Department of Chemical and Environmental Engineering

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David C. Venerus

Associate Chair, Undergraduate Affairs:
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Paul R. Anderson

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Fouad Teymour

The mission of the Department of Chemical and Environmental Engineering is to meet the present and future needs of society and industry by providing state-of the-art education and research programs. In order to accomplish this mission, the department provides graduate students with:

- Fundamental knowledge and design capability in biological engineering, chemical engineering, gas engineering, environmental engineering, and food process engineering.
- Advanced research programs in core competency areas.
- Knowledge of industrial ecology/design for the environment
- Understanding of ethical, economic and social issues that influence intellectual technological choices.
- Leadership and communication skills.
- Lifelong learning capabilities.

Degrees Offered

Master of Biological Engineering
Master of Chemical Engineering
Master of Environmental Engineering
Master of Gas Engineering (Internet only)
Master of Science in Chemical Engineering
Master of Science in Environmental Engineering
Doctor of Philosophy in Chemical Engineering
Doctor of Philosophy in Environmental Engineering

With the National Center for Food Safety and Technology:
Master of Food Process Engineering
Master of Science in Food Process Engineering

With the Department of Electrical and Computer Engineering, and the Department of Mechanical, Materials and Aerospace Engineering:
Master of Manufacturing Engineering
Master of Science in Manufacturing Engineering

Dual-Degree Programs

Master of Science in Computer Science/Master of Chemical Engineering

Certificate Programs

Chemical Engineering Certificate Programs

Biological Engineering
Current Energy Issues (Internet only)
Food Process Engineering
Particle Processing
Pharmaceutical Engineering
Polymer Science and Engineering
Process Operations Management

Environmental Engineering Certificate Programs

Air Resources
Hazardous Waste Engineering
Indoor Air Quality
Water and Wastewater Treatment

Department of Chemical and Environmental Engineering

Interdisciplinary Programs

Energy/Environment/Economics (E^3) specialization (see page 206)

With the Stuart School of Business:
Master of Science in Environmental Management (degree is offered by the Stuart School of Business)

Research Centers

Energy + Power Center: Henry R. Linden, director

Center for Electrochemical Science and Engineering: Jai Prakash, director

Center of Excellence in Polymer Science and Engineering: Jay Schieber, director

Particle Technology and Crystallization Center: Dimitri Hatziavramidis, director

Research Facilities

Research facilities of the department include:

- Air Resource Lab
- Biochemical Engineering Lab
- Biointerfaces Lab
- Biomaterials Lab
- Center for Electrochemical Science and Engineering Lab
- Center of Excellence in Polymer Science and Engineering Lab
- Computational Fluid Dynamics Lab
- Environmental Biotechnology Lab
- Environmental Engineering Analytical Lab
- Environmental Risk Lab
- Fuel Cell Lab
- Fuel Cell Battery Lab
- Fluidization Lab
- Gas Processing Lab
- Interfacial Phenomena Lab
- Light Scattering Lab
- Multiphase Flow and Fluidization Lab
- Particle Technology Lab
- Pharmaceutical and Crystallization Lab
- Polymer Characterization Lab
- Polymer Reaction Engineering Lab
- Porous Media and Core Analysis Lab
- Process control & Optimization Lab
- Process Modeling, Monitoring and Control Lab
- Rheology Lab
- Riser Lab
- Solar Hydrogen Lab
- Solar/Photo Voltaic Lab

The computational facilities of the department include the Advanced Computer Laboratory, and the computer facilities of each research group. There are 26 Pentium-based computers in the PC lab that can access the workstations, creating a 26-seat computational lab for instructional activities at the graduate and undergraduate levels. All computers are connected to the IIT computer network by ethernet. Both the PCs and workstations access the multimedia system to provide data visualization and high-quality presentations. Each research lab also has specialized computer facilities. The computational capability for the department is provided by three servers that include both Linux and Windows. Students also have access to the university's Computing and Network Services.

Research Areas

Faculty members conduct numerous projects in the department's core areas of research competency:

- Air pollution and gas separation
- Biological, biochemical and biomedical engineering
- Chemical process modeling, statistical monitoring and control
- Computational fluid dynamics and fluidization
- Crystallization and particulate technology
- Electrochemical science and engineering
- Energy, sustainability and renewable resources
- Environmental engineering
- Food processing and safety
- Fuel cells and batteries
- Gas processing and pollution control
- Interfacial science
- Multiphase flow
- Polymer science and engineering
- Waste remediation, wastewater treatment and water resources

Department of Chemical and Environmental Engineering

Faculty

Javad Abbasian (abbasian@iit.edu), GTI Associate Professor of Chemical Engineering and Associate Chair, Undergraduate Affairs. B.S., Abadan Institute of Technology (Iran); M.S., Ph.D., Illinois Institute of Technology. Research interests: High temperature gas cleaning, pollution control and solid waste management; gas separation and purification; and process design and development.

Nader Aderangi (aderangi@iit.edu), Lecturer in Chemical Engineering and Director of Department Laboratories. B.S., University of Tehran; M.S., University of Colorado; Ph.D., Illinois Institute of Technology. Research interests: Unit operations, chemical processes, interfacial mass transfer, rheological properties.

Paul Anderson (andersonp@iit.edu), Associate Professor of Environmental Engineering and Director of Rice Campus. B.S., Purdue University; M.S., University of California, San Diego; Ph.D., University of Washington. Research interests: Physical-chemical processes in water and wastewater treatment, watershed management, industrial ecology education, biosolids mineralization, and trace element geochemistry.

Hamid Arastoopour (arastoopour@iit.edu), Max McGraw Professor of Energy, Environment and Economics and Dean, Armour College of Engineering. B.S., Abadan Institute of Technology (Iran); M.S., Ph.D., Illinois Institute of Technology. Research interests: Computational fluid dynamics (CFD) of multiphase flow, fluidization, flow in porous media, particle technology and material processing, and environmental engineering problems.

Barry Bernstein (bersteinb@iit.edu), Professor of Chemical Engineering and Applied Mathematics. B.S., City College of New York; M.A., Ph.D., Indiana University. Research interests: Computational fluid mechanics, materials properties, and polymer rheology.

Donald J. Chmielewski (chmielewski@iit.edu), Associate Professor of Chemical and Environmental Engineering. B.S., Illinois Institute of Technology; M.S., Ph.D., University of California–Los Angeles. Research interests: Advanced process control; fuel cell system design and control.

Ali Cinar (cinar@iit.edu), Professor of Chemical Engineering, Dean of the Graduate College and Associate Vice President for Research. B.S., Robert College (Turkey); M.S., Ph.D., Texas A&M. Research interests: Fundamental methodology and tools used in various applications including: polymer reaction engineering, food processing, medicine and biotechnology.

David Gidalevitz (gidalevitz@iit.edu), Assistant Professor of Chemical Engineering. B.S., Urals Technical University (Russia); Ph.D., Weizmann Institute of Science (Israel). Research interests: Membrane biophysics, biomaterials, drug delivery, biosensors and biomimetic thin films, and polymer films.

Dimitri Gidaspow (gidaspow@iit.edu), IIT Distinguished Professor of Chemical Engineering. B.S., City College of New York; M.S., Polytechnic Institute of Brooklyn; Ph.D., Illinois Institute of Technology. Research interests: Hydrodynamic theories of fluidization and multiphase flow, gas-solid transport, and hydrodynamic models for slurry bubble column reactors.

Henry Linden (linden@iit.edu), Max McGraw Professor of Energy, Power Engineering and Management and Director, IIT Energy + Power Center. B.S., Georgia Institute of Technology; M.Ch.E., Polytechnic Institute of Brooklyn; Ph.D., Illinois Institute of Technology. Research interests: Fossil fuel technologies, energy and resource economics, energy and environmental policy, electrification and distributed generation, global climate change, and industrial ecology.

Demetrios J. Moschandreas (moschandreas@iit.edu), Professor of Environmental Engineering. B.S. Stetson University; M.S., University of Kentucky; M.S. Ph.D., University of Cincinnati. Research interests: Air quality transport, exposure analysis, risk assessment, indoor air quality, Environmental Index theory and application, sustainable environmental development.

Allan S. Myerson (myerson@iit.edu), Armour Professor of Chemical Engineering, and Provost and Senior Vice President. B.S., Columbia University; M.S. and Ph.D., University of Virginia. Research interests: Crystallization from solution, and nucleation molecular modeling.

Kenneth E. Noll (noll@iit.edu), Professor of Environmental Engineering. B.S., Michigan Technical University; M.S., Ph.D., University of Washington. Research interests: Design of air pollution control devices, study of atmospheric aerosols, VOC emissions from wastewater treatment plants, and physical and chemical changes and fates of toxic air.

Krishna Pagilla (pagilla@iit.edu), Associate Professor of Environmental Engineering. B.E., Osmania University (India); M.S., University of Oklahoma, Norman; Ph.D., University of California, Berkeley. Research interests: Water and wastewater engineering, environmental microbiology, biological nutrient control, soil remediation, and sludge treatment.

Satish Parulekar (parulekar@iit.edu), Professor of Chemical Engineering. B.S., University of Bombay; M.S., University of Pittsburgh; Ph.D., Purdue University. Research interests: Biochemical engineering and chemical reaction engineering.

