

# Chemical Engineering

Administered by the Department of Chemical and Biological Engineering

## Undergraduate Study

For undergraduate curriculum in chemical engineering leading to the degree bachelor of science. This curriculum is accredited under the General Criteria and the Chemical Engineering Program Criteria by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

Chemical engineering is a profession, which provides a link between scientific knowledge and manufactured products. The chemical engineer relies on science, experience, creativity, and ingenuity to produce these materials economically. Almost everything of a material nature used by society today has at some point felt the influence of the chemical engineer. From raw materials such as minerals, coal, petroleum, and agricultural products, chemical engineers create versatile intermediate and commodity chemicals, high performance fuels, new materials for construction, pharmaceuticals, high performance foodstuffs, synthetic textiles, plastics, solid state electronic components, and dozens of other engineered materials. The chemical engineer's influence has been important in the development of catalysts, fuel cells, automatic controls, biochemical processes, artificial kidneys, tissue engineering, nuclear energy, medical instruments and devices, as well as in the development of air and water pollution control systems. Many new and equally exciting challenges await the practicing chemical engineer of the future.

The profession of chemical engineering embraces a wide variety of activities including research, process development, product development, design, manufacturing supervision, technical sales, consulting, and teaching. The engineer can be behind a desk, in a laboratory, in a manufacturing plant, or engaged in nationwide and worldwide travel. Successful chemical engineers find chemistry, mathematics, and physics to be interesting and exciting. Many chemical engineers also have interest in the biological sciences. The curriculum in chemical engineering includes continued study of chemistry, biochemistry, mathematics, and physics as well as intensive study in the engineering sciences such as chemical reaction engineering, thermodynamics, mass transfer, fluid mechanics, heat transfer, system analysis and process synthesis, and design.

The curriculum in chemical engineering is designed to produce graduates that have the ability to apply knowledge of mathematics, science, and engineering; the ability to design, conduct and interpret experiments; and the ability to design a chemical engineering system, component, or process. Graduates should also have the ability to function on multi-disciplinary teams; the ability to identify, formulate, and solve chemical engineering problems; and the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The curriculum should also assure that graduates have the ability to communicate effectively, the broad education necessary to understand the impact of chemical engineering solutions in a global and societal context, and recognition of the need for, and an ability to engage in life-long learning, as well as a knowledge of contemporary issues and an understanding of professional and ethical responsibility.

The curriculum assures that graduates have a thorough grounding in chemistry, along with a working knowledge of advanced chemistry such as organic, inorganic, physical, analytical, materials chemistry, or biochemistry. In addition, a working knowledge, including safety and environmental aspects, of material and energy balances applied to chemical processes; thermodynamics of physical and chemical equilibria; heat, mass, and momentum transfer; chemical reaction engineering; continuous and stage-wise separation operations; process dynamics and control; process design; and appropriate modern experimental and computing techniques is assured.

## Program Educational Objectives

The objectives of the Chemical Engineering Program at Iowa State University are to produce graduates who:

- will excel in careers as professional chemical engineers in the businesses and industries related to chemical engineering; and
- will successfully pursue research and advanced studies in chemical engineering, or in related fields such as chemistry or biology, or in related professional fields such as medicine, law, and business.

## Biological Engineering Option

Students may enhance their academic preparation for the growing opportunities in the biologically-related industries by pursuing a selection of courses with a biological emphasis.

## Cooperative Education

A cooperative education program is available to students in chemical engineering.

## Graduate Study

The department offers work for the degrees master of science, master of engineering, and doctor of philosophy with major in chemical engineering, and minor work to students taking major work in other departments. Prerequisite to major graduate work is a bachelor's degree in chemical engineering, chemistry, or other related field. Students with undergraduate background other than chemical engineering should contact the department for further details. A thesis is required for the master of science degree. The master of science degree also requires a minimum of 30 graduate credits (minimum of 15 for coursework, 12 within Ch E and 3 outside). The master of engineering requirements are the same for total credits but include a special project or coursework rather than research thesis. The doctor of philosophy degree requires a minimum of 72 graduate credits (minimum of 30 for coursework, at least 16 inside Ch E and a minimum of 8 credits taken outside of Ch E). Candidates for the doctor of philosophy degree can refer to the department's home page and/or the department's Graduate Student Handbook for degree options and credit requirements.

