Chemical Engineering

Department of Chemical and Biological Engineering

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Overview

Chemical engineering concerns the design, scale-up, and operation of chemical processes, and the understanding and design of technologically useful materials. Chemical engineers are responsible for the economical, safe, and environmentally benign production of useful quantities of vital materials - from grams of a new drug to tons of a commodity chemical. Chemical engineers use these same skills to understand and manipulate natural processes, such as in biological systems. The program at UB is broadly based to prepare graduates for positions in engineering development, design, economic evaluation, sales, construction, production, and management. A number of undergraduates go on to graduate work and careers in research, and some pursue degrees in medicine, business, or law.

Students intending to major in chemical engineering should have strong backgrounds in chemistry and mathematics. Sophomore- and junior-year students take a combination of theoretical and applied courses in chemical engineering, in addition to several courses in biology and physical and organic chemistry. The senior year extends this base and builds upon it with courses in systems, design and electives. Many of the courses are accompanied by laboratory sessions. Communication skills, both oral and written, are stressed through laboratory reports. Some senior students are exposed to research in a senior projects course; others obtain industrial experience through local internships or through the engineering co-op program.

Our curriculum is designed to meet several educational objectives, which are stated as goals and abilities we expect our graduates to achieve within a few years of the conferral of their degree. Our educational objectives read as follows:

Within a few years of obtaining a bachelor's degree in chemical engineering from the University at Buffalo, the recent graduate:

- Demonstrates professional engineering competence, via promotions and/or advancement to positions of increasing responsibility; via satisfactory progress towards completion of an advanced degree; or via a successful transition from the "traditional" chemical engineering career path into medicine, business, government, education, etc.
- Develops and implements innovative and effective solutions to difficult problems. Shows proficiency in the application of engineering science in the presence of practical constraints or complicating factors to solve real-world technical problems.
- Grows continuously in the range of people with whom he/she interacts professionally. Assumes responsibilities that require increasingly broad and diverse interpersonal interactions, indicating the ability to relate well to superiors, subordinates, and peers, inside or outside the organization, perhaps involving difficult circumstances. Provides input to others' work that enables them to do their job better. Reaches team leadership positions.
- Demonstrates excellence and leadership in ethical standards, on-the-job safety, and environmental protection through participation in appropriate training activities, short courses, or conferences; through employer recognition for achievement in the corresponding professional practice (e.g. safety awards); or by assumption of recognized leadership positions in these areas (e.g. safety officer).
- Communicates his/her ideas, findings, and knowledge through the composition of papers and/or internal reports; authorship of standards and guidelines; publication of scholarly articles; application for patents; delivery of effective presentations to group leaders, internal and external customers, and at technical conferences; and/or training of coworkers and associates.
- Engages in life-long learning via participation in a professional society, continuing education course(s), professional engineering certification, professional development course(s), and/or industry training course(s).

About our Degrees

The chemical engineering BS degree is accredited by the Accreditation Board of Engineering and Technology (ABET) and prepares students for graduate study and/or professional practice.

Acceptance Information

See the School of Engineering and Applied Sciences Acceptance Criteria in the Undergraduate Catalog.

Degree Requirements

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Please see Degrees and Policies.

About our Courses

The curriculum includes many elective courses that permit the student to pursue particular interests related to chemical engineering. Often these are used by the student to develop depth in chemistry, biology, environmental engineering, information technology, or materials science; other students use these courses across disciplines to develop instead their breadth of expertise.

The typical class size for:

Sophomore/intermediate courses is: 70
Upper level/advanced courses is: 55

In Chemical Engineering, what do teaching assistants (TAs) do?

TAs grade homework and supervise labs.

For course descriptions, please see Courses.