Victor H. Pérez-Luna (perezluna@iit.edu), Associate Professor of Chemical Engineering. B.S., M.S. Universidad de Guadalajara (Mexico); Ph.D., University of Washington. Research interests: Surface analysis and modification, biomaterials and biosensors, and tissue engineering

Jai Prakash (prakash@iit.edu), Professor of Chemical Engineering and Director, Center for Electrochemical Science and Engineering. B.S., M.S., Ph.D., University of Delhi; Ph.D., Case Western Reserve University. Research interests: Electrochemistry, materials development, and batteries and fuel cells.

Faculty continued

Vijay K. Ramani (ramani@iit.edu) Assistant Professor of Chemical Engineering. B.E. Annamalai University (India); Ph.D., University of Connecticut. Research interests: Hybrid materials for sustainable chemical and electrochemical energy conversion, hydrogen and liquid fueled polymer electrolyte fuel cells (PEFCs), degradation mitigation strategies in PEFCs, and development of educational modules to demonstrate sustainable energy economy concepts.

Jay D. Schieber (schieber@iit.edu), Professor of Chemical Engineering and Director, Center of Excellence in Polymer Science and Engineering. B.S., University of Illinois-Urbana; Ph.D., University of Wisconsin, Madison. Research interests: Kinetic theory, polymer rheology predictions, and thermal conductivity measurements.

Fouad A. Teymour (teymour@iit.edu), Johnson Polymer Professor of Chemical Engineering and Chairman. B.S., M.S., Cairo University; Ph.D., University of Wisconsin-Madison. Research interests: Polymer reaction engineering, mathematical modeling, nonlinear dynamics, and complexity and complex systems.

David C. Venerus (venerus@iit.edu), Professor of Chemical Engineering and Associate Chair, Graduate Affairs. B.S., University of Rhode Island; M.S., Ph.D., Pennsylvania State University. Research interests: Transport phenomena in complex materials, Forced Rayleigh Scattering, polymer rheology, and polymer foam processing.

Darsh T. Wasan (wasan@iit.edu), Motorola Chair Professor of Chemical Engineering and Vice President of International Affairs. B.S., University of Illinois, Urbana-Champaign; Ph.D., University of California, Berkeley. Research interests: Thin liquid films, foams, emulsions and nano-particle suspensions, film rheology and applications, wetting, spreading and adhesion of nano-fluids on solid surfaces, environmental technologies, food colloids.

Research Faculty

Said Al-Hallaj (alhallaj@iit.edu), Research Associate Professor of Chemical Engineering and Coordinator, Renewable Energy Programs. B.S., M.S., University of Science and Technology (Jordan); Ph.D., Illinois Institute of Technology. Research interests: Hydrogen storage and production, renewable energy systems, water desalination, advanced batteries and fuel cell systems for hybrid/electric vehicles, electrochemical engineering and technology, distributed power generation systems, energy, environment and economics and renewable energy, heat and mass transfer, and thermodynamics of chemical processes, thermal modeling and scale-up design, and unit operation and system integration.

Dimitri T. Hatziavramidis (hatziavramidis@iit.edu), Research Professor and Director of the Particle Technology and Crystallization Center. B.S., National Technical University of Athens; M.S., University of Manchester; Ph.D., University of Illinois at Urbana-Champaign. Research interests: Drug delivery, fluid and thermal sciences' molecular simulations, pharmaceutical technology.

George K. Ivanov (ivanovg@iit.edu), Research Professor of Chemical Engineering. B.S., M.S., Ph.D., University of Chemical Technology and Metallurgy (Bulgaria). Research interests: Thermoplastic and thermoset resins; polymer composites, alloys and blends; plastics pulverization and recycling.

Zoltan Nagy, (nagy@iit.edu) Research Professor of Chemical Engineering. Dipl. Ch.E., Technical University of Veszprem (Hungary); Ph.D., University of Pennsylvania. Research interests: Electrochemistry.

Alex Nikolov (nikolov@iit.edu) Research Professor of Chemical Engineering. B.S., Ph.D., University of Sofia (Bulgaria). Research interests: Interfacial rheology, foams, emulsion, dispersion, and thin liquid films.

Bert Plomp (l.plomp@ecn.nl) Research Professor of Chemical Engineering and Project Manager Supercapacitors, Energy Research Centre of the Netherlands ECN. Ing. Electrical Engineering and Information Technology, Ir. Applied Physics Delft University of Technology (Netherlands); Dr. Physical Chemistry, Free University of Amsterdam (Netherlands) Research interests: Fuel cells and supercapacitors.

Giselle Sandi (sandi@iit.edu), Research Associate Professor of Chemical Engineering. B.S., M.S., University of Costa Rica (Costa Rica); Ph.D., Northern Illinois University. Research interests: Electrochemistry, nanocomposite materials, and polymer electrolytes.

J. Robert Selman (selman@iit.edu), IIT Distinguished Research Professor of Chemical Engineering. Ing., Technical University (Netherlands); M.S., University of Wisconsin-Madison; Ph.D., University of California, Berkeley. Research interests: Fuel cell and battery design and operation; high-temperature fuel cells; lithium battery design and thermal management.

Adjunct Faculty

Michael Caracotsios, Ph.D., University of Wisconsin, Madison.

Ted Knowlton, Ph.D Iowa State University

Harold Lindahl, Ph.D., Illinois Institute of Technology.

Admission Requirements

Cumulative Undergraduate GPA: 3.0/4.0
GRE score minimum:
For tests taken prior to Oct.1, 2002,
M.S./MAS/Ph.D.:1200 (combined)
For tests taken on or after Oct.1, 2002, M.S./MAS: 900 (quantitative + verbal), 2.5 (analytical writing)
For tests taken on or after Oct.1, 2002, Ph.D.: 1000 (quantitative + verbal), 3.0 (analytical writing)
TOEFL minimum score: 550/213*

Note: The GRE requirement is waived for Professional Master's degree applicants who hold a Bachelor of Science in a related field from an ABET-accredited university in the United States, with a minimum cumulative GPA of 3.0/4.0

Certificate program applicants must possess a bachelor's degree with a minimum cumulative GPA of 2.5 on a 4.0 scale. The GRE is not required.

Meeting the minimum GPA and test score requirements does not guarantee admission. Test scores and GPA are just two of several important factors considered.

Admission to graduate study in chemical engineering, biological engineering, or gas engineering requires the completion of a program leading to a bachelor's degree in chemical engineering or another engineering discipline from an accredited institution. Students with degrees in related fields must remove deficiencies or must show proof of proficiency in the required undergraduate material before entering the graduate program. Students with a B.S. degree in science are required to take up to four engineering deficiency courses. Admission to the graduate degree program in biological engineering requires one college-level semester of biology. Students not meeting this requirement may be admitted, but will have to take CHE 412 to remove the deficiency.

Admission to graduate degree programs in environmental engineering requires a bachelor degree in an appropriate undergraduate field, awarded by an educational institution of recognized standing. In addition, proof of high-quality academic ability in the applicant s undergraduate program must be provided. Prerequisites for the program vary; however, it is expected that all applicants will have had one year each of calculus and chemistry. Qualified applicants with degrees in the life sciences, engineering and the physical sciences will normally be admitted to the program without extensive prerequisites.

Admission to graduate degree programs in food process engineering normally requires a bachelor's degree in chemistry; biology; food science; chemical, agricultural, food or environmental engineering; or a related field. Depending on the student's background, additional deficiency courses, some of which may not count toward the degree, may be required.

* Paper-based test score/computer-based test score.

Master of Biological Engineering

30 credit hours
No Thesis Requirement

The objective of this degree program is to prepare students for professional practice in any field of engineering involving heavy emphasis on biological processes, and to provide a foundation in the fundamental knowledge of biological engineering. Candidates are required to take a total of 30 credits, 9 credits for core courses, 7 credits of required biology courses, 2 credits of a required professional course, and 12 credits of electives chosen from the list below.

Core courses:

CHE 406	Transport Phenomena
CHE 503	Thermodynamics
CHE 577	Bioprocess Engineering

Biology requirement:

BIOL 504	Biochemistry Lectures
BIOL 515	Molecular Biology (after completing BIOL 504)

Professional requirement:

CHE 506	Entrepreneurship and Intellectual Property Management

Electives

BME 533	Biostatistics
BME 570	Engineering Biocompatible Materials
CHE 552	Bionanotechnology and Interfacial Phenomena
CHE 514	Process Analytical Technology
CHE 519	Biosensors
CHE 533	Statistical Analysis of Systems
CHE 545	Metabolic Engineering
CHE 573	Bioseparations
CHE 580	Biomaterials
CHE 583	Pharmaceutical Engineering
CHE 584	Tissue Engineering/BME 525: Concepts of Tissue Engineering
CHE 585	Drug Delivery
CHE 597	Research Project
ENVE 513	Biotechnological Processes in Environmental Engineering

Any 500 level Food Process Engineering course

Other approved electives from CHE, CHEM, BME, BIOL

Master of Chemical Engineering

30 credit hours
No Thesis Requirement
Project option

The objective of this degree program is to prepare students for professional practice in the field of chemical engineering, and to provide a foundation in the fundamental knowledge of chemical engineering. Candidates are required to take a total of 30 credits, 12 credits for core courses, 2 credits of a required professional course, and 16 credits of electives.

