grade only (A-F).

### **555./455. Environmental Compliance (3)**

Prerequisite: CHEM 327 with a grade of "C" or better or consent of instructor.

Physical and chemical properties of hazardous materials and wastes. Environmental hazards. An examination of environmental laws, regulations and standards dealing with storage, transportation, treatment and disposal of hazardous wastes. Emergency planning and preparedness.

Extra requirement for graduate students: term papers or projects. (Lecture-problems 3 hours) Letter grade only (A-F).

### **560. Advanced Chemical Process Control (3)**

Prerequisite: One of the following: CH E 460, E E 370/L, 411, 470, 471, 511, MAE 376, E T 492 all with a grade of "C" or better or consent of instructor.

Principles and practices of controller selection and tuning, advanced control loops, model predictive control, decoupling, hands-on experience of control loop design and implementation using Labview.

(Lecture-Problems 3 hours) Letter grade only (A-F).

### **565./465. Biochemical Engineering (3)**

Prerequisites: CH E 200, 330, 430 all with a grade of "C" or better and life science course(s) with instructor's approval.

Review of basic science. Kinetics of enzyme-catalyzed reactions. Kinetics of substrate utilization, product formation and biomass production. Design and analysis of bioreactors. Product recovery operations. Applications to natural systems.

Extra requirements for graduate students. (Lecture-problems 3 hrs) Letter grade only (A-F).

### **575./475. Environmental Pollution (3)**

Prerequisite: CHEM 320A or 327 all with a grade of "C" or better or consent of instructor.

Application of chemistry to the problems of pollution. Graduate students have additional assignments.

(Lecture-problem 3 hours). Letter grade only (A-F).

**580./480. Theoretical Methods in Chemical Engineering (3)**

Prerequisites: CH E 420, 430 all with a grade of "C" or better.

Simulation and optimization of chemical engineering processes by mathematical formulation and computer modeling.

Extra requirements for graduate students: term papers or projects. (Lecture-problems 3 hours) Letter grade only (A-F).

**581./481. Advanced Theoretical Methods in Chemical Engineering (3)**

Prerequisites: MATH 370A, CH E 480, or 580 all with a grade of "C" or better or consent of instructor.

Solutions of problems encountered in models of chemical processes: boundary value ordinary differential equations and partial differential equations.

Graduate students have additional assignments. (Lecture-problem 3 hours). Letter grade only (A-F).

**585./485. Air Pollution (3)**

Prerequisite: CH E 475 or CE 364 all with a grade of "C" or better or consent of instructor.

Air pollution chemistry; control strategies; origin of pollutants; meteorology; vapor dispersion models; control principles for particulates, sulfur dioxide, and nitrogen oxides.

Extra requirement for graduate students: term papers or projects. (Lecture-problems 3 hrs) Letter grade only (A-F).

**697. Directed Research (1-3)**

Prerequisite: Graduate standing.

Individual research or intensive study under the guidance of a faculty member on theoretical or experimental problems in chemical engineering.

(Independent Study) Letter grade only (A-F).

**698. Thesis or Industrial Project (2-6)**

Prerequisite: Advancement to Candidacy.

Preparation and completion of a thesis or industrial project in chemical engineering.

May be repeated to a maximum of 6 units.