About our Faculty

Faculty are very active in education and research, and are well recognized within and outside the university for their accomplishments. Distinctions include four recipients of the SUNY Chancellor's Award for Excellence in Teaching, six National Science Foundation Young Investigator awards, three members of the National Academy of Engineering, a recipient of the National Medal of Science, a recipient of the National Medal of Technology (the National Medal provides the nation's highest scientific/technology honor), as well as numerous other national research and teaching awards. Our faculty ranks also include two SUNY Distinguished Professors and a SUNY Distinguished Teaching Professor.

See a list of our Undergraduate Faculty.

Transfer Policy

Transfer students must first apply to the university and meet the university transfer admission requirements. For admission of transfer students to engineering, see the School of Engineering and Applied Sciences Transfer Policy section.

Extracurricular Activities

The student chapter of the American Institute of Chemical Engineers (AIChE) is very active, and hosts many fundraisers to support group activities. Each year students participate in the national "Chem-E Car" competition, traveling to the national meeting to compete.

Students and faculty also have regular joint activities, such as bowling outings and an annual banquet. Town meetings are held each semester to solicit feedback and constructive criticism from students on the curriculum and operation of the courses.

See the UB Student Association.

Practical Experience and Special Academic Opportunities

Notable Program Features

Honors, Awards, and Scholarships
Students enrolled in the B.S. CE program may participate in the departmental Honors Program during their senior year. Application forms for the CE Honors Program are available in the departmental office, 303 Furnas Hall, North Campus. CE Honors students must achieve a GPA of 3.20 or higher in all required chemical engineering courses. Requirements for honors also include 6 credits of independent study supervised by a member of the faculty and participation in the department's Research Fair. During the first semester of independent study the student enrolls in either CE 496 (industrial-based project) or CE 498 (university research-based project). This experience may be used to satisfy one of the CBE technical elective requirements for the CE degree. During the second semester of independent study the student enrolls in CE 497, which culminates in the completion and defense of an undergraduate thesis. The three credits obtained via participation in CE 497 are in addition to

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the standard requirement for the B.S. CE degree, i.e., the course does not satisfy a CBE technical elective requirement. Departmental honors are noted on transcripts as highest distinction (GPA of 3.75 to 4.00), high distinction (3.50 to 3.74), or distinction (3.20 to 3.49).

Internships and Co-Ops
Students are encouraged to participate in work experience classes and research opportunities as part of their undergraduate experience

Work experience opportunities are posted via UB's Career Services BullsEye website. Occasionally, information regarding opportunities may be distributed via the departmental listserv. In many cases, students can receive academic credit for their work experiences by participating in CE 496 Internship/Practicum. Interested students should contact the CBE Internship Coordinator for more information.

Undergraduate Research and Practical Experience
Undergraduate research experiences are available for course credit. The Center for Undergraduate Research and Creative Activity serves as a clearing house for information regarding undergraduate research opportunities. Alternatively, research activities may instead be arranged directly between students and faculty members

Career Information and Further Study

Any company concerned with the design, production, or use of materials has need for chemical engineers. Consequently, many diverse industries employ chemical engineers. Historically a large fraction work for either petroleum or chemical companies, but lately many are finding employment in nontraditional industries, such as electronics. BS graduates find work in production, design, operations, sales, or process development. With further study graduates also move into careers in medicine, law, education, and management.

The AIChE and Sloan Career Cornerstone Center have much more detailed information about careers and opportunities. See www.aiche.org and www.careercornerstone.org, respectively.

Salary Information

A typical starting salary is now about $65,000/year (up-to-date information can be found at the AIChE or the U.S. Department of Labor web sites). A BS is sufficient for a typical starting position, except research and development where a master's degree or PhD is needed.

What percentage of graduates goes on to find related employment?

Variable with year; sometimes close to 100%. Up-to-date information for the profession is available at the AIChE web site.

What percentage of graduates goes on to graduate school? 25%

Additional Resources

American Institute of Chemical Engineers (AIChE)

Degree Options

In addition to the regular BS program, a five-year BS-CE/MBA combined degree program has been established. Also, the Department of Biological Sciences offers a special biotechnology minor exclusively for chemical engineering majors. Details may be obtained at the department web site.

