Chemical and Biochemical Engineering

Chair
- C. Allan Guymon

Undergraduate major: chemical engineering (B.S.E.)
Graduate degrees: M.S. in chemical and biochemical engineering; Ph.D. in chemical and biochemical engineering
Faculty: http://www.engineering.uiowa.edu/cbe/people/faculty-cbe
Web site: http://www.engineering.uiowa.edu/cbe/

Chemical and biochemical engineers combine engineering principles with knowledge of mathematics and specific sciences—chemistry, the biological sciences, and physics—to develop and operate processes that convert raw materials into products that benefit society. For example, biochemical engineers might develop and operate processes to convert switchgrass into biofuels or to mass produce an antibiotic.

Chemical and biochemical engineers engage in a wide variety of activities that benefit the global community. Fuel cells, solar energy, and biorenewable fuels (e.g., biodiesel or ethanol) fall within the realm of chemical engineering. Chemical engineering distinguishes itself from other engineering professions with its reliance on chemical reactions and physicochemical transformations to produce a wide variety of important materials and products. Biochemical engineers are involved in a wide variety of industrial biocatalytic, fermentation, and cell culture processes that generate products ranging from the high fructose corn syrup in soft drinks to recombinant human insulin.

As part of their training, chemical and biochemical engineers learn ethical design and a respect for the larger issues in any design, such as community health, employee safety, and the global implications of the design. The University of Iowa’s curriculum emphasizes chemical process safety and environmentally conscious chemical engineering design.

Chemical and biochemical engineers work in a wide range of industries, including petroleum and specialty chemical production, polymer and plastic production, food processing, energy, microelectronics production, pharmaceutical production, biochemical processing, and environmental compliance. Potential jobs include production, process development, plant design and construction, and fundamental research. Many experienced chemical and biochemical engineers move through management ranks to high-level administrative positions.

Undergraduate Program of Study
- Major in chemical engineering (Bachelor of Science in Engineering)

The undergraduate program in chemical engineering produces graduates who have a strong foundation of scientific and technical knowledge and are equipped with problem solving, teamwork, and communication skills that will serve them throughout their careers, consistent with the following educational objectives.

Within a few years of graduation, the program’s graduates will:
- attain careers as practicing chemical engineers in fields such as pharmaceuticals, microelectronics, chemicals, polymers/advanced materials, food processing, energy, biotechnology, and environmental engineering;
- attain advanced studies in disciplines such as chemical engineering, environmental engineering, medicine, law, and business; and
- assume professional leadership roles.

The undergraduate program in chemical engineering uses the following methods and strategies to achieve its educational objectives:
- foster a personalized, supportive environment for all students by taking advantage of the unique combination of a small college atmosphere in a major research university;
- enrich the undergraduate experience through cultural diversity and international opportunities or experiential learning;
- provide a solid foundation and understanding of the fundamental principles of mathematics, science, and engineering;
- provide students with experience in learning and applying tools (e.g., computer skills) to solve theoretical and open-ended chemical engineering problems;
- provide students with opportunities to participate in multidisciplinary teams and to develop and practice written and oral communication skills, both within the team and to a broader audience;
- provide students with opportunities to design and conduct chemical engineering experiments and to design systems, components, and chemical processes to meet specific needs and constraints; and
- provide a contemporary grounding in professional responsibility, including ethics, the global and societal impact of engineering decisions, and the need for lifelong learning.

Bachelor of Science in Engineering

The Bachelor of Science in Engineering requires a minimum of 128 s.h. The major in chemical engineering provides a broad education at the leading edge of technology. It emphasizes fundamental concepts, problem solving, laboratory techniques, and communication skills. The biological sciences join physics, chemistry, and mathematics as foundation disciplines for chemical engineering.

All engineering students complete the B.S.E. core requirements, which include RHET:1030 Rhetoric; ENGR:1100 Engineering Problem Solving I and ENGR:1300 Engineering Problem Solving II; and courses in chemistry, engineering mathematics and fundamentals, and physics. They must earn a grade of C-minus or higher in the core requirements MATH:1550 Engineering Mathematics I: Single Variable Calculus and MATH:1560 Engineering Mathematics II: Multivariable Calculus.
They also complete the curriculum designed for their major program, which covers four major stems: mathematics and basic sciences, engineering topics, an elective focus area, and the general education component (15 s.h. of humanities and social science courses). For information about the curriculum stems, see Bachelor of Science in Engineering in the Catalog.

Seminars do not count toward the 128 s.h. required for the degree.

For chemical engineering students, the sophomore, junior, and senior years emphasize chemical engineering courses such as process calculations, engineering flow and heat exchange, chemical engineering thermodynamics, mass transfer and separations, chemical reaction engineering, chemical process safety, chemical engineering laboratories, biochemical engineering, process dynamics and control, and process design. Experience in instrumentation, analysis, and design is obtained through an integrated laboratory program. Routine use is made of computer-based data analysis, simulation, and design.

Students are required to participate in at least one enriching activity, which may include a research experience, a cooperative education or internship experience, study abroad, completion of the Certificate in Technological Entrepreneurship, or other approved experiences.

Chemical engineering students may gain depth of knowledge related to a career path through their selection of science, engineering, humanities, and social science electives. Several preapproved elective focus areas may help students define potential careers.

Students must select elective focus area courses according to guidelines established by the Department of Chemical and Biochemical Engineering. See "Elective Focus Area" after the following curriculum list.

The following study plan includes the B.S.E. core requirements and the curriculum for the chemical engineering major. Some courses in this plan are prerequisites for others. Students must complete a course's prerequisites before they may register for the course. Those who take courses in the order below satisfy the prerequisite requirements automatically.