Well-qualified juniors and seniors in chemical engineering who are interested in graduate study may apply for concurrent enrollment in the Graduate College to simultaneously pursue both the Bachelor of Science and Master of Science.

## Curriculum in Chemical Engineering

Administered by the Department of Chemical and Biological Engineering  
Leading to the degree bachelor of science.

**Total credits required: 129 cr. See also Basic Program and Special Programs.**

**International Perspectives: 3 cr. <sup>1</sup>**

**U.S. Diversity: 3 cr. <sup>1</sup>**

**Communication Proficiency/Library requirement:**

ENGL 150	Critical Thinking and Communication	3
ENGL 250	Written, Oral, Visual, and Electronic Composition	3
LIB 160	Information Literacy (See Basic Program for credit requirements)	1
One of the following		3
ENGL 309	Report and Proposal Writing	
ENGL 312	Biological Communication	
ENGL 314	Technical Communication	
JL MC 347	Science Communication	

**The CBE Department requires a grade of a C- or better for any transfer credit course that is applied to the degree program.**

**Social Sciences and Humanities: 15 cr. <sup>2</sup>**

Complete a total of 15 cr. with at least 6 cr. but not more than 9 cr. from the same department.

**Basic Program: 27 cr. <sup>4</sup>**

Complete with 2.00 GPA including transfer courses:

CHEM 177	General Chemistry I	4
or CHEM 167	General Chemistry for Engineering Students	
ENGL 150	Critical Thinking and Communication (see above for grade requirements)	3
ENGL 250	Written, Oral, Visual, and Electronic Composition (see above for grade requirements)	3
ENGR 101	Engineering Orientation	R
CH E 160	Chemical Engineering Problems with Computer Applications Laboratory <sup>3</sup>	3

LIB 160	Information Literacy	1
MATH 165	Calculus I	4
MATH 166	Calculus II	4
PHYS 221	Introduction to Classical Physics I	5
Total Credits		27

**Math and Physical Science: 30 cr.**

MATH 265	Calculus III	4
MATH 267	Elementary Differential Equations and Laplace Transforms	4
PHYS 222	Introduction to Classical Physics II	5
CHEM 177L	Laboratory in General Chemistry I	1
or CHEM 167L	Laboratory in General Chemistry for Engineering	
CHEM 178	General Chemistry II	3
CHEM 178L	Laboratory in College Chemistry II	1
CHEM 325	Chemical Thermodynamics	3
CHEM 331	Organic Chemistry I	3
CHEM 332	Organic Chemistry II	3
BBMB 301	Survey of Biochemistry	3
Total Credits		30

**Chemical Engineering Core: 36 cr. <sup>4</sup>**

CH E 210	Material and Energy Balances	3
CH E 202	Chemical Engineering Seminar	1
CH E 310	Computational Methods in Chemical Engineering	3
CH E 325	Chemical Engineering Laboratory I	2
CH E 356	Transport Phenomena I	3
CH E 357	Transport Phenomena II	3
CH E 358	Separations	3
CH E 381	Chemical Engineering Thermodynamics	3
CH E 382	Chemical Reaction Engineering	3
CH E 420	Chemical Process Safety	3
CH E 421	Process Control	3
CH E 426	Chemical Engineering Laboratory II	2
CH E 430	Process and Plant Design	4
Total Credits		36

**Other Remaining Courses: 21 cr. <sup>2</sup>**

One of the following Communication Elective:	3
ENGL 309 Report and Proposal Writing	
ENGL 312 Biological Communication	
ENGL 314 Technical Communication	
JL MC 347 Science Communication	
Chemistry Electives <sup>2</sup>	3
Statistical Electives <sup>2</sup>	3
Chemical Engineering Electives <sup>2</sup>	6
300+ level course in Engineering	3
Professional Elective <sup>2</sup>	3
Total Credits	21

**Biological Engineering Option**

The standard Chemical Engineering program may be modified to meet the option requirements for Biological Engineering:

Math and Physical Science – BBMB 404 Biochemistry I or BIOL 313 Principles of Genetics, 3 cr., may be substituted for BBMB 301 Survey of Biochemistry from list above when taken with BBMB 405 Biochemistry II or BIOL 314 Principles of Molecular Cell Biology, respectively. BBMB 420 must be taken in combination with BBMB 301.

