

CHEMICAL AND BIOLOGICAL ENGINEERING

The Department of Chemical and Biological Engineering (<http://www.colorado.edu/chbe/>) offers degrees at the bachelor's, master's and doctoral levels. The department offers two distinct BS degree programs, one in chemical engineering and one in biological engineering.

Chemical engineering prepares students for careers in a range of industries including energy, consumer products, sustainability and semiconductors. Modern industry depends on chemical engineers to tailor manufacturing technology to the requirements of its products, and chemical engineers play a central role in development of new polymeric materials, alternative energy sources and safe, efficient processes for chemical synthesis.

The biological engineering undergraduate program prepares students for careers in biotechnology, pharmaceuticals, medicine and materials. Exploring the structure of protein molecules, the functioning of cells and the growth and regeneration of tissues are among the new frontiers that biological engineering students will address.

In addition to the standard chemical and biological curricula, a premedicine curriculum is also offered. The chemical and biological engineering department has active research and educational programs in the exciting field of biotechnology, which involves the use of individual cells and their components for producing pharmaceuticals and other important products. The department is also active in biomedical engineering, which involves medical devices, tissues and biomaterials.

There are opportunities to specialize via electives, independent study, research and senior thesis.

Students can carry out part of their studies in another country while staying on track to a four-year degree. This is a wonderful opportunity to delve into a new culture and learning environment, and can be valuable professional experience given the international ties of many companies and researchers. Many faculty members have significant international experience.

Course codes for these programs are CHEN and BIEN.

Senior Thesis

The department offers this program for undergraduates with a strong interest in research. The student carries out a yearlong project under the direction of a faculty member in lieu of taking CHEN 4130 (for CHEN students) or BIEN 4810 (for BIEN students). Students must apply at the end of their junior year.

Research Facilities

Chemical and biological engineering research facilities are extensive and modern. Nearly all research equipment is interfaced to computers for automated data collection, monitoring and control. A full description of chemical and biological engineering research facilities can be found on the department website. (<http://www.colorado.edu/chbe/>)

Bachelor's Degrees

- Biological Engineering - Bachelor of Science (BSBE) (<https://catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/chemical-biological-engineering/biological-engineering-bachelor-science-bsbe/>)

- Chemical Engineering - Bachelor of Science (BSCE) (<https://catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/chemical-biological-engineering/chemical-engineering-bachelor-science-bsce/>)

Minors

- Biological Engineering - Minor (<https://catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/chemical-biological-engineering/biological-engineering-minor/>)
- Chemical Engineering - Minor (<https://catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/chemical-biological-engineering/chemical-engineering-minor/>)

Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Anseth, Kristi S. (https://experts.colorado.edu/display/fisid_103471/)
Distinguished Professor; PhD, University of Colorado Boulder

Bay, R. Kōnane (https://experts.colorado.edu/display/fisid_172688/)
Assistant Professor; PhD, University of Massachusetts at Amherst

Bowman, Christopher N. (https://experts.colorado.edu/display/fisid_102043/)
Distinguished Professor; PhD, Purdue University

Bryant, Stephanie J. (https://experts.colorado.edu/display/fisid_111810/)
Professor; PhD, University of Colorado Boulder

Burdick, A. Jason (https://experts.colorado.edu/display/fisid_168868/)
Professor; PhD, University of Colorado Boulder

Cha, Jennifer N. (https://experts.colorado.edu/display/fisid_151746/)
Professor; PhD, University of California, Santa Barbara

Clough, David Edwards (https://experts.colorado.edu/display/fisid_102332/)
Professor Emeritus; PhD, University of Colorado Boulder

Davis, Robert H. (https://experts.colorado.edu/individual/fisid_113653/)
Distinguished Professor; PhD, Stanford University

deGrazia, Janet (https://experts.colorado.edu/display/fisid_107661/)
Teaching Professor Emerita; PhD, University of Colorado Boulder

