CHEMICAL ENGINEERING

http://www.cbe.iastate.edu/

Administered by the Department of Chemical and Biological Engineering

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 who 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.

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. [1]
U.S. Diversity: 3 cr. [1]
Communication Proficiency/Library requirement:

ENGL 150	Critical Thinking and Communication (C or better in this course)	3
ENGL 250	Written, Oral, Visual, and Electronic Composition (C or better in this course)	3
LIB 160	Information Literacy	1
One of the following (C or better in this course)		3
ENGL 309	Proposal and Report 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 but will not be calculated into the ISU cumulative GPA, Basic Program GPA or Core GPA

Social Sciences and Humanities: 15 cr. [2]
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. [3]
A minimum GPA of 2.00 required for this set of courses, including any transfer courses (please note that transfer course grades will not be calculated into the Basic Program GPA). See Requirement for Entry into Professional Program in College of Engineering Overview section.

CHEM 177	General Chemistry I	4

or CHEM 167	General Chemistry for Engineering Students	
ENGL 150	Critical Thinking and Communication	3
ENGL 250	Written, Oral, Visual, and Electronic Composition	3
ENGR 101	Engineering Orientation	R
CH E 160	Chemical Engineering Problems with Computer Applications Laboratory [3]	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.
(A minimum GPA of 2.00 required for this set of courses, including any transfer courses; please note that transfer course grades will not be calculated into the Core GPA).

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. [2]

One of the following Communication Elective:		3
ENGL 309	Proposal and Report Writing	
ENGL 312	Biological Communication	
ENGL 314	Technical Communication	
JL MC 347	Science Communication	
Chemistry Electives [2]		3
Statistical Electives [2]		3
Chemical Engineering Electives [2]		6
Engineering Electives [2]		3
Professional Elective [2]		3
Total Credits		**21**

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CH E 205	Chemical Engineering Progress Assessment	R

* BBMB 301 Survey of Biochemistry may not be used for a technical elective. See department approved list (http://www.cbe.iastate.edu/current-students/guides-and-handbooks) for approved course substitutions for BBMB 301.

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 – 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 [2]

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 (http://www.cbe.iastate.edu/current-students/guides-and-handbooks) .
3. See Basic Program for Professional Engineering Curricula for accepted substitutions for curriculum designated courses in the Basic Program.

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.

Pass-Not Pass Policy
A maximum of nine Pass-Not Pass semester credits may be used to meet graduation requirements. Courses offered on a Satisfactory-Fail basis may not be taken on a Pass-Not Pass basis. Pass-Not Pass credits can be applied toward requirements for a B.S. degree in chemical engineering only if the course is specified in the curriculum as a social science and humanities elective or is a course not used in the degree program. Pass-Not Pass credits are not acceptable for technical elective courses or for courses used to satisfy the US diversity or international perspectives requirements.

See also: A 4-year plan of study grid showing course template by semester. (http://catalog.iastate.edu/previouscatalogs/2016-2017/collegeofengineering/chemicalengineering/#fouryearplantext)

Chemical Engineering, B.S.

Freshman

Fall	Credits	Spring	Credits
MATH 165	4	MATH 166	4
ENGR 101	0	PHYS 221	5
CHEM 177	4	CHEM 178	3
CHEM 177L	1	CHEM 178L	1
LIB 160	1	SSH Elective*	3
ENGL 150	3		
CH E 160	3		
	16		**16**

Sophomore

Fall	Credits	Spring	Credits
MATH 265	4	MATH 267	4
PHYS 222	5	CHEM 325	3
CHEM 331	3	CHEM 332	3
CH E 210	3	CH E 356	3
CH E 202	1	ENGL 250	3
CH E 205	0		
	16		**16**

Junior

Fall	Credits	Spring	Credits
CH E 381	3	CH E 325	2
BBMB 301	3	CH E 358	3
CH E 357	3	CH E 382	3
CH E 310	3	SSH Elective*	3
Stat Elective*	3	Advanced CHEM Elective*	3
		Communication Elective*	3
	15		**17**

Senior

Fall	Credits	Spring	Credits
CH E 420	3	CH E 426	2
CH E 421	3	CH E 430	4
SSH Elective*	3	SSH Elective*	3
ENGR Elective*	3	SSH Elective*	3
CH E Elective*	3	CH E Elective*	3
		Professional Elective*	3
	15		**18**

Total Credits: 129

* Choose from department approved list (http://www.cbe.iastate.edu/current-students/guides-and-handbooks).

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.