**FIRST YEAR**

**First Semester**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR:1000</td>
<td>Engineering Success for First-Year</td>
<td>1 s.h.</td>
</tr>
<tr>
<td>Students (credit does not count toward B.S.E. degree)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENGR:1100</td>
<td>Engineering Problem Solving I</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:1110</td>
<td>Principles of Chemistry I</td>
<td>4 s.h.</td>
</tr>
<tr>
<td>MATH:1550</td>
<td>Engineering Mathematics I: Single</td>
<td>4 s.h.</td>
</tr>
<tr>
<td>Variable Calculus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RHET:1030</td>
<td>Rhetoric</td>
<td>4 s.h.</td>
</tr>
</tbody>
</table>

**Second Semester**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBE:1000</td>
<td>CBE Departmental Seminar</td>
<td>1 s.h.</td>
</tr>
<tr>
<td>ENGR:1300</td>
<td>Engineering Problem Solving II</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:1120</td>
<td>Principles of Chemistry II</td>
<td>4 s.h.</td>
</tr>
<tr>
<td>MATH:1560</td>
<td>Engineering Mathematics II: Multivariable Calculus</td>
<td>4 s.h.</td>
</tr>
</tbody>
</table>

**SECOND YEAR**

**First Semester**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBE:2105</td>
<td>Process Calculations</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>ENGR:2110</td>
<td>Engineering Fundamentals I: Statics</td>
<td>2 s.h.</td>
</tr>
<tr>
<td>ENGR:2120</td>
<td>Engineering Fundamentals II: Electrical Circuits</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>ENGR:2130</td>
<td>Engineering Fundamentals III: Thermodynamics</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>MATH:2560</td>
<td>Engineering Mathematics IV: Differential Equations</td>
<td>3 s.h.</td>
</tr>
</tbody>
</table>

**Second Semester**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBE:3000</td>
<td>Professional Seminar: Chemical</td>
<td>1 s.h.</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBE:3105</td>
<td>Chemical Engineering Thermodynamics</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CBE:3110</td>
<td>Engineering Flow and Heat Exchange</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:2210</td>
<td>Organic Chemistry I</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>General education component course</td>
<td>3 s.h.</td>
<td></td>
</tr>
<tr>
<td>Statistics elective</td>
<td>3 s.h.</td>
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**THIRD YEAR**

**First Semester**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBE:3000</td>
<td>Professional Seminar: Chemical</td>
<td>1 s.h.</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBE:3115</td>
<td>Mass Transfer and Separations</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CBE:3150</td>
<td>Thermodynamics/Transport Laboratory</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>ENGR:2720</td>
<td>Materials Science</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:2220</td>
<td>Organic Chemistry II</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:2410</td>
<td>Organic Chemistry Laboratory</td>
<td>3 s.h.</td>
</tr>
</tbody>
</table>

**Second Semester**

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<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBE:3000</td>
<td>Professional Seminar: Chemical</td>
<td>1 s.h.</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBE:3120</td>
<td>Chemical Reaction Engineering I</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CBE:3125</td>
<td>Chemical Process Safety</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CBE:3155</td>
<td>Chemical Reaction Engineering/</td>
<td>2 s.h.</td>
</tr>
<tr>
<td>Separations Laboratory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General education component courses</td>
<td>6 s.h.</td>
<td></td>
</tr>
<tr>
<td>Elective focus area course</td>
<td>3 s.h.</td>
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</table>

**FOURTH YEAR**

**First Semester**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit Hours</th>
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</thead>
<tbody>
<tr>
<td>CBE:3000</td>
<td>Professional Seminar: Chemical</td>
<td>1 s.h.</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBE:3120</td>
<td>Chemical Reaction Engineering I</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CBE:3125</td>
<td>Chemical Process Safety</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CBE:3155</td>
<td>Chemical Reaction Engineering/</td>
<td>2 s.h.</td>
</tr>
<tr>
<td>Separations Laboratory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBE:5205</td>
<td>Introduction to Biochemical Engineering</td>
<td>3 s.h.</td>
</tr>
</tbody>
</table>
opportunities for graduates are in research and energy, the environment, biotechnology, and materials. The principles in contemporary applications related to the principles of engineering science and use those principles in contemporary applications related to energy, the environment, biotechnology, and materials. The department emphasizes research, since most opportunities for graduates are in research and development.

Elective Focus Area
The elective focus area enables students to gain depth of knowledge in a career path. Students meet with their chemical engineering academic advisor to discuss career options and develop a plan for choosing electives based on their career interests. The department offers preapproved elective focus areas in bioengineering, pharmaceutics, chemical process engineering, polymers, energy and environment, sustainability, pre-medicine, business, and entrepreneurship.

Students may prefer to develop an individualized elective focus area, which is subject to approval by the department's curriculum committee. See Chemical Engineering Curriculum on the Department of Chemical and Biochemical Engineering web site for detailed descriptions of preapproved elective focus areas, guidelines for tailored elective focus areas, and typical four-year study plans based on elective focus areas.

Joint B.S.E./M.S.
The College of Engineering offers a joint (fast-track) Bachelor of Science in Engineering/Master of Science for chemical engineering undergraduate students who intend to earn an M.S. in chemical and biochemical engineering. B.S.E./M.S. students may count 12 s.h. of course work (typically advanced chemistry sequences and electives) toward both degrees. Once students complete the requirements for the bachelor's degree, they are granted the B.S.E., and they normally complete the M.S. one year later.

To be admitted to the joint degree program, students must have completed at least 80 s.h., must have a cumulative g.p.a. of at least 3.25, and must submit a letter of application and statement of purpose to the chair of the Department of Chemical and Biochemical Engineering. Visit B.S./M.S. Programs on the department's web site to learn more.