Core courses:

CHE 406	Transport Phenomena
CHE 503	Thermodynamics
CHE 525	Chemical Reaction Engineering*

AND one of the following:

CHE 535	Applications of Mathematics to Engineering or
CHE 530	Advanced Process Control

*Note: Interested students can substitute, upon advisor consent, CHE 577: Bioprocess Engineering for CHE 525: Chemical Reaction Engineering.

Professional requirement:

CHE 506	Intellectual Property Management and Entrepreneurship

Master of Environmental Engineering

Master of Food Process Engineering

32 credit hours
Project option

The objective of these degree programs is to prepare students for professional practice in their major discipline (environmental or food process engineering) and to provide a foundation in the fundamental knowledge of their major. The requirements are the same as those for the M.S. degree, with the following exceptions:

At least 18 credit hours must be taken in 500-level courses in the student's chosen program (environmental engineering, food process engineering), and the thesis work should be replaced by six to eight hours of coursework or a project.

The student may choose courses in any of the areas of specialization listed on page 117 for the M.S. programs. Undergraduate courses may sometimes be used to fulfill graduate program requirements in order to overcome deficiencies or to broaden the candidate's background. The limit is 12 credit hours in courses numbered 400—499.

Students in Master of Food Process Engineering are strongly encouraged to do an independent project for up to four credit hours.

Master of Gas Engineering (Internet only)

30 credit hours
No Thesis Requirement

The Online Professional Master's Degree Program in Gas Engineering is a joint program offered by Illinois Institute of Technology (IIT) and Gas Technology Institute (GTI). The objective of this degree program is to enable the student to build a strong foundation in the fundamentals of gas engineering, energy engineering, and related environmental and economic issues. Applicants to the program should hold an engineering degree (preferably in chemical or mechanical engineering), or a bachelor's degree in science (such as environmental science, physics or chemistry). Students with a science degree must take the following bridging courses or demonstrate proficiency in each of these areas:

- Material and Energy Balances (CHE 202)
- Fluid Mechanics and Heat Transfer Operations (CHE 301)
- Mass-Transfer Operations (CHE 302)
- Chemical Engineering Thermodynamics (CHE 351)

All departmental minimum admission requirements must be met.

Candidates are required to take a total of 30 credit hours, 3 core courses are required, and 7 courses may be chosen from the 11 electives listed below. All courses are administered online.

Core Courses

CHE 406	Transport Phenomena
CHE 505	Fluid Properties
CHE 543	Energy, Environment, and Economics

Electives

CHE 426	Statistical Tools for Engineers
CHE 481	Flow-Through Porous Media and Fundamentals of Reservoir Engineering
CHE 489	Fluidization
CHE 515	Natural Gas Processing
CHE 516	Gas Transmission and Distribution
CHE 517	Gas Utilization Technologies and Economics
CHE 520	LNG Fundamentals and Technologies
CHE 522	Fundamentals of Combustion
CHE 541	Renewable Energy Technologies
CHE 565	Electrochemical Engineering
ENVE 578	Physical and Chemical Processes for Industrial Gas Cleaning

Master of Science in Chemical Engineering

32 credit hours
Thesis

The objective of this degree program is to enable the student to build a strong foundation in multiple areas of chemical engineering and to specialize in one area via research and thesis. Candidates are required to take a total of 32 credit hours, 12 credits of which must be for the chemical engineering core courses listed below, and six to eight credit hours must be in research and thesis work.

Core courses

CHE 525	Chemical Reaction Engineering
CHE 535	Applications of Mathematics to Engineering
CHE 551	Advanced Transport Phenomena
CHE 553	Advanced Thermodynamics

The student must have a minimum grade point average of 3.0/4.0 in the core areas. Aside from the core courses, coursework may be selected (with advisor approval) to satisfy the needs of the individual student or may be concentrated in any area of specialization available in the department, including:

Biological Engineering
Electrochemical Science and Engineering
Energy/Environment/Economics (E3)
Environmental Engineering
Food Process Engineering
Particle Technology and Multiphase Flow
Pharmaceutical Engineering
Polymer Science and Engineering
Process Design, Statistical Modeling and Control

Undergraduate courses may sometimes be used to fulfill graduate program requirements in order to overcome deficiencies or to broaden the candidate s background. The limit is 12 credit hours in courses numbered 400—499. A thesis may be completed outside the department only by special arrangement with the department chair. The successful M.S. degree candidate will complete a thesis based on research as well as an oral defense of the thesis, under the direction of the thesis examining committee.

Master of Science in Environmental Engineering

32 credit hours
Thesis

The objective of this program is to enable the student to build a strong foundation in multiple areas of environmental engineering and to specialize in one area via research and thesis. Candidates are required to take a total of 32 credit hours, 15 credits of which must be for the environmental engineering core courses listed below, and six to eight credit hours must be in research and thesis work.

Core courses

ENVE 426*	Statistical Tools for Engineers
ENVE 501	Environmental Chemistry
ENVE 506	Chemodynamics
ENVE 542	Physicochemical Processes in Environmental Engineering
ENVE 580	Hazardous Waste Engineering

* Students with background in statistics (before joining the graduate program) equivalent to ENVE 426 will be required to take ENVE 527 as a core course (in place of ENVE 426). Students should consult the course descriptions on page 127 for details.

The student must have a minimum grade point average of 3.0/4.0 in the core areas. Aside from the core courses, coursework may be selected (with adviser approval) to satisfy the needs of the individual student or may be concentrated in one of the areas of specialization available in the department, including:

Air Pollution Engineering
Chemical Engineering
Energy/Environment/Economics (E^3)
Environmental Chemistry
Environmental Resource Management
Hazardous Waste Engineering
Water and Wastewater Engineering

Undergraduate courses may sometimes be used to fulfill graduate program requirements. The limit is six credit hours in courses numbered 400—499. A thesis may be completed outside the department only by special arrangement with the department chair. The successful M.S. degree candidate will complete a thesis based on research as well as an oral defense of the thesis, under the direction of the thesis examining committee.

Master of Science in Food Process Engineering

32 credit hours
Thesis

The objective of this program is to educate engineers and scientists in different aspects of food engineering and food processing with specialization in an area of food process engineering. Candidates are required to take a total of 32 credit hours, 12 credits of which must be for the core courses listed below, and six to eight credit hours must be in research and thesis work.

Core Courses

Choose 4 of the following:

FPE 505	Food Microbiology
FPE 521	Food Process Engineering
FPE 522	Advanced Food Process Engineering
FPE 524	Fundamentals of Food Science and Technology (For students with non-food science background)
FPE 541	Principles of Food Packaging

Proficiency Requirement

These courses may be required if the student has not taken an equivalent course at the undergraduate level:

CHE 406	Transport Phenomena
CHE 423	Chemical Reaction Engineering
CHE 435	Process Control

The student must have a minimum grade point average of 3.0/4.0 in the core areas. In addition to the core courses, coursework may be selected (with adviser approval) to satisfy the needs of the individual student or may be concentrated in one of the following areas of specialization:

Process and product development
Food processing operations
Packaging
Food Safety
Food Biotechnology
Process and quality monitoring and control
Required courses for these specializations are described on page 130.

Electives

Students must take at least two courses from the following group of food process engineering courses:

FPE 504	Food Biotechnology
FPE 506	Food Microbiology Laboratory
FPE 507	Food Analysis
FPE 511	Food Law and Regulation
FPE 531	HACCP Planning and Implementation

Students must take at least two courses from the following group of chemical and environmental engineering courses:

CHE 439	Numerical Analysis
CHE 494	Chemical Process Design
CHE 560	Statistical Quality and Process Control
CHE 573	Bioseparations
CHE 577	Bioprocess Engineering
CHE 579	Enzyme Reactor Engineering
CHE 761	Statistical Design of Experiments for Process Improvement
CHE 771	Applications of Enzymes and Microbes in Food Processing
ENVE 513	Biotechnological Processes in Wastewater Treatment
ENVE 542	Environmental Unit Processes

A thesis may be completed outside the department only by special arrangement with the department chair. The final examination is normally oral, but may be written at the discretion of the thesis examining committee.

Master of Science in Computer Science/Master of Chemical Engineering

44 credit hours
No thesis requirement

The objective of the program is to educate, and prepare for professional practice, process engineers with broad based knowledge of chemical engineering and computer science fundamentals, and computer scientists with strong engineering fundamentals. Candidates are required to take 18 credit hours in graduate chemical engineering courses (courses numbered 500 or higher) and 26 credit hours in computer science courses (of which 20 credit hours must be in courses numbered 500 or higher). The 18 credit hours in chemical engineering courses consist of 12 credit hours in core courses listed in the description of the Master of Science in Chemical Engineering requirements and six credit hours from the following courses:

CHE 507	Computer-Aided Design
CHE 508	Process Design and Optimization
CHE 528	Analysis and Simulation of Chemical Processing
CHE 532	Process Modeling
CHE 533	Statistical Analysis of Systems
CHE 536	Computational Techniques in Engineering
CHE 560	Statistical Quality and Process Control

Students should refer to the Department of Computer Science section (page 148) for details on computer science course requirements for the dual degree.