Falconer, John L. (https://experts.colorado.edu/display/fisid_101426/)
Professor Emeritus; PhD, Stanford University

Fox, Jerome Michael (https://experts.colorado.edu/display/fisid_156682/)
Assistant Professor; PhD, University of California, Berkeley

Franklin, Trevor (https://experts.colorado.edu/display/fisid_175743/)
Teaching Assistant Professor; PhD, Cornell University

Goodwin, Andrew Pratt (https://experts.colorado.edu/display/fisid_151595/)
Associate Professor; PhD, University of California, Berkeley

Gupta, Ankur (https://experts.colorado.edu/display/fisid_165822/)
Assistant Professor; PhD, Massachusetts Institute of Technology

Hayward, Ryan (https://experts.colorado.edu/individual/fisid_166416/)
Endowed/Named Professor; PhD, University of California Santa Barbara

Heinz, Hendrik (https://experts.colorado.edu/display/fisid_156488/)
Professor; PhD, ETH Zurich (Switzerland)

Hind, Laurel (https://experts.colorado.edu/individual/fisid_165642/)
Assistant Professor; PhD, University of Pennsylvania

Holewinski, Adam P. (https://experts.colorado.edu/display/fisid_155859/)
Assistant Professor; PhD, University of Michigan Ann Arbor

Hrenya, Christine M.
Professor Emerita; PhD, Carnegie Mellon University

Keyvani, Ehsan
Teaching Assistant Professor; PhD, Northeastern University

Kohlmeier, Carolyn (https://experts.colorado.edu/individual/fisid_158386/)
Teaching Associate Professor; PhD, University of Colorado Boulder

Krantz, William
Professor Emeritus

Mahoney, Melissa J.
Teaching Professor; PhD, Cornell University

Marder Seth (https://experts.colorado.edu/display/fisid_167617/)
Professor; PhD, University of Wisconsin-Madison

McGehee, Michael D. (https://experts.colorado.edu/display/fisid_163453/)
Professor; PhD, University of California, Santa Barbara

Medlin, James William (https://experts.colorado.edu/display/fisid_122699/)
Professor; PhD, University of Delaware

Nuttelman, Charles Raymond (https://experts.colorado.edu/display/fisid_142758/)
Teaching Professor; PhD, University of Colorado Boulder

O'Harra, Katie
Teaching Assistant Professor; PhD, University of Alabama

Ramirez, Walter
Professor Emeritus

Randolph, Theodore W. (https://experts.colorado.edu/display/fisid_101768/)
Professor; PhD, University of California, Berkeley

Schwartz, Daniel K. (https://experts.colorado.edu/display/fisid_118479/)
Professor, Endowed Chair; PhD, Harvard University

Shields, C. Wyatt IV (https://experts.colorado.edu/individual/fisid_165173/)
Assistant Professor; PhD, Duke University

Shirts, Michael R. (https://experts.colorado.edu/display/fisid_156474/)
Professor; PhD, Stanford University

Smith, Wilson (https://experts.colorado.edu/display/fisid_166095/)
Professor; PhD, University of Georgia

Sprenger, Kayla (https://experts.colorado.edu/individual/fisid_165650/)
Assistant Professor; PhD, University of Washington

Stansbury, Jeffrey W.
Professor; PhD, University of Maryland

Toney, Michael (https://experts.colorado.edu/individual/fisid_167235/)
Professor; PhD, University of Washington

Weimer, Alan W. (https://experts.colorado.edu/display/fisid_109152/)
Professor; PhD, University of Colorado Boulder

White, Timothy J. (https://experts.colorado.edu/display/fisid_163899/)
Professor, Associate Chair; PhD, University of Iowa

Whitehead, Timothy Andrew (https://experts.colorado.edu/display/fisid_164364/)
Associate Professor; PhD, University of California-Berkeley

Young, Wendy Mores (https://experts.colorado.edu/display/fisid_146942/)
Teaching Professor, Associate Chair; PhD, University of Colorado Boulder

Courses

BIEN 2810 (3) Biology for Engineers

Develops a basic understanding of the science of biology, including an introduction to the disciplines of biochemistry, cell organization, metabolism, genetics, genomics, molecular biology, recombinant DNA technology and evolution. Provides a basic introduction to several key techniques used in biological engineering laboratories. Uses examples of complex and creative structures engineered by natural processes. Formerly CHEN 2820.