Chemical Engineering Core <sup>4</sup> – Replace CH E 426 Chemical Engineering Laboratory II, 2 cr. with CH E 427 Biological Engineering Laboratory, 2 cr. in required Core.

**Other Remaining Courses for Biological Engineering Option <sup>2</sup>**

\* not BBMB 301 Survey of Biochemistry

1. These university requirements will add to the minimum credits of the program unless the university-approved courses are also approved by the department to meet other course requirements within the degree program. U.S. diversity and international perspectives courses may not be taken Pass/Not Pass.
2. Choose from department approved list.
3. See Basic Program for Professional Engineering Curricula for accepted substitutions for curriculum designated courses in the Basic Program.
4. 2.00 required including transfer courses.

Note: Transfer students with transfer credits in chemical engineering core courses must earn at least 15 semester credits in ISU courses in this category at the 300-level or above to qualify for the B.S. degree in chemical engineering.

See also: A 4-year plan of study grid showing course template by semester. (<https://nextcatalog.registrar.iastate.edu/planofstudy/engineering/#chemicalengineeringbbs>)

**Courses primarily for undergraduates:****CH E 104. Chemical Engineering Learning Community.**

(1-0) Cr. arr. F.S. *Prereq:* Enrollment in Chemical Engineering Learning Team (1-0) Curriculum in career planning and academic course support for Freshmen learning team.

**CH E 160. Chemical Engineering Problems with Computer Applications Laboratory.**

(2-2) Cr. 3. F.S. *Prereq:* MATH 142 or satisfactory scores on mathematics placement examinations; credit or enrollment in MATH 165

Formulation and solution of engineering problems. Significant figures. Use of SI units. Graphing and curve-fitting. Flowcharting. Introduction to material balances, engineering economics, and design. Use of spreadsheet programs to solve and present engineering problems. Solution of engineering problems using computer programming languages. Chemical Engineering examples.

**CH E 202. Chemical Engineering Seminar.**

(1-0) Cr. 1. F.S. *Prereq:* Sophomore classification in chemical engineering Professionalism in the context of the engineering/technical workplace. Introduction to chemical engineering career opportunities. Process and workplace safety. Development and demonstration of key workplace competencies: teamwork, professionalism and ethical responsibility, ability to engage in life-long learning, and knowledge of contemporary issues. Resumes; professional portfolios; preparation for internship experiences.

**CH E 204. Chemical Engineering Continuing Learning Community.**

Cr. R. F.S. *Prereq:* Corequisite-enrollment in Chemical Engineering Learning Team (1-0) Curriculum and career planning, academic course support for learning community.

**CH E 210. Material and Energy Balances.**

(3-0) Cr. 3. F.S. *Prereq:* Chem 178, Math 166  
Introduction to chemical processes. Physical behavior of gases, liquids, and solids. Application of material and energy balances to chemical engineering equipment and processes.

**CH E 220. Introduction to Biomedical Engineering.**

(Cross-listed with BIOE). (3-0) Cr. 3. S. *Prereq:* BIOL 212, ENGR 160 or equiv, MATH 166, CHEM 167 or 178, PHYS 222

Engineering analysis of basic biology and engineering problems associated with living systems and health care delivery. The course will illustrate biomedical engineering applications in such areas as: biotechnology, biomechanics, biomaterials and tissue engineering, and biosignal and image processing, and will introduce the basic life sciences and engineering concepts associated with these topics.

**CH E 298. Cooperative Education.**

Cr. R. F.S.SS. *Prereq:* Permission of department and Engineering Career Services

First professional work period in the cooperative education program. Students must register for this course before commencing work.

**CH E 310. Computational Methods in Chemical Engineering.**

(3-0) Cr. 3. F.S. *Prereq:* CH E 210 and ENGR 160

Numerical methods for solving systems of linear and nonlinear equations, ordinary differential equations, numerical differentiation and integration, and nonlinear regression using chemical engineering examples. Nonmajor graduate credit.

**CH E 325. Chemical Engineering Laboratory I.**

(0-4) Cr. 2. F.S. *Prereq: CH E 357, credit or enrollment in CH E 381*  
Experiments covering fundamental material and energy balances, momentum and energy transport operations, and thermodynamics. Computer applications. Nonmajor graduate credit.