Doctor of Philosophy

84 credit hours
Qualifying exam
Comprehensive exam
Thesis proposal
Dissertation and oral defense

The doctorate degree in chemical/environmental engineering is awarded in recognition of mastery in chemical/environmental engineering and upon demonstration of an ability to make substantial creative contributions to knowledge in chemical/environmental engineering. The recipients of these degrees will be capable of a continuing effort toward advancement of knowledge and achievement in research while pursuing an academic or industrial research career. The program should satisfy the following requirements: chemical engineering or environmental engineering study, 30—40 percent; research, 40—50 percent; other fields of study, 10—30 percent. The coursework must include up to 18 credits of core chemical or environmental engineering courses.

For the Ph.D. in Chemical Engineering, students must take the following core courses:

CHE 551	Advanced Transport Phenomena
CHE 553	Advanced Thermodynamics
CHE 525	Chemical Reaction Engineering
CHE 535	Applications of Mathematics to Engineering
CHE 530	Advanced Process Control or CHE 536 Computational Techniques in Engineering

For the Ph.D. in Environmental Engineering, in addition to the core courses listed in Master of Science in Environmental Engineering, students must take:

ENVE 527	Statistical Analysis of Systems

Students should consult the Transfer Credits section for rules on how many credit hours may be transferred from another institution.

Students must pass a written qualifying examination within three semesters after they have been admitted to the Ph.D. program. The exam is diagnostic in nature, and the results of the exam will determine the student's potential for success in the Ph.D. program and recommendations for a future program of study. The examination in the chemical engineering program will cover all core areas, including thermodynamics, reaction engineering and kinetics, transport phenomena, process modeling, design and control, and applied mathematics. The examination in the environmental engineering program will cover core areas, including environmental chemistry, chemodynamics, environmental systems and analysis, and physicochemical processes.

The comprehensive examination is oral and may include a written exam based on the student's performance on the qualifying exam. The exam questions will be formulated by the members of the Ph.D. examining committee. The examination will also include oral presentation and discussion by the student of a journal article in the student's major (chemical/environmental engineering) selected a priori by the examining committee. The exam must be conducted within a year following completion of the qualifying exam. The Ph.D. examining committee, which may be the same as the Ph.D. thesis committee, should be suggested by the adviser and approved and appointed by the chairperson at least three weeks prior to the examination.

The thesis proposal approval examination, which is diagnostic in nature, should be conducted after the comprehensive exam and at least one year before the final thesis defense. The exam will be oral and will be administered by the Ph.D. thesis committee.

Doctoral research can begin after admission to the Ph.D. program. However, the major portion of the research should not be started until the comprehensive examination is passed and the thesis proposal is approved by the committee. All research must be conducted under the supervision of a full-time department faculty member and in the laboratories of the university. Off-campus research is possible with the approval of the department chairperson. The preliminary thesis draft must meet the approval of all members of the examination committee. An oral examination in defense of the thesis is given as an open university seminar. The thesis defense must meet with the approval of the examination committee; if it does not, the committee has the authority to determine whether or not to grant a re-examination.

Certificate Programs

The department offers 11 graduate certificate programs, with one available only via the Internet. These programs provide students with post-baccalaureate knowledge of an area of specialization within chemical or environmental engineering. Students in these programs register as certificate students.

Certificate programs typically require a set of three to four courses that must be completed in three years with a minimum GPA of 3.0/4.0. (Note: Some courses may have prerequisites.) Students who are admitted to master's degree programs may apply coursework previously taken in a certificate program toward the requirements for the master's degree.

Biological Engineering

This program provides an introduction to the field of biological engineering and its application in biological, biomedical and environmental processes. Students must complete four courses (12 credits) to receive the certificate.

Required course

CHE 577 Bioprocess Engineering

AND at least three courses from the elective courses listed under the Master of Biological Engineering.

Current Energy Issues (Internet only)

This program explores issues related to the establishment of sustainable energy systems including energy/environment/economics, renewable energy, batteries and fuel cells. Students must complete 3 of the following 4 courses (9 credits) to receive the certificate.

Required Courses

At least three from the following:

CHE 517	Energy Utilization Technologies and Economics
CHE 541	Renewable Energy Technologies
CHE 543	Energy, Environment and Economics
CHE 565	Electrochemical Engineering

Food Process Engineering

This program provides an introduction to the field of food engineering with applications of chemical engineering to food manufacturing and food safety. Students must complete four courses (12 credits) to receive the certificate.

Required courses

Two from the following:

CHE 406	Transport Phenomena (Prerequisite: CHE 302)
CHE 518	Mass-Transfer (Prerequisite: CHE 302)
CHE 577	Bioprocess Engineering
CHE 584	Tissue Engineering
FPE 521	Food Process Engineering
FPE 522	Advanced Food Process Engineering

AND two courses from the following group:

FPE 504	Food Biotechnology
FPE 505	Food Microbiology
FPE 506	Food Microbiology Laboratory
FPE 507	Food Analysis
FPE 511	Food Law and Regulation
FPE 524	Fundamentals of Food Science and Technology (For students with non-food science background)
FPE 531	HACCP Planning and Implementation
FPE 541	Principles of Food Packaging

Particle Processing

This program provides an introduction to the field of particle processing, specifically in fluidization and fluid/particle systems. Fundamentals of fluid/particle system design, computational multiphase approach to gas/particle systems and advanced measurement techniques are presented. Students must complete three courses (nine credits) to receive a certificate.

Required courses

At least one of the following courses:

CHE 542	Fluidization and Fluid/Particle Flow Systems
CHE 489	Design of Fluidized Beds and Fluid/Particle Systems

AND one/two of the following courses:

CHE 587	Particle Processing and Characterization
CHE 486	Applied Particle Technology
CHE 582	Interfacial Colloidal Phenomena
CHE 586	Particle Technology

Pharmaceutical Engineering

This program develops, expands and refines skills to advance the technology of prescription drug development and manufacturing. Fundamentals of pharmaceutical engineering, drug delivery systems and regulatory issues are presented. Students must complete four courses (12 credits) to receive a certificate.

Required courses

The following three courses:

CHE 583	Pharmaceutical Engineering
CHE 585	Drug Delivery Systems
CHE 511	Regulatory Issues in Pharmaceutical Processes

AND one of the following:

CHE 514	Process Analytical Technology
CHE 560	Statistical Quality and Process Control

Department of Chemical and Environmental Engineering

Polymer Science and Engineering

This program introduces fundamentals of polymerization and polymer synthesis, polymer kinetics, polymer processing and characterizations. Students must take four courses (12 credits) to receive the certificate.

Required course

CHE 470 Introduction to Polymer Science and Engineering (Prerequisite for all other courses in this certificate program.)

AND any three of the following courses:

CHEM 535 Advanced Polymer Chemistry
CHE 538 Polymerization Reaction Engineering
CHEM 542/
MMAE 579 Characterization of Polymers
CHE 555 Polymer Processing (Prerequisite: CHE 406)

Process Operations Management

This program introduces methodology and tools to improve the technical management of process operations including process modeling, simulation, monitoring, control and optimization. Students must take four courses (12 credits) to receive the certificate.

Required courses

At least one course from each of the following groups:

I

CHE 426 Statistical Tools for Engineers
CHE 533 Statistical Analysis of Systems
CHE 560 Statistical Quality and Process Control
CHE 761 Statistical Design of Experiments for Process Improvement

II

CHE 435 Process Control
CHE 437 Discrete Time Systems and Computer Control
CHE 530 Advanced Process Control (Prerequisite: CHE 435, CHE 437 or equivalent)

III

CHE 431 Artificial Intelligence Applications in Engineering
CHE 508 Process Design Optimization
CHE 528 Analysis and Simulation of Chemical Processing
CHE 532 Process Modeling

Environmental Engineering Certificate Programs

Air Resources

This program explores outdoor air quality, causes of outdoor air pollution, and investigative and diagnostic techniques used in outdoor air quality control. Students must take three courses (nine credits) to complete the certificate.

Required courses

ENVE 570 Air Pollution Meteorology
AND two courses from the following group:
ENVE 502 Atmospheric Chemistry
ENVE 572 Ambient Air Monitoring
ENVE 575 Control of Toxic Air Pollution
ENVE 577 Design of Air Pollution Control Devices
ENVE 578 Physical and Chemical Processes for Industrial Gas Cleaning

Hazardous Waste Engineering

This program is an introduction to the characterization of hazardous waste sites, common and innovative remediation techniques, and current issues in hazardous waste engineering. Students must take three courses (nine credits) to complete the certificate.

Required courses

ENVE 580 Hazardous Waste Engineering
AND two of the following courses:
ENVE 506 Chemodynamics
ENVE 542 Physicochemical Processes in Environmental Engineering
ENVE 577 Design of Air Pollution Control Devices
ENVE 585 Groundwater Contamination

Department of Chemical and Environmental Engineering

Indoor Air Quality

This program covers sick building syndrome, the causes of indoor air pollution, and investigative and diagnostic techniques used in controlling indoor air quality. Students must take three courses (nine credits) to complete the certificate.