Requisites: Requires prereq or coreq course of CHEN 1201 or CHEN 1211 or CHEM 1113 or MCEN 1024 (minimum grade C-). Restricted to College of Engineering (ENGRU) undergraduates and IUT On Track applicants only.

BIEN 2840 (1-4) Independent Study

Available to sophomores with approval of Department of Chemical and Biological Engineering. Subject arranged to fit needs of student.

Repeatable: Repeatable for up to 6.00 total credit hours.

BIEN 3800 (3) Fundamentals of Biotechnology

Surveys the five areas of modern biotechnology (human, industrial, agricultural, animal, environmental), highlighting engineering principles in biology in all five areas. Delves into how biology is used to create useful materials and medicines. Imparts a working knowledge of synthetic DNA technology, including recombinant DNA, genome editing, DNA synthesis, and DNA sequencing.

Requisites: Requires prerequisite courses of BIEN 2810 or MCDB 1150 or EBIO 1220 and APPM 1350 or MATH 1300 and CHEN 1201 or CHEN 1211 or CHEM 1113 or MCEN 1024 (all minimum grade C-).

BIEN 3840 (1-4) Independent Study

Available to juniors with approval of the Department of Chemical and Biological Engineering. Subject arranged to fit needs of the student.

Repeatable: Repeatable for up to 6.00 total credit hours.

BIEN 4010 (2) Biological Engineering Senior Thesis 1

Provides an opportunity for advanced students to conduct exploratory research in biological engineering.

Requisites: Restricted to College of Engineering (ENGRU) undergraduates only.

BIEN 4020 (2) Biological Engineering Senior Thesis 2

Continuation of BIEN 4010.

Requisites: Requires prerequisite course of BIEN 4010 (minimum grade C-). Restricted to College of Engineering students only.

BIEN 4520 (3) Biological Process and Product Design

Provides a team-based capstone design experience for biological engineering students. The design synthesis activities, the considerations of numerous options, and the practical application of the fundamentals all need to be integrated from first year courses through to this senior design course. The sequence provides a culmination for all previous chemical and biological engineering courses (transport processes, thermodynamics, reaction kinetics, unit operations, etc.). Students are expected to know the basics of fluids, heat transfer, bioseparations, and reactor engineering (kinetics). In BIEN 4520, students will be exposed to design of equipment used for separations and reactions. Students will be taught how to select process units and interconnect them in an overall process flowsheet with the primary goal being to find the optimal design conditions for the best possible design scenario among various conceptualized alternatives. With the exception of cost estimation, process economics, heat integration, se

Requisites: Requires prerequisite courses of CHEN 3010 and BIEN 4820 and BIEN 4830 and BIEN 3800 or MCDB 2150 (all minimum grade C-). Restricted to College of Engineering majors only.

BIEN 4530 (2) Biological Engineering Design Project

This is the 2nd course in the team-based capstone biodesign sequence of classes. Projects are sponsored by industry and student design teams collaborate with industrial consultants. Projects consider biological process and product design with emphasis on economic analysis. Deliverables include an oral mid-project design review, a final oral presentation and a final written design report.

Requisites: Requires prerequisite course of BIEN 4520 (minimum grade C-). Restricted to College of Engineering majors only.

BIEN 4801 (3) Pharmaceutical Biotechnology

Focuses on the engineering needed to bring therapeutic products derived from living organisms (e.g., proteins, peptides, DNA, RNA) from the production plant to the patient. Covers the challenges of keeping these products "active" as they are stored, shipped, and administered to patients. Formerly CHEN 4801.