Graduate Programs of Study
• Master of Science in chemical and biochemical engineering
• Doctor of Philosophy in chemical and biochemical engineering

Graduate students in the Department of Chemical and Biochemical Engineering gain an understanding of the principles of engineering science and use those principles in contemporary applications related to energy, the environment, biotechnology, and materials. The department emphasizes research, since most opportunities for graduates are in research and development.

Research and Study Areas
Current research strengths of the Department of Chemical and Biochemical Engineering are in the areas of global and regional atmospheric modeling, biomaterials and medical engineering, cellular engineering, photopolymerization, biocatalysis, and biofuels.

BIOCHEMICAL ENGINEERING
Biochemical engineering involves the industrial application of enzymes, microorganisms, cells, and tissues for production of chemicals, pharmaceuticals, and other materials of commercial value.

The department is working to solve problems with the use of insect cell culture for recombinant protein and viral insecticide production. Research is being conducted to improve the quality and quantity of recombinant proteins produced in large-scale bioreactors. In addition, a continuous viral insecticide production system is being developed for the large-scale production of these environmentally safe alternatives to chemical insecticides. The insect cell/baculovirus system is being used as a model system to investigate the role of oxidative stress in viral cytotoxicity.

Carbon dioxide accumulation, which commonly occurs in large-scale bioreactor systems, affects insect cell growth. The department’s researchers are investigating the corresponding effect on insect cell growth and the baculovirus infection process.

The department works to design technologies for the characterization and use of extremophiles, organisms that possess unusual abilities to survive in harsh chemical environments. In these studies, novel bioreactor systems that can withstand extremes of temperature, pressure, pH, and salinity are being developed. Extremophile strategies for survival also are being studied, with the aim of discovering unique enzymes for industrial application as well as evaluating molecular interactions that govern protein stability under extreme conditions.

In addition to the study of natural extremophiles, efforts to engineer stability in biocatalysts for industrial processing are under way. Novel solvent-tolerant enzymes and organisms for environmentally beneficial chemical reactions are being generated using molecular biology tools. Combinations of chemical and biological processing are being used to produce valued chemicals from renewable feedstocks. This work contributes to the interdisciplinary training of engineers and scientists to address the challenges of minimizing and cleaning up environmental pollution, while maximizing the economic benefits of chemical processing.

The department also conducts research in structural enzymology, molecular mechanisms of host-pathogen interactions, and biocatalysis. The laboratory uses biophysical, structural, and molecular biology techniques to understand the details of enzyme action. This information is used to design and engineer biocatalysts for the production of chiral compounds. Work also is under way on cellular recognition and signaling processing during infection and inflammation. Knowledge gained from these studies aids the design of drugs and biological sensors for bacterial presence.

The integration of biotechnology with traditional chemical engineering has led to an interdisciplinary area involving other engineering departments and the Departments.
of Chemistry and Biology (College of Liberal Arts and Sciences); the Departments of Biochemistry and Microbiology and the Free Radical and Radiation Biology Program (Carver College of Medicine); and the College of Pharmacy. This focus includes involvement in the University’s Center for Biocatalysis and Bioprocessing, whose fermentation capabilities are highlighted by its 1,500-liter fermentor.

**BIOMEDICAL RESEARCH**

The department’s research involves a multidisciplinary approach to solving problems in the medical field, particularly in drug delivery and biomaterials.

Researchers are working to develop safe delivery systems that target drugs precisely in the human body and avoid premature metabolism or elimination. To treat respiratory infections, micron-sized particles are being engineered with properties that enhance aerodynamic performance, particle stability, and targeting within the respiratory tract. Polymeric vehicles are being designed to provide sustained protection and prevention against cancers by kick-starting the immune system. Finally, work is under way to overcome barriers to efficient delivery of DNA, with the potential to provide cures for genetic disorders such as cystic fibrosis and X-Linked Severe Combined Immunodeficiency (X-SCID). This work brings together researchers from the Carver College of Medicine, the Colleges of Dentistry and Pharmacy, and the Departments of Chemistry and Biomedical Engineering.

In the biomaterials realm, new materials are being developed that can interact with the human body to perform certain functions while maintaining compatibility. A project with the Department of Ophthalmology and Visual Sciences involves development of biodegradable stent materials to alleviate a serious eye disease induced by a blood clot in the central retinal vein. Research with the Department of Otolaryngology—Head and Neck Surgery is exploring the development of photo-patterned surfaces for directed growth of cells to improve cochlear implants. Current research in the tissue engineering field applies microfabrication techniques to develop scaffolds that are biodegradable and biocompatible with cell-interactive properties, and that directly incorporate controlled-release functionality within the scaffold.

The department also conducts research that is focused on self-assembling systems, rational design of novel drug and gene delivery systems, and development of sophisticated scaffolds for tissue-specific regeneration. In tissue engineering, microfabrication techniques are applied to novel biomaterials to provide spatial control over tissue formation and to integrate minimally invasive scaffold delivery strategies. In drug and gene delivery, researchers are exploring the synergistic application of degradable particle technology, CpG oligonucleotides, and heat-shock protein therapy for generating sustained, stronger immune responses against carcinomas.

Students involved in animal research have access to the University’s Office of Animal Resources, which is adjacent to the University of Iowa Hospitals and Clinics.

**ENERGY AND ENVIRONMENT**

Chemical engineers are well-suited to make major contributions toward meeting challenges for the environment, energy, and sustainable development. The Department of Chemical and Biochemical Engineering has an active research program in the environmental areas of air pollution, biofuels, atmospheric chemistry, atmospheric CO2 fluxes, environmental change, bioremediation, and the design of new environmentally compatible technologies. Particular emphasis is placed on the chemistry and physics of local, regional, and global air-pollution problems. Research in support of this activity includes high-speed computing and detailed sensitivity analysis.