Degrees Offered

Undergraduate: BS
Combined: BS/MBA

Links to Further Information About this Program

- Undergraduate Catalog
- Undergraduate Admissions
- Graduate Admissions
- Department of Chemical and Biological Engineering
- School of Engineering and Applied Sciences

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Chemical Engineering - B.S.

Acceptance Criteria

See the School of Engineering and Applied Sciences Acceptance Information section.

Advising Notes

Students must meet minimum GPA requirements in engineering as specified by the Dean of Engineering to graduate from the program. See the School of Engineering and Applied Sciences Academic Requirements section.

Students must satisfy a departmental residency requirement that stipulates that a maximum of four courses from another school may be used as substitutes for required (14 total) and elective (2 total) CE courses. CBE places no limits (beyond those already imposed by the University and School of Engineering) on the number of BIO, CHE, MTH, PHY, EAS, general technical electives, and general education transfer credits that are applied to BS degree requirements.

Required Courses

BIO 201 Cell Biology
CE 212 Fundamental Principles of Chemical Engineering
CE 304 Chemical Engineering Thermodynamics
CE 317 Transport Processes I
CE 318 Transport Processes II
CE 327 Chemical Engineering Laboratory I
CE 328 Chemical Engineering Laboratory II
CE 329 Chemical Reaction Engineering
CE 341 Applied Mathematics for Chemical Engineers
CE 404 Chemical Engineering Product Design
CE 407 Separations
CE 408 Chemical Engineering Plant Design
CE 427 Chemical Engineering Laboratory III
CE 428 Chemical Engineering Laboratory IV
CE 433 Materials Science and Engineering
CE 434 Chemical Systems and Control
CHE 107 General Chemistry for Engineers
CHE 108 General Chemistry for Engineers
CHE 201 Organic Chemistry
CHE 204 Organic Chemistry or BIO 205 Fundamentals of Biological Chemistry
CHE 334 Physical Chemistry for Chemical Engineers
EAS 140 Engineering Principles
EAS 202 Engineering Impact on Society
EAS 230 Engineering Computation
MTH 141 College Calculus I
MTH 142 College Calculus II
MTH 241 College Calculus III
MTH 306 Introduction to Differential Equations
PHY 107 General Physics I
PHY 108/PHY 158 General Physics II/Lab
One 200/300/400-level technical elective
Two chemical engineering technical electives

Summary
Total required credit hours for the major: 111

See Baccalaureate Degree Requirements for general education and remaining university requirements.

Recommended Sequence of Program Requirements

FIRST YEAR
Fall CHE 107, EAS 140, MTH 141
Spring EAS 202, CHE 108, MTH 142, PHY 107, EAS 230

SECOND YEAR
Fall CE 212, CHE 201, MTH 241, PHY 108/PHY 158
Spring CE 304, CHE 204 or BIO 205, MTH 306, BIO 201

THIRD YEAR
Fall CE 317, CE 327, CE 329, CE 341, CHE 334
Spring CE 318, CE 328, CE 407, CE 433, one 200/300/400-level technical elective

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FOURTH YEAR
Fall CE 404, CE 427, CE 434, one chemical engineering technical elective
Spring CE 408, CE 428, one chemical engineering technical elective

Chemical Engineering/Business Administration - B.S / M.B.A

Acceptance Criteria

Good standing as a chemical engineering student and acceptance as a graduate student by the School of Management.

Advising Notes

Admission to the MBA program is made through application to the Management School during the junior year.

The MBA courses listed here represent those currently required for the combined degree, but they are subject to change prior to a student's acceptance into the MBA program. Students should confirm MBA program requirements directly with the School of Management upon their application and acceptance to that program.