Courses primarily for undergraduates:

CH E 104: Chemical Engineering Learning Community
Cr. R. F.
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 143 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.
Prereq: Sophomore classification in chemical engineering; credit or enrollment in CH E 210
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.
Prereq: Corequisite-enrollment in Chemical Engineering Learning Team
Curriculum and career planning, academic course support for learning community.

CH E 205: Chemical Engineering Progress Assessment
Cr. R. F.S.
Prereq: CHEM 178, MATH 166; credit or enrollment in CH E 160, CH E 210
Assessment of proficiency in general chemistry, calculus (including infinite series and applications of derivatives and integrals), and material balances, and an ability to use the principles of science and mathematics to identify, formulate, and solve engineering problems. Offered on a satisfactory-fail basis only.

CH E 210: Material and Energy Balances
(3-0) Cr. 3. F.S.
Prereq: Chem 178, Math 166, CH E 160
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 B M E). (3-0) Cr. 3. S.
Prereq: BIOL 212, ENGR 160 or equiv, MATH 166, CHEM 167 or CHEM 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 160, CH E 205, CH E 210, MATH 265
Numerical methods for solving systems of linear and nonlinear equations, ordinary differential equations, numerical differentiation and integration, and nonlinear regression using chemical engineering examples.

CH E 325: Chemical Engineering Laboratory I
(0-4) Cr. 2. F.S.
Prereq: CH E 357, CH E 381; credit or enrollment in CH E 382; credit or enrollment in ENGL 314 or ENGL 309 or ENGL 312 or JL MC 347
Experiments covering fundamental material and energy balances, momentum and energy transport operations, and thermodynamics. Computer applications.

CH E 356: Transport Phenomena I
(3-0) Cr. 3. F.S.
Prereq: CH E 205, 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.

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.

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.

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.

CH E 382: Chemical Reaction Engineering
(3-0) Cr. 3. F.S.
Prereq: CH E 310; CH E 381, credit or enrollment in CH E 357
Kinetics of chemical reactions. Design of homogeneous and heterogeneous chemical reactors.

CH E 391: Foreign Study Orientation
(3-0) Cr. 3. S.
Prereq: CH E 357 and CH E 381
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 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.
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.

CH E 408: Surface and Colloid Chemistry
(Dual-listed with CH E 508). (3-0) Cr. 3.
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.

CH E 415: Biochemical Engineering
(Dual-listed with CH E 515). (3-0) Cr. 3.
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.

CH E 420: Chemical Process Safety
(3-0) Cr. 3. F.S.
Prereq: CH E 357, CH E 381; 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.

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.

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. Only one of Ch E 426 or 427 may count toward graduation.

CH E 427: Biological Engineering Laboratory
(0-4) Cr. 2. S.
Prereq: CH E 325, CH E 358, CH E 382; BBMB 301 or BBMB 404
Experiments on biological applications in chemical engineering. Only one of CH E 426 or CH E 427 may count toward graduation.

CH E 430: Process and Plant Design
(2-4) Cr. 4. F.S.
Prereq: CH E 358, CH E 382
Synthesis of chemical engineering processes, equipment and plants. Cost estimation and feasibility analysis.

CH E 440: Biomedical Applications of Chemical Engineering
(Dual-listed with CH E 540). (Cross-listed with B M E). (3-0) Cr. 3.
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.

CH E 447: Polymers and Polymer Engineering
(Dual-listed with CH E 547). (3-0) Cr. 3.
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 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 or presentation. 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 or presentation. 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.
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.

CH E 508: Surface and Colloid Chemistry
(Dual-listed with CH E 408). (3-0) Cr. 3.
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.

CH E 515: Biochemical Engineering
(Dual-listed with CH E 415). (3-0) Cr. 3.
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.

CH E 540: Biomedical Applications of Chemical Engineering
(Dual-listed with CH E 440). (3-0) Cr. 3.
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.

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.
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.
Prereq: AER E 541 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 odd-numbered years.
Prereq: M E 538
Single particle, mutliparticle 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 695J: Advanced Topics: Polymeric and Nanostructured Materials
Cr. arr. Repeatable.

CH E 695K: Advanced Topics: Biomaterials and Tissue Engineering
Cr. arr. Repeatable.

CH E 695L: Advanced Topics: Catalysis, Reaction Engineering, and Renewable Energy
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 698: Chemical Engineering Teaching Practicum
(1-0) Cr. 1. F.
Prereq: Graduate student classification and permission of instructor
Discussions intended to foster the development of graduate students as teaching assistants and future chemical engineering instructors. Topics include classroom and laboratory instruction, grading, and developing a teaching philosophy. Offered on a satisfactory-fail basis only.

CH E 699: Research
Cr. arr. Repeatable.
Advanced topic for thesis/dissertation.