This work involves three centers and institutes on campus. The Center for Global and Regional Environmental Research brings together University scientists and scholars from more than 20 disciplines, including chemistry, civil and environmental engineering, geography, geology, law, and medicine. The center’s chief area of concern is environmental change. Chemical and biochemical engineering researchers interact with scientists at IHRR—Hydroscience & Engineering, a research institute focusing on applied fluid mechanics; their collaborations involve environmental fluid mechanics and air pollution field studies. The Nanoscience and Nanotechnology Institute provides an interdisciplinary home for chemical and biochemical researchers working on the development, application, and environmental and health effects of nanomaterials.

**PHOTOPOLYMERIZATION**

Photopolymers are chain reactions in which a liquid monomer is converted to a solid, durable polymer in a process triggered by light of the appropriate wavelength. The use of light, rather than heat, to drive a polymerization reaction offers advantages in developing new processes or products.

Photopolymerizations provide both spatial control and temporal control of reactions, since light can be directed to locations of interest in the system and is easily shuttered on or off. Photopolymerizations also provide solvent-free formulations, which reduce the emissions of volatile organic pollutants, and they exhibit extremely rapid reaction rates. These advantages have led to tremendous growth in the application of photopolymerizations in the private sector, but much of this growth has occurred without a fundamental understanding of the underlying chemical processes.

The department’s research in this area focuses on comprehensive characterization of the kinetics, mechanisms, structure, and properties of photopolymerizations. Work includes the following types of studies: characterization of the photochemical processes by which polymerizations may be initiated; kinetic characterization of cationic photopolymerization; development of methods for photopolymerization of thick polymers and composites; development of photopolymerization systems based upon agricultural feedstocks; new methods for monitoring high-speed photopolymerization reactions; nanostructured materials through photopolymerization; biomedical devices formed by photopolymerization; and influence of order on photopolymerization reactions.

Chemical and biochemical engineering researchers are members of the Photopolymerization Center, an industry/university cooperative center on fundamentals and applications of photopolymerization. The center brings together experts from the University of Iowa, the University of Colorado, and member companies such as 3M, DSM, and Boeing. In addition, interdisciplinary collaborations are fostered on campus through the
The Master of Science program in chemical and biochemical engineering requires a minimum of 30 s.h. of graduate credit, with or without thesis. All M.S. students must earn at least 24 s.h. in approved graduate-level course work; courses numbered below 3000 do not count toward this requirement. Thesis students earn 6 s.h. in CBE:5999 M.S. Thesis Research: Chemical and Biochemical Engineering. Nonthesis students earn 6 s.h. in additional approved course work and are required to complete four core courses with a g.p.a. above 3.25 for those courses.

M.S. students must maintain a graduate g.p.a. of at least 3.00. Each thesis student must pass a final M.S. examination.

There is no world languages requirement.

Graduate students who receive assistantships, fellowships, or other financial support awarded with the understanding that they will pursue an advanced degree with thesis may not elect the nonthesis option.

Graduate students in the nonthesis program may petition for entry into the thesis program or the Ph.D. program by requesting a change of status through the Graduate College. The request is reviewed by the graduate admissions committee. If approved by the committee, it is forwarded to the chemical and biochemical engineering faculty for final approval. Students then are assigned to research advisors as though they were newly admitted graduate students. For a detailed description of program requirements, see CBE Graduate Program on the Department of Chemical and Biochemical Engineering web site.

The Doctor of Philosophy program in chemical and biochemical engineering requires a minimum of 72 s.h. of graduate credit. However, the degree is granted primarily on the basis of achievement rather than on the accumulation of semester hours. Candidates usually are expected to have completed three academic years in residence, or two years if they already hold a recognized master's degree.

All candidates must complete a core course requirement, which consists of a course in transport phenomena, a course in reaction engineering, a course on proposal writing, and a thermodynamics course, as well as six additional courses (total of 30 s.h.). There is no world languages requirement.

Ph.D. candidates must maintain a graduate g.p.a. of at least 3.25.

All doctoral students are required to satisfy a qualifying requirement and pass a comprehensive examination before they can become candidates for the degree. The Ph.D. comprehensive examination is the presentation and defense of the candidate’s Ph.D. research proposal. These examinations are arranged by members of the examining committee and may be repeated at the committee's discretion. Comprehensive examination policies are published in the Manual of Rules and Regulations of the Graduate College. A final examination, which is a defense of the thesis, completes the doctoral program. For a detailed description of program requirements, see CBE Graduate Program on the Department of Chemical and Biochemical Engineering web site.

Applicants must meet the admission requirements of the Graduate College; see the Manual of Rules and Regulations of the Graduate College.

Applicants should have a B.S. in chemical engineering or related discipline, with satisfactory grades, from a recognized college or university in the United States, and a g.p.a. of at least 2.80. Students who do not meet these requirements may be granted conditional admission, with the department chair’s approval. Graduates of non-U.S. universities may be accepted, depending on evaluation of their records.

Applicants must submit their verbal and quantitative scores on the Graduate Record Examination (GRE) General Test with their applications.

Graduate courses in chemical and biochemical engineering are designed for students who have an undergraduate background in chemical engineering. Exceptional students from other areas also may apply for admission to the M.S. or the Ph.D. program in chemical and biochemical engineering. If admitted, they may be required to take specific undergraduate courses to prepare them for graduate course work.

A number of fellowships, assistantships, and scholarships are awarded on a competitive basis to graduate students who qualify.

Graduate students have the opportunity to receive interdisciplinary research training in several fellowship programs administered through the Center for Biocatalysis and Bioprocessing (CBB). The program provides research training in areas that combine basic and applied research. Each year the center offers fellowships to doctoral students in biotechnology. These are funded by grants from the National Institute of General Medical Sciences, National Institutes of Health (NIH), National Science Foundation (NSF), and the CBB with funding from the State of Iowa. Through these programs, chemical and biochemical engineering students interact with students and faculty members from biochemistry, biology, chemistry, civil and environmental engineering, medicinal and natural products chemistry, and microbiology.