Required Courses

All courses required for the chemical engineering BS degree, minus the 200/300/400-level technical elective
MGA 603 Financial Accounting for Managers
MGA 605 Accounting for Management Decision Making
MGB 610 Organizational Behavior
MGB 611 Team Skills
MGE 604 Business Economics
MGF 611 Financial Analysis for Managers
MGG 601 Corporate Social Responsibility/Sustainability
MGG 635 Management Communication
MGM 615 Marketing for Managers
MGO 620 Operations Management
MGO 640 Business Strategy
MGO 642 Integration of Business Functions
MGO 644 Business Practice
MGQ 608 Statistical Analysis for Managers
MGQ 609 Analytics for Managers
MGS 605 IT Management
Seven MGT electives (may include internship)

**Students who have taken CIE 308 are exempt from MGQ 606*

Summary
Total required credit hours for the undergraduate portion: 108

See Baccalaureate Degree Requirements for general education and remaining university requirements.

Refer to the School of Management's MBA handbook for requirements for MBA candidates.

Recommended Sequence of Program Requirements

FIRST YEAR
Fall CHE 107, EAS 140, MTH 141
Spring EAS 202, CHE 108, MTH 142, PHY 107, EAS 230

SECOND YEAR
Fall CE 212, CHE 201, MTH 241, PHY 108/PHY 158
Spring CE 304, CHE 204 or BIO 205, MTH 306, BIO 201

THIRD YEAR
Fall CE 317, CE 327, CE 329, CE 341, CHE 334
Spring CE 318, CE 328, CE 407, CE 433

FOURTH YEAR
Fall CE 434, MGA 603, MGB 610, MGB 611, MGF 611, MGG 601, MGG 635, MGM 615, MGQ 608, MGQ 609

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Spring MGA 605, MGE 604, MGO 620, MGO 640, MGS 605, two CE technical electives

SUMMER
MBA practicum.

FIFTH YEAR
Fall CE 404, CE 427, four MGT electives
Spring CE 408, CE 428, MGO 642, MGO 644, three MGT electives

At completion, you will be awarded a BS diploma and an MBA diploma, with a transcript notation that these degrees were awarded as part of a combined degree program.

CE 100: Special Topics

Credits: 3
Pre-requisites: Permission of director of undergraduate studies
Type: LEC

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy *does not apply.*

Topics in the field of specialization selected with the permission of the instructor.

CE 200: Special Topics

Credits: 3
Pre-requisites: Permission of director of undergraduate studies.
Type: LEC

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy *does not apply.*

Topics in the field of specialization selected with the permission of the instructor.

CE 212: Fundamental Principles of Chemical Engineering

Credits: 4
Semester(s): Fall
Pre-requisites: CHE 108, MTH 142, and PHY 107 or PHY 101
Approved Engineering Majors Only
Type: LEC/REC

Integrates fundamentals of mathematics, physics, and chemistry into chemical engineering concepts; laws of conservation of mass and energy.

CE 300: Special Topics

Credits: 3
Pre-requisites: Permission of director of undergraduate studies
Type: LEC

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy *does not apply.*

Topics in the field of specialization selected with the permission of the instructor.

CE 304: Chemical Engineering Thermodynamics

Credits: 4
Semester(s): Spring
Pre-requisites: CE 212, MTH 241, CE anf BE majors only (for CBE majors, permission of CE advisor).
Type: LEC/REC

Applies the laws and tools of equilibrium thermodynamics to chemical engineering problems, including calculation of thermodynamic properties of pure fluids and mixtures, computation of energy requirements for changing the state of a system, analysis of phase equilibria (emphasizing vapor-liquid equilibrium), and treatment of chemical reaction equilibria.

CE 317: Transport Processes I

Credits: 4
Semester(s): Fall
Pre-requisites: MTH 241, PHY 107
Co-requisites: MTH 306
Approved Chemical Engineering Majors Only
Type: LEC/REC

Introduces fluid statics and dynamics with examples from chemical engineering operations. Applies macroscopic mass, energy, and momentum balances to fluid flow problems. Dimensional analysis and correlation of turbulent flow data. Theories of turbulence. The Navier-Stokes equations, momentum transport and velocity profiles in one-dimensional laminar flow, boundary layers, and potential flow.