Required courses

ENVE 546 Industrial Hygiene
ENVE 576 Indoor Air Pollution
AND one of the following courses:
ENVE 426 Statistical Tools for Engineers OR
ENVE 527 Statistical Analysis of Systems
ENVE 575 Control of Toxic Air Pollution
MAE 452 Air Conditioning and Refrigeration
BIOL 514 Toxicology

Waste and Wastewater Treatment

This program is an introduction to the biological and physical/chemical processes used in water and wastewater treatment, and the design of water and wastewater treatment processes. Students must take three courses (nine credits) to complete the certificate.

Required courses

ENVE 513 Biotechnological Processes in Environmental Engineering
ENVE 542 Physicochemical Processes in Environmental Engineering
AND one of the following courses:
ENVE 551 Industrial Waste Treatment
ENVE 555 Industrial Waste Treatment Design Criteria
ENVE 561 Design of Sanitary Engineering Processes

Course Descriptions

Numbers in parentheses respectively indicate class, lab and credit hours. Note: Core courses are available once per year. Other courses may be offered less frequently.

Chemical Engineering

CHE 503
Thermodynamics
Laws of thermodynamics applied to chemical and biological engineering problems, properties of real fluids, phase and chemical equilibria, applications to chemical and biological process and auxiliary equipment. Core course. Prerequisites: CHE 351, CHE 451. (3-0-3)

CHE 505
Fluid Properties
Prediction and correlation of physical and transport properties using equations of state, thermodynamic relationships, phase and chemical equilibrium. (3-0-3)

CHE 506
Entrepreneurship and Intellectual Property Management
This course aims to introduce and develop a number of diversified professional skills necessary for success in an engineering research and development environment. Selected topics covered in the areas of technology entrepreneurship, opportunity assessment, creativity and innovation, project management, management of organizational change, entrepreneurial leadership, and intellectual property management. Prerequisite: Graduate standing or consent of the instructor. (2-0-2)

CHE 507
Computer-Aided Design
Computer process simulation to develop technically and economically optimum overall process designs. Simulation framework includes unit operation computations, physical property determinations, Newton-Raphson convergence procedures and simulation language. Prerequisite: CHE 494. (3-0-3)

CHE 508
Process Design Optimization
Organization of the design problem and application of single and multi-variable search techniques using both analytical and numerical methods. Prerequisite: CHE 494. (3-0-3)

CHE 509
Advanced Topics in Reactor Engineering
Selected topics based on current research interests of the instructor. Typical examples are reactor stability analysis, diffusional effects in heterogeneous catalysis, catalyst and enzyme deactivation analysis, immobilized enzyme reaction systems, liquid-liquid or gas-liquid dispersed phase reactors, biological reactors for wastewater treatment, photochemical reactors, polymerization reactors and crystallization dynamics. Prerequisite: CHE 525 or instructor approval. (3-0-3)

CHE 510
Fluid Dynamics
Cross listed with MMAE 510
Kinematics of fluid motion. Derivation of equations of motion and Navier-Stokes equations. Exact and approximate solution techniques. Boundary layer theory. Introduction to stability and turbulence. Prerequisite: CHE 406 (3-0-3)

CHE 511
Regulatory Issues in Pharmaceutical Processes
Legal and scientific issues in regulating the pharmaceutical and healthcare industrial sectors. Role of regulatory agencies; FDA and the Center for Drug Evaluation and Research. Definitions and standards: laws, regulations, policies, procedures. Manufacturing pharmaceutical drugs, devices, and components in compliance with regulations. (3-0-3) Prerequisite: Graduate standing or consent of the instructor. (3-0-3)

CHE 512
Heat Transfer
A survey course in conduction, convection and radiation. Problems in condensation and convection are solved with the use of fundamental laws of fluid dynamics. Finite difference and algebraic solutions for unsteady-state and heat-regenerator problems are covered. Prerequisite: CHE 406. (3-0-3)

CHE 514
Process Analytical Technology
Provides an introduction to Process Analytical Technology (PAT) as a framework to enhance process understanding and assist in the development of reliable yet efficient pharmaceutical operations. The course is divided into four sections. Definition of critical performance attributes within the context of FDA regulations. Overview of analytic measurement methods, including at/in- or on-line measurement of chemical, physical and microbiological quantities. Mathematical description of common data analysis and chemometric methods, including statistical process monitoring, multivariate analysis and parameter estimation. Design of real-time decision systems, including feedback control of operations and risk-based analysis of final product quality (real-time release). Prerequisite: BS in engineering or equivalent. (3-0-3)

CHE 515
Natural Gas Processing
Application of engineering principles to natural gas separation processes, including multi-stage separation, solvent extraction, adsorption, membrane separation, and supercritical extraction. Design and economic analysis of various gas treating processes such as natural gas dehydration, sweetening, and LNG processes, using commercially available process simulators. Prerequisite: CHE 505. (3-0-3)

CHE 516
Gas Transmission and Distribution
Fundamentals of the subsonic compressible flow, flow in gas transmission distribution systems, gas measurement, storage and compression. Gas/liquid two-phase flow fundamentals. Gas transmission and distribution in pipeline network using commercially available process simulators. Prerequisite: CHE 406. (3-0-3)

CHE 517
Gas Utilization Technologies and Economics
Gas and electric energy markets structure, costs and load profiles; Concepts, benefits, and applications of gas for power generation, and integrated energy systems for combined cooling, heating and power (CHP); Power generation technologies of engines, turbines, microturbines, and fuel cells; Thermally-activated technologies, of absorption chillers, desiccant dehumidifiers, and steam turbines; Economics; Case studies; Software tools. Prerequisite: CHE 406. (3-0-3)

CHE 518
Mass Transfer
Principles of diffusion, both steady and unsteady state, as applied to heat transfer, gas absorption, distillation, drying and extraction. Prerequisite: CHE 406. (3-0-3)

CHE 519
Biosensors
Engineering Principles used for the detection of biomolecules and cells in the context of biomedical, environmental, biochemical process applications. Immobilization of biological receptors for interfacing biomolecules with a transducer. Specific and non-specific interactions with surfaces. Transduction mechanisms for signal detection. Signal analyte and multiple analyte detection. Nanotechnology and biosensors. (3-0-3)

CHE 520
LNG Fundamentals and Technologies
Properties and phase equilibria of Natural Gas liquid and gas mixtures at low temperatures. Thermodynamic analysis and design of natural gas liquefaction processes. Recent advances in LNG processing, storage and transportation. Prerequisites: CHE 505 (3-0-3)

CHE 522
Fundamentals of Combustion
Fundamentals of Combustion Thermodynamics of combustion. Combustion reaction kinetics. Combustion of Gaseous and vaporized fuels. Adiabatic flame temperature. Transport processes. Gas flames classification. Premixed flames. Diffusion flames. Laminar and turbulent regimes. Flame propagation. Gas fired furnace combustion. Detonation of Gaseous mixtures. Environmental issues and greenhouse effect. Environmental control technologies. Hydrogen as a fuel. (3-0-3)

CHE 523
Fundamentals of Heterogeneous Catalysis
Fundamental principles governing heterogeneous catalysis, including chemical reaction equilibria, kinetics of gas-surface interactions and surface chemistry. Application of these fundamental principles to catalysis by metals and to acid catalysis. Discussion of several examples of reactions of technological interest. Prerequisites: CHE422; CHE423; CHE351; CHEM343 (3-0-3)

CHE 524
Industrial Catalysis
A comprehensive state-of-the-art introduction to catalytic processes and catalysts used in the chemical and petroleum industries. Prerequisite: Basic background in organic, inorganic and physical chemistry. (3-0-3)

CHE 525
Chemical Reaction Engineering
Advanced treatment of chemical kinetics and reactor systems including non-isothermal, non-ideal flow systems. Modeling of complex reactions, catalysis and heterogeneous reactor analysis. Reactor stability concepts. Core course. Prerequisite: CHE 423 or equivalent. (3-0-3)

CHE 527
Petrochemical Systems
This course will cover descriptions and evaluations of processes designed to manufacture petrochemicals. The source, availability and characterization of feedstock will also be discussed. Process design procedures particular to petrochemicals will be emphasized. Prerequisite: CHE 494. (3-0-3)

CHE 528
Analysis and Simulation of Chemical Processing
Introduction to techniques for computer- aided analysis of chemical processing systems. Study of process simulation computer systems. Prerequisites: CHE 433, CHE 439, CHE 494. (3-0-3)

CHE 529
Advanced Process Design of Chemical Processes
In depth treatment of topics on the chemical engineering design and operation of chemical processes. Selected process applications are emphasized. Prerequisites: CHE 495, CHE 496(3-0-3)

CHE 530
Advanced Process Control
State space, transfer function and discrete-time representations of process systems. Control system design. Interaction assessment. Multivariable and model predictive-control techniques. Core course for Ph.D. Prerequisite: CHE 435. (3-0-3)

CHE 532
Process Modeling
Development of steady-state and dynamic models of various physical and chemical processes. Parameter identification and state-estimation techniques. Prerequisite: CHE 433. (3-0-3)