The Materials Science Laboratory is equipped with optical microscopes and facilities for metallographic preparation. Mechanical tensile testing instruments, heat treatment and sintering furnaces, and hardness testing machines also are available. Teaching aids include metallography specimen kits and crystallography packages.
Required Undergraduate Laboratories

CHEMICAL ENGINEERING LABORATORY

The Chemical Engineering Laboratory provides instruction for undergraduate students in CBE:3150 Thermodynamics/Transport Laboratory and CBE:3155 Chemical Reaction Engineering/Separations Laboratory. It is equipped for experimentation in thermodynamics, fluid flow, heat transfer, mass transfer, chemical reaction engineering, and separations. The laboratory includes pilot plant equipment, such as a distillation column, wiped film evaporator, shell-and-tube heat exchanger, jacketed kettle, and agitated extractor. Other equipment includes a concentric tube heat exchanger, reciprocating plate extractor, membrane gas separator, fluid friction apparatus, and heat conduction apparatus. Analytical equipment includes gas chromatographs, UV/visible spectrophotometers, polarimeters, and refractometers.

The laboratory is continuously updated to reflect advances at the forefront of chemical engineering technology. Additionally, a wide array of small equipment is available to support laboratory projects and demonstrations in chemical engineering courses and for use by students performing independent investigations.

CHEMICAL PROCESS SAFETY LABORATORY

The Chemical Process Safety Laboratory is an integral part of CBE:3125 Chemical Process Safety. It is equipped with two Miniflash automatic flash point tester (closed cap), an advanced reactive system screening tool (ARSSST), a minimum ignition energy (MIE) apparatus, a flammability chamber, a modified Hartmann tube, a Hartmann bomb, a liquid conductivity apparatus, a powder changeability apparatus, a powder volume resistivity apparatus, a Van de Graaff generator, two high impedance electrometers, a field meter, a Faraday cage, and relief sizing software. This equipment is used in a series of experiments to demonstrate the principles of flammability, reactivity, explosions, relief valve sizing, and electrostatics relevant to industry.

BIOCHEMICAL ENGINEERING LABORATORY

The Biochemical Engineering Laboratory is an integral part of CBE:5205 Introduction to Biochemical Engineering. It is equipped with two controlled New Brunswick BioFlo CelliGen 115 bioreactors, three New Brunswick C76 Water Bath Shakers, a UV/visible spectrometer, a Thermo Scientific Nanodrop 3300 fluorospectrometer, and a YSI 2700 Select Biochemistry Analyzer. This equipment is used to study the growth and metabolism of microorganisms and recombinant protein production.

PROCESS CONTROL LABORATORY

The Process Control Laboratory is a modern, computer-based instructional laboratory that is integral to CBE:4105 Process Dynamics and Control in Design. The laboratory consists of computer control of a shell-and-tube heat exchanger, and a level-and-flow control process rig with state-of-the-art industrial control interfaces.

The Computer Control Laboratory offers an ensemble of learning experiences with the same equipment.

Additional laboratories provide instruction in the use of process simulators that provide analogies and better insight into the control process. Topics include determination of the gain and time constants for single-capacitance systems; determination of gain, time constant, and damping factor of second-order processes; determination of open-loop and closed-loop response to step-and-ramp changes in input for single-capacitance and multicapacitance processes; approximations of multicapacitance systems as first-order and second-order processes with dead time; analysis of instrumentation characteristics and transfer functions; tuning and optimization of feedback control parameters (P, PI, PID); system identification through frequency response methods; and determination of system stability.

Experimental arrangements in the laboratory are simple enough in design to be easily understood, yet complicated enough to help students appreciate system characteristics inherent in industrial processes (e.g., large time lags, error in parameter estimation).

Graduate Facilities and Laboratories

The department offers a wide variety of facilities to support and develop research activities.

AIR POLLUTION COMPUTATIONAL, FIELD, AND LABORATORY STUDIES

The department maintains extensive facilities for computational, field, and laboratory studies of air pollution, carbon cycle gases, aerosols, and nanoparticles at the Center for Global and Regional Environmental Research (CGRER). The center occupies 5,000 square feet of laboratory and office space on the fourth floor of the Iowa Advanced Technology Laboratories.

CGRER houses one R2 ImmersaDesk Portable Large Scale Visualization System and is linked on campus to two more R2 ImmersaDesk units.

The center’s computer laboratory for environmental and spatial data analysis provides numerous Windows and UNIX workstations, sophisticated software packages, and workstations and a file server necessary to run intensive visualization programs. The network backbone is University supported with high-speed wireless throughout. A variety of digital environmental databases and an extensive library of documentation and related references are available. There are 4 Beowulf Linux clusters on site and Linux clusters of 4, 16, 18, and 20 nodes for large computations and data assimilation. CGRER retains 15 TB of redundant storage and 50 TB of total storage; local storage space is scalable and expandable. A variety of software packages and programming languages are available for data analysis and display, including Arc/Info, Arcview, NCAR Graphics, Matlab, S-Plus, and Vis5d, as well as geographical information software. The ESRI software suite is part of a University-wide site license.