CE 318: Transport Processes II

Credits: 4
Semester(s): Spring
Pre-requisites: CE 317, MTH 306, Permission of CBE advisor, CE majors only
Type: LEC/REC

The equations of change of heat and mass transport. Steady- and unsteady-state heat conduction in one and two dimensions. Free and forced convection; prediction and correlation of heat transfer. Mass transfer by diffusion and convection; analogies with heat transfer. Simultaneous mass transfer and chemical reaction.

CE 327: Chemical Engineering Lab I: Probability, Statistics, & Data Analysis

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Credits: 4
Semester(s): Fall
Type: LEC/LAB

Fundamentals of design, execution, analysis, and documentation of engineering experiments. One three-hour laboratory per week or equivalent.

CE 328: Chemical Engineering Laboratory II

Credits: 2
Semester(s): Spring
Type: LEC/LAB

Accompanies CE 318. Continuation of CE 327.

CE 329: Chemical Reaction Engineering

Credits: 3
Semester(s): Fall
Pre-requisites: CE 212, CE 304, MTH 306 or MTH 242
Approved Chemical Engineering Majors Only
Type: LEC

Chemical kinetics as applied to the design of chemical reaction equipment. Introduces the theory of reaction rates in homogeneous and heterogeneous systems; experimental methods; analysis of rate data; reactor types and design; selectivity in complex reaction systems.

CE 341: Applied Mathematics for Chemical Engineers

Credits: 3
Pre-requisites: EAS 230, MTH 241 and
Co-requisites: CE 212, MTH 306
Approved Chemical Engineering Majors Only
Type: LEC

This course covers fundamental numerical and computational methods for modeling physical phenomena and processes with a focus on chemical engineering applications. An emphasis is placed on the implementation of the numerical methods in a programming environment and computer based modeling of chemical engineering applications.Topics include the solution of linear and nonlinear algebraic equations, eigenvalue problems. application of finite difference methods, interpolation, differentiation and integration, solution of systems of ordinary differentialequations, boundary value problems, partial differential equations, and linear and nonlinear regression analysis. These methods are demonstrated via problems encountered in chemical engineering practice.

CE 400: Special Topics

Credits: 3
Pre-requisites: Approved Chemical Engineering Majors Only
Type: LEC

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy does not apply.

Topics in the field of specialization selected with the permission of the instructor.

CE 404: Chemical Engineering Product Design

Credits: 4
Semester(s): Fall
Pre-requisites: CE 433 and CE 318
Approved Chemical Engineering Majors Only
Type: LEC/REC

Integrates the general framework for product design and development with molecular structure-property relations, enables students to evaluate the design of existing products and participate in the design of improved and new products.

CE 405: Special Topics

Credits: 3
Pre-requisites: Approved Chemical Engineering Majors Only
Type: LEC

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy does not apply.

Topics in the field of specialization selected with the permission of the instructor.

CE 406: Chemical Engineering Projects

Credits: 3
Semester(s): Fall, Spring
Pre-requisites: Permission of director of undergraduate studies, Approved Chemical Engineering Majors Only
Type: TUT

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy does not apply.

Problems vary year to year, but may include chemical process studies, studies of engineering materials, computer analysis of specific chemical engineering problems. Problems announced in previous semester. Assignments, where possible, follow student preferences and require consent of faculty members who guide the work.

CE 407: Separations

Credits: 3
Semester(s): Spring
Pre-requisites: CE 212, CE Majors Only
Co-requisites: CE 304, CE 318
Type: LEC

Staged operations of distillation, absorption, leaching, and extraction. Phase equilibria and application of equilibrium data to calculational methods provide knowledge of solution methods and limitations for binary and multicomponent systems.