**CH E 356. Transport Phenomena I.**

(3-0) Cr. 3. F.S. *Prereq: CH E 210, PHYS 221, credit or enrollment in MATH 267*  
Momentum and mechanical energy balances. Incompressible and compressible fluid flow. Applications to fluid drag, piping system design, filtration, packed beds and settling. Nonmajor graduate credit.

**CH E 357. Transport Phenomena II.**

(3-0) Cr. 3. F.S. *Prereq: Credit or enrollment in CH E 310; CH E 356*  
Conduction and diffusion, convective heat and mass transfer, boiling and condensation, radiation, and design of heat exchange equipment. Introduction to diffusion. Nonmajor graduate credit.

**CH E 358. Separations.**

(3-0) Cr. 3. F.S. *Prereq: CH E 310, CH E 357*  
Diffusion and mass transfer in fluids. Analysis and design of continuous contacting and multistage separation processes. Binary and multicomponent distillation, absorption, extraction, evaporation, membrane processes, and simultaneous heat and mass transfer. Nonmajor graduate credit.

**CH E 381. Chemical Engineering Thermodynamics.**

(3-0) Cr. 3. F.S. *Prereq: Credit or enrollment in CH E 310; MATH 267, PHYS 222, CHEM 325*  
Application of thermodynamic principles to chemical engineering problems. Thermodynamic properties of fluids, phase equilibria, and chemical reaction equilibria. Nonmajor graduate credit.

**CH E 382. Chemical Reaction Engineering.**

(3-0) Cr. 3. F.S. *Prereq: Credit in CH E 310; CH E 381, credit or enrollment in CH E 357*  
Kinetics of chemical reactions. Design of homogeneous and heterogeneous chemical reactors. Nonmajor graduate credit.

**CH E 391. Foreign Study Orientation.**

(3-0) Cr. 3. *Prereq: Credit or enrollment in CH E 357 and CH E 381 or permission of instructor*  
Offered on a satisfactory-fail basis only. Credit for graduation allowable only upon completion of Ch E 392.  
Meets International Perspectives Requirement.

**CH E 392. Foreign Study Program.**

Cr. 4. SS. *Prereq: CH E 391*  
Study of chemical engineering including laboratories and lectures at University College London or other collaborating international universities. Comparative study of U.S. and international manufacturing facilities. Expenses required.  
Meets International Perspectives Requirement.

**CH E 396. Summer Internship.**

Cr. R. Repeatable. SS. *Prereq: Permission of department and Engineering Career Services*  
Summer professional work period. Students must register for this course prior to commencing work.

**CH E 397. Engineering Internship.**

Cr. R. Repeatable. F.S. *Prereq: Permission of department and Engineering Career Services*  
One semester maximum per academic year professional work period. Students must register for this course prior to commencing work.

**CH E 398. Cooperative Education.**

Cr. R. F.S.SS. *Prereq: CH E 298, permission of department and Engineering Career Services*  
Second professional work period in the cooperative education program. Students must register for this course before commencing work.

**CH E 406. Environmental Chemodynamics.**

(Dual-listed with CH E 506). (3-0) Cr. 3. Alt. F., offered 2013. *Prereq: CH E 381, credit or enrollment in CH E 358*  
Examines the mechanisms and rates of chemical transport across air, water, and soil interfaces. Applications of transport and thermodynamic fundamentals to movement of chemicals in the environment. Nonmajor graduate credit.

**CH E 408. Surface and Colloid Chemistry.**

(Dual-listed with CH E 508). (3-0) Cr. 3. Alt. F., offered 2012. *Prereq: CH E 381 or equivalent*  
Examines the factors underlying interfacial phenomena, with an emphasis on the thermodynamics of surfaces, structural aspects, and electrical phenomena. Application areas include emulsification, foaming, detergency, sedimentation, fluidization, nucleation, wetting, adhesion, flotation, and electrophoresis. Nonmajor graduate credit.

**CH E 415. Biochemical Engineering.**

(Dual-listed with CH E 515). (3-0) Cr. 3. S. *Prereq: CH E 357, CH E 382 recommended, CHEM 331*  
Application of basic chemical engineering principles in biochemical and biological process industries such as enzyme technology and fermentation. Nonmajor graduate credit.

**CH E 420. Chemical Process Safety.**

(3-0) Cr. 3. S. *Prereq: CH E 357, CH E 381 (or equivalents); junior classification*  
Application of transport phenomena, thermodynamics, and chemical kinetics to the study of safety, health, and loss prevention. Government regulations, industrial hygiene, relief sizing, runaway reactions, toxic release, and dispersion models will be used. Fires, explosions, risk assessment, hazard identification, case studies, accident investigations, and design considerations will be studied. Nonmajor graduate credit.