Laboratory and field equipment includes aerosol samplers, including scanning mobility particle sizers for aerosols from 3 nm to 1 micron with time resolution to 30 seconds; aerosol particle sizers for aerodynamic measurements of in situ particles with time resolution to 1 second; and varied condensation particle counters for measuring total particle counts. Several hygroscopic tandem differential mobility analyzers are used, as well as varied aerosol generation devices and unique aerosol inlets for RH and temperature modification and control. Cloud droplet number can be measured in the lab or in the field using a Droplet Measurement Technologies cloud condensation nuclei detector. Advanced computer control of instruments is available through Labview.
Selected instruments are field deployable in a custom air-conditioned trailer. Through collaboration with the IIHR—Hydroscience & Engineering, access to micrometeorology sensors, 1-D and 2-D elastic and Raman LIDAR, and gas sensors is available, including multichannel ammonia monitors.

**BIOCHEMICAL ENGINEERING**

Biochemical engineering laboratories provide facilities for preparation of biological media and cultivation of organisms as well as for separation and analysis of biomolecules. This equipment includes biological incubators and floor incubator shakers, agitated and airlift bioreactors, light microscopes, autoclaves, Vi-Cell cell counter, thermocycler for PCR amplification of DNA, high- and low-speed centrifuges, UV-Vis spectrophotometers, a lyophilizer, biological safety cabinets, and an anaerobic glove box. Phase-contrast and epifluorescence microscopes, gel electrophoresis systems, gas chromatography units with flame ionization and electron capture detectors, and several high-performance liquid chromatography systems with refractive index and photodiode array detectors are available for characterization of microorganisms and constituent biomolecules. In addition, the lab has multiple extremophile cultivation systems including a high-pressure (0.1-100 MPa) cell cultivation system, several continuous cultivation systems, and high-temperature oil bath shakers for physiological studies of extremophilic microbes.

Through collaborative research agreements, graduate students also have access to specialized facilities for electron microscopy, large-scale fermentation, protein structure, recombinant DNA research, and tissue culture/hybridoma; the Flow Cytometry Facility; and the High Resolution Mass Spectrometry Facility.

**BIOMEDICAL ENGINEERING**

The biomedical engineering laboratories house particle technology equipment including microemulsion equipment for drug encapsulation, sonicators, benchtop scale spray dryers, laser diffraction particle sizer, zetapotentiometer; DNA preparation equipment, gel electrophoresis apparatus; interfacial stress rheometer, surface tensiometer, UV-Vis/fluorescent plate reader, high-performance liquid chromatograph, luminometer, lyophilizer, custom-built simulated cough machine, microscopes, incubators, wet chemistry equipment, rotary shakers, incubated plate shakers, autoclave, centrifuges, and laboratory computers. Cell culture and bacterial culture facilities are housed adjacent to the laboratories.

Graduate students also have access to core research facilities including the Central Microscopy Research Facility, Flow Cytometry Facility, Iowa Institute of Human Genetics, Electron Spin Resonance Facility, Nuclear Magnetic Resonance Facility, High Resolution Mass Spectrometry Facility, and the Center for Gene Therapy.

**COMPUTER FACILITIES**

The departmental computer facilities contain a variety of graphics workstations, printers, and microcomputers. The department is supported by the college’s Engineering Computer Services, which maintains a large network of high performance UNIX and Windows XP workstations along with extensive commercial and public domain software. The department also has access to the University’s central research facility in high-speed vector computation. This facility has SGI Power Challenger minisupercomputers and provides nodes for external links for access to supercomputers.

**FUNDAMENTALS AND APPLICATIONS OF PHOTOPOLYMERIZATION**

The Photopolymerization Center was established to advance fundamental understanding of the kinetics and mechanisms of photopolymerizations. To this end, the center provides unique opportunities for collaborations by industrial and academic investigators to explore photopolymerization processes and develop novel applications based on photopolymerizations.

The center provides equipment and instrumentation for the characterization of photopolymerization systems on the molecular, microscopic, and macroscopic levels. Center researchers pursue understanding of fundamental photophysical and photochemical processes involved in the photoinitiation reaction; characterization of high-speed propagation and termination kinetics that lead to the polymer structure; and evaluation of material properties through the course of the photopolymerization reaction. Both radical and cationic photopolymerizations are studied with state-of-the-art experimental techniques to elucidate the complex chemical and physical mechanisms that control the initiation, propagation, and termination of the active centers.

**Courses**

**General Topics**

**CBE:0000 Cooperative Education Training Assignment: Chemical Engineering**

Chemical engineering students participating in the Cooperative Education Program register for this course during work assignment periods; registration provides a record of participation in the program on the student's permanent record. Requirements: admission to Cooperative Education Program.

**CBE:0002 Half-time Cooperative Education Training Assignment: Chemical Engineering**

Registration for work assignment periods; for students participating in the Cooperative Education Program.

**CBE:1000 CBE Departmental Seminar**

1 s.h.

Introduction to the profession and the department; presentations by guest speakers, visits to laboratories and industries.

**CBE:1180 First-Year Seminar**

1 s.h.

Small discussion class taught by a faculty member; topics chosen by instructor; may include outside activities (e.g., films, lectures, performances, readings, visits to research facilities, field trips). Requirements: first- or second-semester standing.
CBE:2030 Energy and Society 3 s.h.
History of energy development and use throughout the world; how energy has affected the development of human societies; societal impact of engineering advances; current state of energy consumption worldwide, including distribution of energy sources, global variations in consumption, advantages and disadvantages of current energy sources; role of fossil fuel consumption in global climate change; potential scenarios for the future of energy.

CBE:2105 Process Calculations 3 s.h.
Fundamental principles of chemical process analysis, including material and energy balances for single-unit and multiple-unit processes, analysis of reactive and nonreactive systems, introduction to equations of state, thermodynamics of multiphase systems. Prerequisites: MATH:1550.

CBE:3000 Professional Seminar: Chemical Engineering 1 s.h.
Professional aspects of chemical engineering presented through lectures and discussions by guest speakers, field trips, films, panel discussions. Prerequisites: CBE:2105. Requirements: sophomore standing.