CE 408: Chemical Engineering Plant Design

Credits: 4
Semester(s): Spring
Pre-requisites: CE 318, CE 329, CE 407, CE 434
Approved Chemical Engineering Majors Only
Type: LEC/REC

Applies chemical engineering principles to the design of chemical plants and process equipment. Preliminary economic evaluations of plants. Process flow sheet development; material and energy

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balances; equipment specification, fundamentals of engineering economics and profitability analysis; strategies in process design and synthesis.

CE 410: Molecular Modeling

Credits: 3
Pre-requisites: CE 304, CHE 334
Type: LEC

Examines chemical and transport phenomena from a microscopic perspective. Topics include molecular simulation, advanced thermodynamics, and statistical mechanics.

CE 412: Special Topics

Credits: 3
Pre-requisites: Permission of director of undergraduate studies
Type: LEC

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy does not apply.

Topics in the field of specialization selected with the permission of the instructor.

CE 419: Alternative Fuels

Credits: 3
Pre-requisites: CE 329 and CE 407; or permission of instructor, CE Majors Only
Type: DIS

Examines several types of alternative fuels that might be used to replace fuels such as gasoline and diesel that are derived from crude oil. Discusses the technology, economics, and other aspects of converting crude oil into gasoline. Considers other fuels including ethanol and biodiesel, hydrogen, synthetic gasoline from coal or shale oil, and a few other, less likely possibilities. Understanding the chemical processing and technology involved will be a major objective, but the course will also stress the importance of making equitable comparisons between the technologies. In addition to technological issues, the alternative fuel technologies will be assessed with respect to environmental impact, economics, and economic impact, sustainability/renewability, vulnerability and capacity (US and worldwide).

CE 420: Rheology of Fluids

Credits: 3
Pre-requisites: Introductory course in fluid mechanics
Type: LEC

Technologies involving rheologically complex liquids; interpretation of rheological anomalies; stress, strain, and rate of deformation; rheological equations of state. Measures rheological parameters; laminar flow of rheologically complex liquids in pipes, stirred tanks, and porous media. Turbulent flow and drag reduction. Heat transfer.

CE 423: Green Engineering for Chemical Engineers

Credits: 3
Pre-requisites: Senior standing or permission of instructor
Type: LEC

Introduces the technological processes of Green Engineering. Discusses pollution problems of manufacturing of ammonia, sulfuric and nitric acids, and fertilizers. Presents an analysis of energy producing units as nuclear and coal-fired power-plants. Describes elimination of exhaust gases in Otto and Diesel engines. New ways of design of chemical, petrochemical and energy producing systems are evaluated based on green chemistry, new solvents and new synthetic pathways. Unit operations are discussed in relation to possible environmental impact. Presents an evaluation of the environmental performance of a flow-sheet.

CE 427: Chemical Engineering Laboratory III

Credits: 2
Semester(s): Fall
Pre-requisites: CE 318
Co-requisites: CE 329
Approved Chemical Engineering Majors Only
Type: LEC/LAB

Continuation of CE 328.

CE 428: Chemical Engineering Laboratory IV

Credits: 2
Semester(s): Spring
Type: LEC/LAB

A continuation of CE 427.

CE 433: Materials Science and Engineering

Credits: 3
Semester(s): Spring
Type: LEC/LAB

Properties of solids, which chemical engineers need to understand and exploit in regard to chemical processing and industrial equipment; how chemical and physical structures determine the uses of the products of the chemical industry. Crystal structure, crystal defects, and how they dominate mechanical properties. Thermal and electrical properties of solids. Polymer structures and properties. Corrosion: mechanisms and prevention.

CE 434: Chemical Systems and Control

Credits: 3
Semester(s): Fall
Pre-requisites: CE 212, MTH 306 or MTH 242
Approved Chemical Engineering Majors Only
Type: LEC/REC

Equips engineering students with the fundamental concepts of process control design. An introduction to the benefits of having a good control process is followed by the definitions of the control objectives, feedback and feedforward control, and the various types of variables found in process control problems. Includes the development of dynamic mathematical models for simple processes, using mass and energy balances. Introduces mathematical tools (Laplace Transformations) that help solve such mathematical models as well as define the transfer functions of typical process systems (first and second order systems). Introduces the controller concept, together with the basic principles behind the feedback control loop and its stability characteristics.