CHE 533
Statistical Analysis of Systems
Multivariate probability distributions. Inference about mean, variance. Multivariate linear regression and response surface analysis. Principal components analysis, factor analysis, canonical correlation analysis. Clustering, discrimination and classification. Selected advanced topics such as survey design, design of experimental techniques, statistical methods for discrete and binary variables, time series analysis, partial least squares techniques. Prerequisites: CHE 426, ENVE 426. Same as ENVE 527. (3-0-3)

CHE 535
Applications of Mathematics to Chemical Engineering
Mathematical techniques and their application to the analytical and numerical solution of chemical engineering problems. The analytical component includes review of linear algebra, as well as solution of ordinary, partial differential and integral equations. The numerical component includes iterative solution of algebraic equations, numerical analysis and solution of ordinary differential equations. Core course. (3-0-3)

CHE 536
Computational Techniques in Engineering
Advanced mathematical techniques, numerical analysis, and solution to problems in transport phenomena, thermodynamics and reaction engineering. Review of iterative solution of algebraic equations. Nonlinear initial and boundary value problems for ordinary differential equations. Formulation and numerical solution of parabolic, elliptic and hyperbolic partial differential equations. Characteristics, formulation and numerical solution of integral equations. Solution of transient two-phase flow problems using CFD codes. Prerequisite: A familiarity with FORTRAN is desirable. Core course for Ph.D. (3-0-3)

CHE 538
Polymerization Reaction Engineering
The engineering of reactors for the manufacture of synthetic polymeric materials, commercial processes for manufacture of polymers of many types, polymer chemistry and engineering reactor design. Prerequisite: CHE 423. (3-0-3)

CHE 540
Flow-Through Porous Media and Fundamentals of Reservoir Engineering
Introduction to structural geology and gas and oil formation. Reservoir rock and fluid properties. Darcy's Law and applications. Single and multiphase flow in porous media. Fundamentals of enhanced oil recovery. Unconventional gas and petroleum reserves. (3-0-3)

CHE 541
Renewable Energy Technologies
Topics related to renewable energy technologies including review of renewable energy sources (solar, wind, biomass, etc.), energy storage and conversion with emphasis on batteries and fuel cells, hydrogen as an energy carrier, and the hydrogen economy. (3-0-3)

CHE 542
Fluidization and Gas-Solids Flow Systems
Fluidization phenomena (bubbling, slugging, elutriation and jets in fluidized beds). Multiphase flow approach to fluidization and gas/solids flow systems. Kinetic theory approach to fluid/particle flow systems. Analysis of flow of particles in pneumatic conveying lines (dilute flow) and stand pipe (dense flow). Hydrodynamic analysis of spouted and circulating fluidized beds. Examples from current literature on applications of multiphase flow. Prerequisites: CHE 501, CHE 535. (3-0-3)

CHE 543
Energy, Environment and Economics
The linkage of energy, environmental and economic issues. The impact of energy supply and end use on human well-being and the ecosystem. A comprehensive approach to the resolution of resource, technical, economic, strategic, environmental, socio- and geopolitical problems of the energy industries. Pathways to a sustainable global energy system. Same as ENVE 544. (3-0-3)

CHE 544
Kinetic Theory of Multiphase Flow
The classical theory of gases is applied to particulate flow and to fluidization by the introduction of a granular temperature concept. Equations of state for powders, viscosities of suspensions and Navier-Stokes-like equations of motion are derived. Applications to the design of industrial equipment, such as fluidized bed catalytic crackers, are shown using solutions of these equations with workstations. (3-0-3)

CHE 545
Metabolic Engineering
Cellular metabolism, energetics and thermodynamics of cellular metabolism, regulation of metabolic pathways, metabolic flux analysis, metabolic control analysis, analysis of metabolic networks, synthesis and manipulations of metabolic pathways, applications – case studies. (3-0-3)

CHE 551
Advanced Transport Phenomena
Formulation, solution and interpretation of problems in momentum, energy and mass transport phenomena that occur in chemical and biological processes. Prerequisite: CHE 406. (3-0-3)

CHE 552
Bionanotechnology and Interfacial Phenomena
Bionanotechnology and Interfacial Phenomena The course will introduce the students to the interdisciplinary concept of bionanotechnology, where engineering at atomic and molecular scale is achieved via biological principles of self-assembly and self-organization. Structural and functional principles of bionanotechnology will be discussed with an emphasis on impact of biological nanoengineering or interfacial science. (3-0-3)

CHE 553
Advanced Thermodynamics
Advanced thermodynamics for research-oriented graduate students. The course covers the fundamental postulates of thermodynamics and introductory statistical mechanics, with applications to pure fluids, fluid mixtures, elastic solids, surfaces and macromolecules. (3-0-3) Prerequisite: CHE 351, CHE 451. (3-0-3)

CHE 555
Polymer Processing
Analysis of momentum, heat- and mass-transfer polymer processing operations. Polymer processes considered include extrusion, calendering, fiber spinning, injection molding and mixing. Prerequisite: CHE 406. (3-0-3)

Department of Chemical and Environmental Engineering

CHE 560
Statistical Quality and Process Control
Basic theory, methods and techniques of on-line, feedback, quality-control systems for variable and attribute characteristics. Methods for improving the parameters of the production, diagnosis and adjustment processes so that quality loss is minimized. Same as MMAE 560. (3-0-3)

CHE 561
Chemical Engineering Calculations
Comprehensive problems to give the student a higher degree of proficiency in analyzing and solving comprehensive problems and situations. Subject matter varies with the interest and background of the instructor. (2-3-3)

CHE 563
Separation Processes
Application of chemical engineering principles to separation processes, including distillation, extraction, chromatographic separation, electrokinetic separation, membrane separation, supercritical extraction, crystallization, foam fractionation and solubilization and coacervation. Prerequisites: CHE 301, CHE 302, CHE 351. (3-0-3)

CHE 565
Electrochemical Engineering
Basic concepts of electrochemistry used in electrochemical reactor analysis and design. Electrolytic mass transfer, current and potential distribution, corrosion engineering. Electrodeposition. Batteries and fuel cells. Industrial electrolysis and electrosynthesis. (3-0-3)

CHE 566
Fundamentals of Electrochemistry
Thermodynamics and potential, Marcus theory, charge transfer kinetics and mass transport of simple systems. Electrode reactions coupled with homogeneous chemical reactions. Double-layer structure and adsorbed intermediates in electrode processes. Potential step and potential sweep methods. (3-0-3)

CHE 573
Bioseparations
Recovery of particulates (cells and other solids), chromatographic separations and applications, membrane separations, electrophoresis, recycle and immobilization, economics of bioseparations. (3-0-3)

CHE 575
Polymer Rheology
Flow of viscoelastic fluids, integral and differential constitutive equations from continuum and molecular considerations, methods of experimental evaluations. Prerequisite: CHE 406. (3-0-3)

CHE 576
Industrial Chemistry: Catalytic and Thermal Reactions and Processes
Includes petroleum refining, gasoline and alternative fuels, petrochemicals, such as polymers and polymer intermediates for films, fibers, elastomers and thermosets; surfactants, adhesives, lubes and gasoline additives; paper, wood, pesticides, pharmaceutical and biotechnology; sulfuric acid and derivatives, fertilizers, ceramics, glasses and other aspects of materials science. (3-0-3)

CHE 577
Bioprocess Engineering
Application of engineering principles to the biological production processes. Enzyme kinetics, cell culture kinetics, transport phenomena in cells, membranes, and biological reactors, genetics, bioseparation and downstream processing, energetics of metabolic pathways, operation modes of cell cultures, mixed cultures and their applications (3-0-3)

CHE 579
Enzyme Reactor Engineering
The biochemical structure of proteins (enzymes), enzyme kinetics, methods of enzyme production and purification and methods of enzyme immobilization are discussed. Fundamentals of reactor design with emphasis on diffusional influences in heterogeneous systems are developed to permit analysis of novel immobilized enzyme processes. Prerequisite: CHE 423 (3-0-3)

CHE 580
Biomaterials
Metal, ceramic, and polymeric implant materials. Structure-property relationships for biomaterials. Interactions of biomaterials with tissue. Selection and design of materials for medical implants. (3-0-3)

CHE 581
Processing and Applications of Polymer Composite Materials
Types, multiphase structures, classification, processing. Different moldings, foamed and cellular composites, cellular structure, types of foams. Applications. (3-0-3)

CHE 582
Interfacial and Colloidal Phenomena with Applications
Applications of the basic principles of physical chemistry, surfactants and interfacial phenomena, surface and interfacial tension, adsorption of surfactants from solutions, spreading, contact angles, wetting, electrokinetic phenomena, rheology, dynamic interfacial properties, mass transport across interfaces. Applications include emulsions, foams, dispersions, tribology, detergency, flotation, enhanced oil recovery, suspension, emulsion polymerization and liquid membranes. Prerequisites: CHEM 343, CHE 406. (3-0-3)

CHE 583
Pharmaceutical Engineering
Application of transport phenomena, and reaction engineering to pharmaceutical processes. Heat and mass transfer in bioreactors and the fluidized beds. Drying, coating and granulation. Environmental and economical issues in the pharmaceutical processes. Examples from industrial processes and current literature. (3-0-3)

CHE 584
Tissue Engineering
Growth and differentiation of cells and tissue. In vitro control of tissue development. In vivo synthesis of tissues and organs. Transplantation of engineered cells and tissue. Techniques and clinical applications of tissue engineering. (3-0-3)

CHE 585
Drug Delivery
Principle of diffusion in liquid membranes and polymers, and methods for measurement and analysis of diffusion coefficient. Principle of molecular transport in polymeric material, and drug solubility in polymers. Intravenous infusion, and polymer drug delivery systems. Process involved and kinetics of solute release. Design and optimization of drug delivery systems based on pharmacokinetic/pharmacodynamic requirements. (3-0-3)

CHE 586
Particulate Technology
Advances in applied particulate technology. Current specialized topics in systems such as powders, emulsions, suspensions, dusts and mists. (3-0-3)

CHE 587
Particle Processing and Characterization
Particle rheology, particle size and distribution measurements, pulverization and attrition processes, agglomeration and materials processing. (3-0-3)

CHE 591
Research and Thesis for M.S. Degree

CHE 593
Seminar in Chemical Engineering
Presentations on recent developments in the field by academic and industrial visitors. (1-0-1)

CHE 594
Special Projects
Advanced projects involving computer simulation, modeling or laboratory work. (Credit: 1—6 credit hours.)