CBE:3105 Chemical Engineering Thermodynamics 3 s.h.
Applications of thermodynamic principles to chemical and physical processes; prediction of material properties; phase and chemical equilibria applied to mixtures and reacting systems. Prerequisites: ENGR:2130. Corequisites: CBE:2105.

CBE:3120 Chemical Reaction Engineering 3 s.h.
Application of chemical reaction kinetics to design of chemical reactors: batch reactors, mixed flow reactors, plug flow reactors; reversible and irreversible single reactions; parallel, series, and mixed reactions; temperature and pressure effects on reactor design; heterogeneous catalysis; transport in porous catalysts. Prerequisites: CBE:3115.

CBE:3150 Thermodynamics/Transport Laboratory 3 s.h.

CBE:3155 Chemical Reaction Engineering/ Separations Laboratory 2 s.h.
Experimental design, data collection techniques, report writing, oral presentations; laboratory investigations of chemical reaction engineering and separations; experiments with plug flow and batch reactors, distillation, evaporation, membrane separation. Prerequisites: CBE:3115 and CBE:3150. Corequisites: CBE:3120.

CBE:3998 Individual Investigations: Chemical Engineering arr.
Individual projects for chemical engineering undergraduate students, such as laboratory study, engineering design project, analysis and simulation of an engineering system, computer software development, research.

CBE:4195 Senior Enriching Activities 0 s.h.
Seminar
Aspects of chemical engineering education, including multidisciplinary team skills, understanding the impact of engineering practice locally and globally. Corequisites: CBE:4110.

CBE:4410 Sustainable Systems 3 s.h.
New and emerging concepts in sustainable systems design and assessment. Same as CEE:4107.

CBE:5104 Introduction to Literature Review and Technical Writing 3 s.h.
Review of technical literature, how to contribute to it; produce and present orally a peer-reviewed-journal-quality review article; brainstorming, group writing, research ethics, plagiarism. Recommendations: nonthesis track graduate standing.

CBE:5105 Introduction to Literature Review and Proposal Writing 3 s.h.
Tools for reviewing literature, skills for critical reading of publications, training in successful proposal writing; experience drafting a proposal that can be used as a starting point for the Ph.D. comprehensive.

CBE:5110 Intermediate Thermodynamics 3 s.h.
Fundamental principles of thermodynamics as applied to phase equilibrium; properties of fluids, first and second law, variable composition systems, behavior of real fluids, mathematical techniques for solution thermodynamics. Requirements: CBE:3105 or ME:3040 or graduate standing. Same as ME:5210.

CBE:5140 Mathematical Methods in Engineering 3 s.h.

CBE:5199 Contemporary Topics: Chemical and Biochemical Engineering arr.
Research techniques for graduate students in chemical and biochemical engineering. Requirements: graduate standing.

CBE:5240 CEBC Colloquium 1 s.h.
Sustainable development issues addressed by guest speakers from chemical industries; process economics, environmental impact assessment.

CBE:5390 Photopolymerization Topics 1 s.h.
Seminars presented by faculty members, research assistants, students.
Biochemical Engineering

CBE:5205 Introduction to Biochemical Engineering 3 s.h.
Biochemistry, cellular biology, recombinant DNA and hybridoma technologies; emphasis on engineering aspects of biotechnology, including enzyme kinetics, cell growth kinetics, transport phenomena in bioreactors, bioreactor design, bioseparations, formulation and sterilization of growth media, commercial applications of biotechnology. Prerequisites: CBE:3120.

CBE:5210 Bioseparations 3 s.h.
Unit operations used to isolate and purify biologically-derived chemicals, including flocculation, filtration, centrifugation, extraction, adsorption, chromatography, precipitation, crystallization, electrophoresis and cell disruption for intracellular product recovery.

CBE:5215 Advanced Biochemical Engineering 3 s.h.
Advanced concepts regarding behavior of biological systems used in modern technologies (e.g., food processing, pharmaceutical production, environmental remediation, chemical synthesis); principles of biochemical engineering applied to design, development, and analysis of processes that use biocatalysts; second in series addressing engineering aspects of biotechnology. Recommendations: CBE:5205.

CBE:5250 Introduction to Biocatalysis 3 s.h.
Applications of biological catalysis in varied industries; potential of biological catalysis to address future challenges in science and engineering.

CBE:5875 Perspectives in Biocatalysis 1-3 s.h.
Applied enzymology, protein design, structure-activity relationships, biosensor technology, microbial transformations, biodegradation of environmental pollutants. Requirements: graduate standing in a participating department supported by the Predoctoral Training Program in Biotechnology. Same as CHEM:5875, PHAR:5875, CEE:5875, MICR:5875, BIOC:5875.

CBE:6210 Biotechnology of Extremophiles 3 s.h.
Evolution and engineering of biocatalysis under extreme conditions; physiological, kinetic, and molecular behavior of systems that perform under extremes of temperature, pH, salinity, pressure, solvent concentrations.

Environmental Engineering

CBE:3160 Engineering Analysis of Alternative Energy Systems 3 s.h.
Engineering and sustainability analyses of conventional and emerging energy technologies; alternative energy sources, including biomass, wind, solar, geothermal; alternative energy carriers (transportation fuels), including varied biofuels, hydrogen, natural gas, ammonia. Prerequisites: ENGR:2130.

CBE:4459 Air Pollution Control Technology 3 s.h.
Sources, environmental and health impacts, regulations, modeling of air pollution; processes and alternative strategies for control; global climate considerations. Prerequisites: CEE:2150. Same as CEE:4159.