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CE 435: Introduction to Polymers

Credits: 3
Pre-requisites: Approved Chemical Engineering Majors Only
Type: LEC

Classifies polymers with respect to structure and formation reaction; relations between chemical structure and physical properties; some characteristics of polymer solutions; mechanical behavior; and engineering properties.

CE 442: Engineering and Process Economics

Credits: 3
Pre-requisites: Senior standing or permission of instructor
Type: LEC

Economic aspects of chemical engineering: time value of money, including interest and investments; alternative methods of analysis, such as annual costs, percent, and rate of return; process costs and concepts, including cost estimation, and chemical equipment and plant costs; a small cost-related process design project.

CE 443: Chemical Process Analysis and Synthesis

Credits: 3
Pre-requisites: CE 407
Co-requisites: CE 408
Type: LEC

Introduces fundamentals of process design utilizing computer techniques and methods.

CE 444: Chemical Process Control

Credits: 1
Pre-requisites: Senior standing or permission of instructor
Type: LAB

Introduces principles of process control. Feedback, feedforward, and open-loop control. Effects of major controller actions on typical processes: on-off, proportional, integral, and derivative. Predicts the dynamic response of a process through mathematical models. Frequency response analysis; introduces tuning of a system.

CE 446: Biochemical Engineering

Credits: 3
Pre-requisites: Senior standing or permission of instructor
Type: LEC

Significant microbial products, organisms, and substrates; directing microbial activity by random mutation and recombinant DNA; kinetics of growth and product formation; types of fermenters; aeration and agitation; scale-up; sterilization; product separation.

CE 447: Biological Transport and Kinetics

Credits: 3
Pre-requisites: BIO 201, CE 318, CE 329
Approved Chemical Engineering Majors Only
Type: LEC

Discusses the application of biological transport and kinetics principles in normal human physiology, disease states and during treatment. Focuses on selected aspects of the nature of receptor-ligand interactions, cell adhesion mechanics, drug delivery, and biological transport in organs. Topics include experimental methods for measuring receptor-ligand interactions, models for receptor-ligand binding and analysis of real data, methods for measuring and analyzing cell adhesion both in suspension and substrate based assays, cardiovascular fluid mechanics, blood components and blood viscosity measurements, flow in arteries and microcirculation, fahraeus effect, engineering principles for drug delivery including diffusion and convective transport of drugs to organs, pharmacokinetic modeling, drug delivery system design and controlled drug release, transport between blood and tissues, and between kidneys and tumors.

CE 448: Cellular and Molecular Bioengineering

Credits: 3
Pre-requisites: Senior standing or permission of instructor
Type: LEC

Introduces biomedical engineering with emphasis on vascular engineering. Gives students an understanding of how quantitative approaches can be combined with biological information to advance knowledge in the areas of thrombosis, inflammation biology and cancer metastasis. Emphasizes cellular and molecular bioengineering methods.

CE 449: Biological Systems Engineering

Credits: 3
Pre-requisites: BIO 201, MTH 306
Approved Chemical Engineering Majors Only
Type: LEC

Topics include mathematical techniques for optimization, genomics-genome sequencing, genome sequence annotation, metabolic networks, linear and quadratic optimization for metabolic network optimizations, experimental approaches to metabolic network optimization, c-labeling for metabolic flux determination, examples of using such approaches for high value chemical production optimization, background on cell signaling, biochemical/biophysical description of major signaling pathways including techniques for collecting experimental data, strategies for modeling signaling networks, examples of utilizing a mathematical framework to predict (and manipulate) cellular behavior in response to specific stimuli, examples of cell signaling in disease states, background and description of genetic networks, experimental approaches to genetic networks, strategies for modeling genetic networks, examples of describing/predicting genetic network behavior using mathematical tools, and an overview of genomic and proteomic methodologies.