CHE 597
Special Problems
Independent study and project. (Credit: Variable)

CHE 691
Research and Thesis for Ph.D. Degree

CHE 701
Computer-Aided Process Design and Optimization
Process design, steady-state and dynamic process simulation and process optimization using commercial software for computer-aided process design and optimization. Prerequisites: CHE 494 or consent of instructor. (2-0-2)

CHE 703
Computer Aided Process Modeling
Computer-aided modeling of lumped and distributed parameter systems of process models. Numerical algorithms for solving the resultant differential equations. Nonlinear parameters estimations from single and multi-response data, optimal experimental design and model discrimination. (2-0-2)

CHE 761
Statistical Design of Experiments for Process Improvement
Full and fractional factorial designs of experiments, optimal designs, interactions, analysis of variance, empirical modeling and regression analysis, response surface analysis, process improvement by Taguchi methods and alternative designs of experiments. Prerequisite: Consent of instructor. (2-0-2)

CHE 771
Applications of Enzymes and Microbes in Food Processing
Kinetics of enzyme-catalyzed reactions, applied enzyme catalysis in the food industry, stoichiometry of cell growth and product formation, carbon metabolism pathways, fermentation technology, applications of mixed cultures in the food industry, case studies. Prerequisite: CHE 411 or consent of instructor. (2-0-2)

Environmental Engineering

ENVE 485
Pollution Prevention
(Note: This course will be renamed Industrial Ecology.) (Co-listed with EM 507) Industrial Ecology is the study of material and energy flows from industrial and consumer activities, and the related regulatory, political, economic, technical, and social issues. Industrial ecologists strive to bring environmental concerns into harmony with economic development. The course includes several projects and readings on current topics such as life cycle analysis (LCA), design for the environment (DFE), and environmental management systems. (3-0-3)

ENVE 501
Environmental Chemistry
Chemical processes in environmental systems, with an emphasis on equilibrium conditions in aquatic systems. The types of processes examined include acid-base, dissolution-precipitation, air-water exchange and oxidation-reduction reactions. Methods presented for describing chemical speciation include analytical and graphical techniques, as well as computer models. Core course. (3-0-3)

ENVE 502
Atmospheric Chemistry
The fundamentals and applied aspects of the photochemical processes that drive the daytime chemistry of the lower atmosphere are discussed. Basic chemistry of photochemical smog, acid deposition, and fate of gaseous and airborne toxic chemicals in the atmosphere are presented. An in-depth review of the experimental techniques employed in fundamental and applied studies of reaction in real and simulated atmospheres is also provided. Prerequisites: ENVE 463, ENVE 501. (2-0-2)

ENVE 503
Water and Wastewater Analysis
Standard and advanced analytical techniques for measuring water quality and efficiencies of water and wastewater treatment processes. Course covers both theoretical and applied aspects of standard methods and advanced techniques for trace metal and organic analyses. Prerequisite:ENVE 501 or consent of instructor. (2-3-3)

ENVE 504
Advanced Techniques in Environmental Analysis
Principles and applications of advanced techniques in analytical chemistry appropriate to environmental surveillance and control. Includes pesticide analysis, trace metal identification, and automated photometric techniques. Prerequisite: ENVE 501 or consent of instructor. (2-3-3)

ENVE 505
Principles of Water Chemistry
Examination of current research theories and state-of-the-art in subjects pertinent to the chemical aspects of environmental science. Includes chemistry of humic substances and of pesticides in natural waters; physical, chemical and biological fates of trace metals and organic pollutants, and chemistry of biological nutrients. Prerequisite: ENVE 501 or consent of instructor. (3-0-3)

ENVE 506
Chemodynamics
The dynamics of pollutant transfer in biogeochemical systems of the earth. The overall objective of this course is to introduce fundamental science and engineering principles needed to formulate creative, comprehensive solutions to transport problems; critically evaluate proposed solutions to transport problems; and acquire and integrate new information to build on these fundamentals. Core course. (3-0-3)

ENVE 509
Special Topics in Environmental Chemistry
Lectures and field studies on topics pertinent to the chemical aspects of environmental systems. May be repeated with change of course content, up to a maximum of six credits. Prerequisite: Consent of instructor. (Credit: 1—3 hours.)

ENVE 510
Environmental Biodynamics
Properties and characteristics of microorganisms as they relate to water quality and to treatment processes. Batch population growth characteristics. Microbial degradation of organic compounds. Microbial pathogens of waterborne diseases and microbial indicators. Biogeochemical relations. (3-1 4)

ENVE 512
Special Topics in Environmental Biology
Selected laboratory techniques pertinent to the biological aspects of environmental engineering. May be repeated with change of course content, up to a maximum of six credits. Prerequisite: Consent of instructor. (Credit: 1—3 hours.)

ENVE 513
Biotechnological Processes in Environmental Engineering
Fundamentals and applications of biological mixed culture processes for air, water, wastewater and hazardous waste treatment. Topics include biochemical reactions, stochiometry, enzyme and microbial kinetics, detoxification of toxic chemicals, and suspended growth and attached growth treatment processes. The processes discussed include activated sludge process and its modifications, biofilm processes including trickling filters and biofilters, nitrogen and phosphorous removal processes, sludge treatment processes including mesophilic and thermophilic systems, and natural systems including wetlands and lagoons. Prerequisite: ENVE 542 or consent of instructor. (3-0-3)

ENVE 520
Environmental Monitoring and Assessment
Modeling and monitoring methods for the prediction and assessment of environmental impacts due to changes in the physical, chemical and biological environment. Comparative studies of methodologies to assess immediate and extended effects, including trends in space and time due to changes in anthropogenic systems. Dynamics of environmental changes, inventory methods and priority impact criteria. Same as ENVE 405. (3-0-3)

ENVE 525
Advanced Water Resources
Water resources engineering, including hydrology, quality standards, groundwater flow and surface hydraulics. Optimization and allocation of water resources. Prerequisite: ENVE 401. (3-0-3)

ENVE 527
Statistical Analysis of Systems
Multivariate probability distributions. Inference about mean, variance. Multivariate linear regression and response surface analysis. Principal components analysis, factor analysis, canonical correlation analysis. Clustering, discrimination and classification. Selected advanced topics such as survey design, design of experimental techniques, statistical methods for discrete and binary variables, time series analysis, partial least squares techniques. Prerequisites: CHE 426, ENVE 426. Same as CHE 533. (3-0-3)

ENVE 528
Modeling of Environmental Systems
To introduce students to mathematical modeling as a basic tool for problem solving in engineering and research. Environmental problems will be used as examples to illustrate the procedures of model development, solution techniques and computer programming. These models will then be used to demonstrate the application of the models, including simulation, parameter estimation and experimental design. The goal is to show that mathematical modeling is not only a useful tool, but also an integral part of process engineering. (3-0-3)

ENVE 532
Special Topics in Environmental Engineering
Lectures and discussion on topics pertinent to the engineering aspects of environmental systems. May be repeated with change of course up to a maximum of six credits. Prerequisite: Consent of instructor. (Credit: 1—3 hours.)