CBE:5152 Environmental Chemistry I 3 s.h.
Principles of general, physical, organic chemistry applied in water and air systems; emphasis on qualitative and quantitative understanding of chemical kinetics and equilibrium; acid-base reactions, complex formation, precipitation, dissolution, and oxidation-reduction reactions; organic nomenclature. Prerequisites: CHEM:1120. Same as CEE:5152.

CBE:5405 Green Chemical and Energy Technologies 3 s.h.
Strategies for pollution prevention for chemical processes studied at the macroscale (industrial sector), the mesoscale (unit operations), and the microscale (molecular level); case studies. Prerequisites: CBE:2105.

CBE:5425 Atmospheric Chemistry and Physics 3 s.h.
Principal chemical and physical processes affecting atmospheric trace gas and pollutant cycles; emphasis on atmospheric photochemistry, aerosol science, major sources and removal processes. Corequisites: CBE:3120. Same as CEE:5115.

Transport Phenomena

CBE:3110 Engineering Flow and Heat Exchange 3 s.h.
Fundamentals of fluid flow and heat transfer; fluid rheology, boundary layer theory, potential flow, dimensional analysis, laminar and turbulent flow in pipes, flow through packed beds, fluidized beds, pumps, flow measurement, filtration, heat exchanger design, and conductive, convective, and radiative heat transfer. Corequisites: CBE:2105.

CBE:3115 Mass Transfer and Separations 3 s.h.
Mechanisms of diffusional mass transfer; solution of industrial problems, including the design of distillation, extraction, absorption, adsorption, drying, membrane processes; mechanical separations. Prerequisites: CBE:3105 and CBE:3110.

CBE:5115 Transport Phenomena I 3 s.h.
Unified treatment of momentum, mass, energy transport in chemical engineering problems; use of vector and tensor notations in expressing equations of continuity, motion, energy.

CBE:6145 Diffusive Transport 3 s.h.
Diffusive transport of heat, mass, and momentum; phenomenological laws and analogies; analytical and numerical solution techniques; inverse heat conduction; multiphase and multicomponent systems. Prerequisites: ME:5145. Same as ME:6245.

Materials Science

Microscopy methods for research; all aspects of research, from sample preparation to imaging to data analysis; when to use a particular microscopy procedure; theory, operation, and application of scanning electron microscopy, scanning probe microscopy, laser scanning microscopy, X-ray microanalysis. Requirements: a physical science course. Same as ACB:4156, EES:4156.
CBE:5309 Polymer Fundamentals  1 s.h.
Basic knowledge of polymers required as a foundation for other UI courses on polymers: basic polymer terminology, polymer groups, polymerization mechanisms, molecular weight determination. Five weeks. Same as BME:5415.

CBE:5310 Polymer Science and Technology  3 s.h.
Uses, properties of industrially important polymeric materials; polymer chemistry, polymer structure, characterization, polymer processing. Prerequisites: CHEM:2220. Corequisites: CBE:3120.

CBE:5315 Polymer Chemistry  3 s.h.
Monomer reactivity and polymerization reactions; step, radical, ionic, and ring-opening polymerizations. Prerequisites: CHEM:2220.

Process Dynamics, Design, Analysis

CBE:3125 Chemical Process Safety  3 s.h.
Application of transport phenomena, thermodynamics, chemical kinetics to study of safety, health, loss prevention; government regulations, toxicology/industrial hygiene, relief sizing, runaway reactions, toxic release and dispersion models, source models, fires and explosions, risk assessment, hazard identification, case studies and accident investigation, incorporation of safety into design; laboratory experiments. Prerequisites: CBE:3115. Corequisites: CBE:3120.

CBE:4105 Process Dynamics and Control in Design  3 s.h.
Theory and application of process dynamics to the design of chemical process control systems; mathematical models of unit operations, transfer functions, feedback and feed-forward control, stability, instrumentation, digital control systems; computer methods, including simulation and commercial software use; laboratory focus on process analysis and design. Prerequisites: CBE:3120.

CBE:4109 Chemical Engineering Process Design I  2 s.h.
Engineering economics of process evaluation, including time value of money and bases for cost estimation; preliminary design of chemical process plants using computer-aided engineering. Prerequisites: CBE:3115 and CBE:3120 and CBE:3125.

CBE:4110 Chemical Engineering Process Design II  3 s.h.
Capstone chemical engineering course; design and optimization of chemical process plants; application of process calculations, thermodynamics, kinetics, process synthesis, energy efficiency in separations, heat-exchanger network synthesis, physical property estimation, safety, computer-aided design, unit operations theory, process control, and economics. Prerequisites: CBE:4109.

Graduate Seminars, Advanced Topics, Research

CBE:5000 Seminar in Chemical and Biochemical Engineering  1 s.h.
Presentation and discussion of recent advances and research in chemical and biochemical engineering by guest lecturers, faculty, students. Requirements: graduate standing.

CBE:5100 Graduate Professional Development Seminar  1 s.h.
Seminar participants work with a faculty member to select and attend eight hours of approved seminars and professional development trainings at the University of Iowa; final meeting of participants is held to share notable seminars; typical seminar series include College of Engineering lectures, departmental and research center graduate seminars, the CBE professional seminar series, offerings of the Center for Teaching and Learning. Requirements: CBE masters standing.

CBE:5998 Individual Investigations: Chemical and Biochemical Engineering  arr.
Individual projects for chemical and biochemical engineering graduate students; may include laboratory study, engineering design project, analysis and simulation of an engineering system, computer software development, research. Requirements: graduate standing.

CBE:5999 M.S. Thesis Research: Chemical and Biochemical Engineering  arr.
Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for M.S. with thesis in chemical and biochemical engineering. Requirements: graduate standing.

CBE:7999 Research: Chemical and Biochemical Engineering Ph.D. Dissertation  arr.
Experimental and/or analytical investigation of an approved topic for Ph.D. in chemical and biochemical engineering.