CE 450: Protein Engineering

Credits: 3
Pre-requisites: CHE 201, CE 304
Type: LEC

Introduction to protein engineering and design. This course teaches students to think of protein as an entity that can be engineered using molecular tools in order to achieve novel physical and chemical properties. Students first learn the fundamentals of protein structure and how protein structure dictates function, which includes

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discussion of protein structure, biochemistry, molecular biology techniques, the basics of physical and organic chemistry, and molecular modeling through computer visualization. Additionally, students learn different protein design strategies, including knowledge-based design, computational protein design, and directed evolution, that are commonly used for protein engineering. Examples of engineered proteins with novel structural and functional properties are extensively discussed to illustrate how design principles are applied to real life problems.

CE 456: Introduction to Aerosol Science

Credits: 3
Pre-requisites: Approved Chemical Engineering Majors Only
Type: LEC

Introduces aerosol science and technology at a senior undergraduate/beginning graduate level. Provides the knowledge and skills needed to understand and predict the production, transport, and other behavior of aerosols and introduces technologies for producing, measuring, and collecting them.

CE 457: Colloid and Surface Phenomena

Credits: 3
Pre-requisites: Senior standing or permission of instructor
Type: LEC

Dispersed systems (e.g., suspensions, emulsions, foams, and other systems) in which surface effects dominate behavior. Surface tension. Gas adsorption and adsorption from solution. Effects of surface charge. Wetting, detergency, adhesion. Transport processes dominated by surface tension.

CE 459: Special Topics

Credits: 1-4
Pre-requisites: Permission of director of undergraduate studies
Type: LEC

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy *does not apply.*

Topics in the field of specialization selected with the permission of the instructor.

CE 460: Special Topics

Credits: 1-4
Pre-requisites: Permission of director of undergraduate studies
Type: LEC

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy *does not apply.*

Topics in the field of specialization selected with the permission of the instructor.

CE 471: Frontiers of Chemical Technology

Credits: 3
Pre-requisites: Senior standing or permission of instructor
Type: LEC

Exposes students to a broad range of industrial problems and the techniques to solve them using a project-oriented approach.

CE 496: Internship/Practicum

Credits: 3
Pre-requisites: Permission of instructor and director of undergraduate studies; Approved Chemical Engineering Majors Only
Type: TUT

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy *does not apply.*

Hands-on experience in the field. Problems vary from year to year, and may include chemical process studies, engineering materials studies, or computer-based analysis of specific chemical engineering problems. Internship assignments follow student preferences where possible and require consent of a faculty members who guide the work. Typically, students are required to spend approximately ten unpaid hours per week at an industrial site. Grading is based in part on written and oral reports that are required upon completion of the internship.

CE 497: Departmental Honors Thesis/Project

Credits: 1-3
Pre-requisites: Acceptance in to the departmental honors program, permission of instructor and director of undergraduate studies; Approved Chemical Engineering Majors Only
Type: TUT

Accepted seniors pursue a specialized, independent study leading to an Honors thesis or project.

CE 498: Undergraduate Research and Creative Activity

Credits: 1-3
Pre-requisites: Permission of instructor and director of undergraduate studies; Approved Chemical Engineering Majors Only
Type: TUT

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy *does not apply.*

Students collaborate with faculty research mentors on an ongoing faculty research project or conduct independent research under the guidance of a faculty member. This experience provides students with an inquiry-based learning opportunity and engages them as active learners in a research setting.

CE 499: Independent Study

Credits: 1-9
Pre-requisites: Permission of instructor and director of undergraduate studies; Approved Chemical Engineering Majors Only
Type: TUT

The content of this course is variable and therefore it is repeatable for credit. The University Grade Repeat Policy *does not apply.*

Students should be accepted for work on a specific topic by a member of the teaching staff of the chemical engineering

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department.