**CH E 421. Process Control.**

(3-0) Cr. 3. F.S. *Prereq: CH E 358, CH E 382, Math 267*  
Control of industrial chemical processes. Device applications and limitations. Dynamics of chemical process components and process control systems. Nonmajor graduate credit.

**CH E 426. Chemical Engineering Laboratory II.**

(0-4) Cr. 2. F.S. *Prereq: CH E 325, CH E 358, CH E 382*  
Experiments in heat and mass transfer, staged operations, chemical reactor performance, unit processes. Computer applications. Nonmajor graduate credit. Only one of Ch E 426 or 427 may count toward graduation.

**CH E 427. Biological Engineering Laboratory.**

(0-4) Cr. 2. S. *Prereq: Credit in CH E 325, CH E 358, CH E 382, and BBMB 301*  
Experiments on biological applications in chemical engineering. Nonmajor graduate credit. Only one of CH E 426 or CH E 427 may count toward graduation.

**CH E 430. Process and Plant Design.**

(2-6) Cr. 4. F.S. *Prereq: CH E 358, CH E 382*  
Synthesis of chemical engineering processes, equipment and plants. Cost estimation and feasibility analysis. Nonmajor graduate credit.

**CH E 440. Biomedical Applications of Chemical Engineering.**

(Dual-listed with CH E 540). (Cross-listed with BIOE). (3-0) Cr. 3. Alt. F., offered 2013. *Prereq: CH E 210, MATH 266, PHYS 222*  
Applications of material and energy balances, transport phenomena, chemical reaction engineering, and thermodynamics to problems in biomedical engineering and applied physiology; survey of biomedical engineering; biomaterials; biomedical imaging. Nonmajor graduate credit.

**CH E 447. Polymers and Polymer Engineering.**

(Dual-listed with CH E 547). (3-0) Cr. 3. S. *Prereq: CH E 382 and CHEM 331 or MAT E 351*  
Chemistry of polymers, addition and condensation polymerization. Physical and mechanical properties, polymer rheology, production methods. Applications of polymers in the chemical industry. Nonmajor graduate credit.

**CH E 490. Undergraduate Research/Independent Study.**

(0-18) Cr. 1-6. Repeatable, maximum of 6 credits. *Prereq: Permission of Department*  
Investigation of topics of special interest to student and faculty with a final written report. Election of course and topic must be approved in advance by Department with completion of Study Proposal. No more than 6 credits of ChE 490 may be counted towards technical electives.

**CH E 490H. Undergraduate Research/Independent Study, Honors.**

(0-18) Cr. 1-6. Repeatable, maximum of 6 credits. *Prereq: Permission of Department*  
Investigation of topics of special interest to student and faculty with a final written report. Election of course and topic must be approved in advance by Department with completion of Study Proposal. No more than 6 credits of ChE 490 may be counted towards technical electives.

**CH E 498. Cooperative Education.**

Cr. R. Repeatable. F.S.SS. *Prereq:* CH E 398, permission of department and Engineering Career Services

Third and subsequent professional work periods in the cooperative education program. Students must register for this course before commencing work.

**Courses primarily for graduate students, open to qualified undergraduates:**

**CH E 506. Environmental Chemodynamics.**

(Dual-listed with CH E 406). (3-0) Cr. 3. Alt. F., offered 2013. *Prereq:* CH E 381, credit or enrollment in CH E 358

Examines the mechanisms and rates of chemical transport across air, water, and soil interfaces. Applications of transport and thermodynamic fundamentals to movement of chemicals in the environment. Nonmajor graduate credit.

**CH E 508. Surface and Colloid Chemistry.**

(Dual-listed with CH E 408). (3-0) Cr. 3. Alt. F., offered 2012. *Prereq:* CH E 381 or equivalent

Examines the factors underlying interfacial phenomena, with an emphasis on the thermodynamics of surfaces, structural aspects, and electrical phenomena. Application areas include emulsification, foaming, detergency, sedimentation, fluidization, nucleation, wetting, adhesion, flotation, and electrophoresis. Nonmajor graduate credit.