ENVE 542
Physicochemical Processes in Environmental Engineering
Fundamentals and applications of physicochemical processes used in air, water, wastewater and hazardous waste treatment systems. Topics include reaction kinetics and reactors, particle characterization, coagulation and flocculation, sedimentation, filtration, membrane separation, adsorption and absorption. Prerequisite: ENVE 404 or consent of instructor. Co-requisite: ENVE 501 or consent of instructor. Core course. (3-0-3)

ENVE 544
Energy, Environment and Economics
The linkage of energy, environmental and economic issues. The impact of energy supply and end-use on human well-being and the ecosystem. A comprehensive approach to the resolution of resource, technical, economic, strategic, environmental, socio- and geopolitical problems of the energy industries. Pathways to a sustainable global energy system. Same as CHE 543. (3-0-3)

ENVE 545
Environmental Regulations and Risk Assessment
One third of the course is a review of current environmental regulations, including the Clean Air Act, Clean Water Act, Toxic Substances Control Act, Resource Conservation and Recovery Act, CERCLA, and the Pollution Prevention Act. The rest of the course deals with the fundamentals of risk assessment, including hazard identification, dose-response assessment, exposure assessment and risk characterization for public health and ecosystems. (3-0-3)

ENVE 546
Industrial Hygiene
An introduction to toxicology, exposure routes and physiological classification of toxicants. Epidemiological considerations, measurement methods, strategies and calculations. Modeling of exposures and evaluation of controlling parameters. Ventilation methods of control. Physical stressors of sound, heat, vibration and lifting. Methods for measurement and calculation of exposure/compliance levels. (3-0-3)

ENVE 551
Industrial Waste Treatment
Industrial waste sources and characteristics, significance of industrial wastes as environmental pollutants; applications of standard and special treatment processes, including physical, chemical and biological systems. Prerequisite: ENVE 513, ENVE 542 or consent of instructor. (3-0-3)

ENVE 555
Industrial Waste Treatment Design Criteria
Theoretical and laboratory development of industrial wastewater treatment systems design criteria. Evaluation and selection of unit treatment processes. Application of design procedures for selected representative industrial wastewater. Prerequisites: ENVE 513, ENVE 542 or consent of instructor. (2-3-3)

ENVE 561
Design of Environmental Engineering Processes
Design of water and wastewater treatment systems. System economics and optimal design principles. Prerequisite: ENVE 513, ENVE 542 or consent of instructor. (3-0-3)

ENVE 563
Systems Engineering: Waste Facility Design and Operation
Fundamentals of systems engineering applied to wastewater facility design and operation. Modeling, simulation, optimization, techniques for biological and physicochemical treatment processes. Process analysis and control simulations, cost optimization. Prerequisite: ENVE 404 or consent of instructor. (3-0-3)

ENVE 570
Air Pollution Meteorology
Physical processes associated with the dispersion of windborne materials from industrial and other sources. Atmospheric motion, including turbulence and diffusion, mathematical models and environmental impact assessment. Global climate change, ozone depletion, acid rain are studied. Prerequisite: ENVE 513, ENVE 542 or consent of instructor. (3-0-3)

ENVE 572
Ambient Air Monitoring
Ambient air sampling and pollutant analysis. Methods for collection and identification of gaseous and particulate pollutants. Air monitoring survey design, instrument calibration, interpretation of atmospheric data. Prerequisites: ENVE 501, ENVE 570. (2-3-3)

ENVE 573
Air Pollution Engineering
Air pollution sources and source control, chemistry and meteorology of the atmosphere, atmosphere diffusion and stack performance, equipment and engineering processes for air emission control. Prerequisite: ENVE 463. (3-0-3)

ENVE 574
Stack Sampling and Analysis
Current practices of measuring pollutants emitted from stationary sources. Methods of collection and analysis of stack effluents, including field-sampling techniques and data evaluation. (2-3-3)

ENVE 575
Control of Toxic Air Pollution
Definition of toxic air pollutants; sources of toxic air pollutants; emissions measurement, air dispersion and deposition models; risk assessment and risk management; ecological risk analysis, gaseous toxic air pollutant control technologies; fugitive emissions control. Pollution prevention. Prerequisite: Consent of instructor. (3-0-3)

ENVE 576
Indoor Air Pollution
Indoor air pollution sources, indoor pollutant levels, monitoring instruments and designs; indoor pollution control strategies: source control, control equipment and ventilation; energy conservation and indoor air pollution; exposure studies and population time budgets; effects of indoor air pollution; risk analysis; models for predicting source emission rates and their impact on indoor air environments. Prerequisite: ENVE 405, ENVE 520 or consent of instructor. (3-0-3)

ENVE 577
Design of Air Pollution Control Devices
Principles and modern practices employed in the design of engineering systems for the removal of pollutants. Design of control devices based on physical and chemical characteristics of polluted gas streams. Prerequisite: ENVE 463. (3-0-3)

ENVE 578
Physical and Chemical Processes for Industrial Gas Cleaning
Application of physical and chemical processes in the design of air treatment systems; fundamentals of standard and special treatment processes. Prerequisite: ENVE 463. (3-0-3)

ENVE 580
Hazardous Wastes Engineering
Sources and characteristics of hazardous wastes, legal aspects of hazardous waste management, siginificance of hazardous wastes as air, water and soil pollutants. Principles and applications of conventional and specialized hazardous waste control technologies. Prerequisites: ENVE 501 and ENVE 506, or consent of instructor. Core course. (3-0-3)

ENVE 585
Groundwater Contamination and Pollutant Transport
Applications of groundwater flow principles, transport phenomena, and chemical and biological processes to problems of groundwater contamination. Simulation model and case studies of current topics. (3-0-3)

ENVE 590
Environmental Engineering Seminar
Presentations on recent developments in the field by academic and industrial visitors. (1-0-1)

ENVE 591
Research and Thesis for M.S.Degree

ENVE 594
Special Projects
Advanced projects involving computer simulation, modeling or laboratory work. (Credit: 1—6 hours.)

ENVE 597
Special Problems
Independent study and project. (Variable credit.)

ENVE 691
Research and Thesis for Ph.D. Degree

Food Process Engineering

FPE 504
Food Biotechnology
Introduction of biotechnology in the food industry including genetic engineering of microorganisms. Fundamentals of microbial genomics and proteomics. Practice of a variety of software and bioinformatics tools including database search, sequence alignment, phylogenetic and cluster analyses, gene prediction, genomic map construction, structural and functional prediction of proteins. Applications of DNA fingerprinting techniques in food safety and public health. Prerequisite: Biology or Microbiology. (3-0-3)

FPE 505
Food Microbiology
Microorganisms of importance to food safety, spoilage and food fermentations. Principles of occurrence and control. Importance of sanitation and prevention of public health problems. Microbiological contaminants and methods for their detection. Mechanisms of microbial inactivation. (3-0-3) Prerequisites: Introductory Microbiology, Food Science and Biochemistry

FPE 506
Food Microbiological Laboratory
Basic microbiological techniques and safe laboratory practices. Introductory Food Microbiology. Isolation of pathogenic bacteria. Spoilage microorganisms. Fermentation. Environmental Monitoring. Rapid Identification tests. Sporeformers. (0-3-3) Prerequisites: Introductory Microbiology and Biochemistry

FPE 507
Food Analysis
Techniques for analyzing food toxins, food constituents of public health concern, intentional and unintentional food additives, modern separation and analytical techniques. Prerequisites: chemistry, analytical chemistry. (3-0-3)

FPE 511
Food Law and Regulation
Legal and scientific issues in regulating the nation's food supply and nutritional status. Rules of regulatory agencies; Federal Food, Drug and Cosmetic Act; definitions and standards for food and adulterated foods. Manufacturing processed foods in compliance with regulations. (3-0-3)

FPE 521
Food Process Engineering
Food engineering fundamentals, heat transfer in food processing, food rheology, freezing of foods, food dehydration, kinetics of chemical reactions in foods, refrigeration and thermal process calculations, alternative methods of food processing. (3-0-3)

FPE 522
Advanced Food Process Engineering
Process calculations for food processing methods such as canning, aseptic processing, ohmic heating, microwave processing and pulsed energy processing. Extrusion techniques in food processing. Discussion of new food processing techniques and safety implications. Prerequisite: FST 521 or permission of the instructor. (3-0-3)

FPE 524
Fundamentals of Food Science and Technology
This course will cover the central food science issues encountered with storage and processing of all major American food commodities including meats, grains, confections, vegetables, eggs, dairy. It will also review the relevant chemistry, physics and engineering required to understand common food-related unit operations such as drying, freezing, sterilization and radiation treatment of foods. An introduction to microbial and chemical issues of food quality and safety will also be covered. (3-0-3)

FPE 531
HACCP Planning and Implementation
Examination of the hazard analysis and critical control point (HACCP) principles; microbiological and process overviews; generic HACCP models, good manufacturing practices; monitoring of critical control points, process control and implementation. (3-0-3)

FPE 541
Principles of Food Packaging
Type and application of packaging materials. Migration Theories. Food Package interaction. Package testing to ensure safety. Special design considerations. Recycling of package materials. (3-0-3)

FPE 591
Research and Thesis
Students conduct their research on a particular topic and write a thesis. Students are also required to write manuscripts from his/her thesis work for publication. (Credit: Variable 1-10 hours)

FPE 593
Seminar on Food Safety and Technology
Students attend seminars offered during the semester. Each student is also required to give a 30 minute presentation on a topic of his/her interest or a research project on which she/he has worked. (Credit: 1 Hour)

FPE 594
Special Projects
Advanced projects involving analysis of food safety processing, packaging and biotechnology systems. (Credit: 1-6 hours)

FPE 597
Special Problems
Independent study focusing on current problems, issues of professional relevance. Topics selected from food process engineering, food safety, packaging, biotechnology. Repeatable to a maximum of six credit hours. (Credit: 1-6 hours)

Undergraduate Courses Available to Graduate Students

With the approval of their advisers, students in the chemical and food process engineering graduate programs may apply up to 12 credits hours to their program from the following400-level undergraduate courses. Environmental engineering students may apply up to six credit hours with the approval of their adviser. This does not apply to students pursuing the dual master's degree in chemical engineering and computer science.