**CH E 515. Biochemical Engineering.**

(Dual-listed with CH E 415). (3-0) Cr. 3. S. *Prereq:* CH E 357, CH E 382, CHEM 331

Application of basic chemical engineering principles in biochemical and biological process industries such as enzyme technology and fermentation. Term project required for graduate credit.

**CH E 540. Biomedical Applications of Chemical Engineering.**

(Dual-listed with CH E 440). (Cross-listed with BIOE). (3-0) Cr. 3. Alt. F., offered 2013. *Prereq:* CH E 210, MATH 266, PHYS 222

Applications of material and energy balances, transport phenomena, chemical reaction engineering, and thermodynamics to problems in biomedical engineering and applied physiology; survey of biomedical engineering; biomaterials; biomedical imaging. Nonmajor graduate credit.

**CH E 542. Polymeric Biomaterials.**

(3-0) Cr. 3. *Prereq:* CHEM 331 or a polymers class

Polymeric biomaterials, overview of biomaterial requirements, different classes of polymers used as biomaterials, specific bioapplications of polymers.

**CH E 545. Analytical and Numerical Methods.**

(3-0) Cr. 3. F. *Prereq:* CH E 358, MATH 267

Analysis of equipment and processes by analytic and/or numerical solution of descriptive differential equations. Operational and series techniques, boundary value problems, numerical interpolation and approximation, integration techniques.

**CH E 547. Polymers and Polymer Engineering.**

(Dual-listed with CH E 447). (3-0) Cr. 3. S. *Prereq:* CH E 382 and CHEM 331 or Mat E 351

Chemistry of polymers, addition and condensation polymerization. Physical and mechanical properties, polymer rheology, production methods. Applications of polymers in the chemical industry.

**CH E 554. Integrated Transport Phenomena.**

(4-0) Cr. 4. F. *Prereq:* CH E 357, CH E 381, Math 267, credit or enrollment in CH E 545

Conservation equations governing diffusive and convective transport of momentum, thermal energy and chemical species. Transport during laminar flow in conduits, boundary layer flow, creeping flow. Heat and mass transport coupled with chemical reactions and phase change. Scaling and approximation methods for mathematical solution of transport models. Diffusive fluxes; conservation equations for heat and mass transfer; scaling and approximation techniques; fundamentals of fluid mechanics; unidirectional flow; creeping flow; laminar flow at high Reynolds number; forced-convection heat and mass transfer in confined and unconfined laminar flows.

**CH E 562. Bioseparations.**

(3-0) Cr. 3. *Prereq:* CH E 357 or advanced standing in a science major

Principles and techniques for separation and recovery of biologically-produced molecules, especially proteins. Relationship between the chemistry of biological molecules and efficient separation and preservation of biological activity. Includes centrifugation and filtration, membrane processing, extraction, precipitation and crystallization, chromatography, and electrophoresis.

**CH E 572. Turbulence.**

(Cross-listed with AER E). (3-0) Cr. 3. Alt. S., offered 2012. *Prereq:* AER E 543 or M E 538

Qualitative features of turbulence. Statistical representation of turbulent velocity fields: averages, moments, correlations, length and time scales and the energy cascade. Averaged equations of motion, closure requirements, Reynolds averaged models. Homogeneous shear flows, free shear flows, boundary layers. Numerical simulation of turbulence: DNS, LES, DES.

**CH E 583. Advanced Thermodynamics.**

(3-0) Cr. 3. F. *Prereq:* CH E 381

Application of thermodynamic principles to chemical engineering problems. Thermodynamic properties of non-ideal fluids and solutions; phase and chemical-reaction equilibria/stability.

**CH E 587. Advanced Chemical Reactor Design.**

(3-0) Cr. 3. S. *Prereq:* CH E 382

Analysis of complex reactions and kinetics. Fixed bed, fluidized bed, and other industrial reactors. Analysis and design of non-ideal flow mixing, and residence times. Heterogeneous reactors.

**CH E 590. Independent Study.**

Cr. 2-6. Repeatable.

Investigation of an approved topic on an individual basis.

**CH E 595. Special Topics.**

Cr. 2-3. Repeatable.

**CH E 595A. Special Topics: Separations.**

Cr. 2-3. Repeatable.

**CH E 595B. Special Topics: Advanced Control Theory.**

Cr. 2-3. Repeatable.

**CH E 595C. Special Topics: Crystallization.**

Cr. 2-3. Repeatable.

**CH E 595D. Special Topics: Thermodynamics.**

Cr. 2-3. Repeatable.

**CH E 595E. Special Topics: Protein Engineering/Bioseparations.**

Cr. 2-3. Repeatable.

**CH E 595F. Special Topics: Biological Engineering.**

Cr. 2-3. Repeatable.

**CH E 595G. Special Topics: Materials and Biomaterials.**

Cr. 2-3. Repeatable.

**CH E 595H. Special Topics: Surfaces.**

Cr. 2-3. Repeatable.

**CH E 595I. Special Topics: Combinatorial Design.**

Cr. 2-3. Repeatable.

**CH E 599. Creative Component.**

Cr. arr. Repeatable.

**Courses for graduate students:****CH E 601. Seminar.**

Cr. R. Repeatable. F.S.

Offered on a satisfactory-fail basis only.

**CH E 625. Metabolic Engineering.**

(3-0) Cr. 3. *Prereq:* CH E 382, CHEM 331

Principles of metabolic engineering. Emphasis on emerging examples in biorenewables and plant metabolic engineering. Overview of biochemical pathways, determination of flux distributions by stoichiometric and labeling techniques; kinetics and thermodynamics of metabolic networks; metabolic control analysis; genetic engineering for overexpression, deregulation, or inhibition of enzymes; directed evolution; application of bioinformatics, genomics, and proteomics.

**CH E 632. Multiphase Flow.**

(Cross-listed with M E). (3-0) Cr. 3. Alt. S., offered 2013. *Prereq:* M E 538

Single particle, multiparticle and two-phase fluid flow phenomena (gas-solid, liquid-solid and gas-liquid mixtures); particle interactions, transport phenomena, wall effects; bubbles, equations of multiphase flow. Dense phase (fluidized and packed beds) and ducted flows; momentum, heat and mass transfer. Computer solutions.

**CH E 642. Principles and Applications of Molecular Simulation.**

(3-0) Cr. 3. *Prereq: CH E 545*

Principles of statistical physics. General features of molecular simulations including Monte Carlo (MC) methods, molecular mechanics (MM), and molecular dynamics (MD). Overview of intermolecular and interatomic potentials. Evaluation of phase equilibria, free energies, and surface/interfacial properties. Coarse-grained methods.

**CH E 652. Advanced Transport.**

(3-0) Cr. 3. *Prereq: CH E 552 and CH E 553*

Advanced topics in momentum transport, fluid mechanics, and mass transport including study of recent literature.

**CH E 688. Catalysis and Catalytic Processes.**

(Cross-listed with BR C). (3-0) Cr. 3. *Prereq: CH E 382*

Principles and applications of heterogeneous and homogeneous catalysis. Adsorption. Reaction kinetics and mass transfer effects. Catalyst characterization. Industrial catalytic processes.

**CH E 692. Independent Study.**

Cr. 2-6. Repeatable.

Investigation of an approved topic on an individual basis. Election of course and topic must be approved in advance by Program of Study Committee.

**CH E 695. Advanced Topics.**

Cr. arr. Repeatable.

**CH E 695A. Advanced Topics: Separations.**

Cr. arr. Repeatable.

**CH E 695B. Advanced Topics: Advanced Statistical Modeling and Control.**

Cr. arr. Repeatable.

**CH E 695C. Advanced Topics: Crystallization.**

Cr. arr. Repeatable.

**CH E 695D. Advanced Topics: Thermodynamics.**

Cr. arr. Repeatable.

**CH E 695E. Advanced Topics: Protein Engineering/Bioseparations.**

Cr. arr. Repeatable.

**CH E 695F. Advanced Topics: Biological Engineering.**

Cr. arr. Repeatable.

**CH E 695G. Advanced Topics: Materials and Biomaterials.**

Cr. arr. Repeatable.

**CH E 695H. Advanced Topics: Surfaces.**

Cr. arr. Repeatable.

**CH E 695I. Advanced Topics: Combinatorial Design.**

Cr. arr. Repeatable.

**CH E 697. Engineering Internship.**

Cr. R. Repeatable. F.S.SS. *Prereq: Permission of major professor, graduate classification*

One semester and one summer maximum per academic year professional work period.

**CH E 699. Research.**

Cr. arr. Repeatable.

Advanced topic for thesis/dissertation.