Requisites: Requires prerequisite courses of CHEN 3320 and prerequisite or corequisite courses of BIEN 4830 or CHEN 4330 (all minimum grade C-). Restricted to College of Engineering majors only.

BIEN 4802 (3) Tissue Engineering and Biofabrication

Tissue engineering demonstrates enormous potential for improving human health and the field of biofabrication has advanced our ability to position cells and materials into 3D configurations for the engineering of new tissues. This course explores principles of tissue engineering and biofabrication, drawing upon diverse fields such as cell biology, material science, and chemical and biological engineering. Current and developing methods of tissue engineering, as well as specific applications will be discussed in the context of these principles. The course will involve review of current literature within this developing field, as well as focus on translational concepts of tissue engineering. Formerly known as CHEN 4802.

Equivalent - Duplicate Degree Credit Not Granted: BIEN 5802

Requisites: Requires prerequisite course of BIEN 2810 or MCDB 1150 or EBIO 1210 and EBIO 1220 and prerequisite or corequisite of BIEN 4520 or CHEN 4520 or BMEN 4010 (minimum grade C-). Restricted to College of Engineering students only.

BIEN 4803 (3) Metabolic Engineering

Introduces basic concepts in metabolic engineering and explores modern approaches in metabolic and strain engineering. Application areas that will be discussed will include the use of metabolic engineering approaches in biofuels and biorefining as well as biopharmaceutical production. Formerly CHEN 4803.

Equivalent - Duplicate Degree Credit Not Granted: BIEN 5803

Requisites: Requires prerequisite course of BCHM 4611 (minimum grade C-). Restricted to College of Engineering majors only.

BIEN 4804 (3) Protein and Enzyme Engineering

This course reviews various applications of protein and enzyme engineering and covers key concepts in protein and enzyme design, including protein structure-function relationships; rational and evolutionary engineering approaches; genetic code expansion; cell-free protein synthesis; computational design; and biophysical methods for protein characterization. Additionally, students gain valuable experience reading, analyzing, and interpreting research results from scientific literature, as well as drafting an original research proposal.

Equivalent - Duplicate Degree Credit Not Granted: BIEN 5804

Requisites: Requires prerequisite courses of CHEN 3320 and BIEN 2810 and BCHM 4611 (minimum grade C-). Restricted to College of Engineering undergraduates only.

BIEN 4805 (3) Biomaterials

Provides an overview of biomaterials. Covers major classes of materials used in medical applications, properties, degradation mechanisms, and characterization methods, foreign body response, methods to control physiological response to biomaterial surfaces, biocompatibility, biomaterials used in soft and hard tissue replacements, drug delivery devices and tissue engineering, and design criteria for developing a material for a given biological application.

Requisites: Requires prerequisite courses of BIEN 2810 or MCDB 1150 or EBIO 1220 and CHEN 3311 (all minimum grade C-). Restricted to College of Engineering students only.

Recommended: Prerequisite CHEN 3331.

BIEN 4806 (3) Immunoengineering

Examines the fundamentals of immunology and covers engineering approaches to study and control immune reactions and their applications in therapy and diagnostics for infectious disease, cancer, allergy, and autoimmune disease.

Equivalent - Duplicate Degree Credit Not Granted: BIEN 5806

Requisites: Requires prerequisite course of BIEN 2810 and prerequisite or corequisite of CHEN 4330 or BIEN 4830 or BMEN 3010 (minimum grade C-). Restricted to College of Engineering students only.

BIEN 4810 (3) Biological Engineering Laboratory

Involves planning and execution of chemical engineering experiments on mass transfer operations, bioseparations, and biological reactors. Interprets experimental data with theoretical principles and statistical analysis. Emphasizes communication with written memos, full reports and oral presentations.

Requisites: Requires prerequisite courses of BIEN 2810 or MCDB 1150 or (EBIO 1210 and EBIO 1220) and CHEN 3010 and BIEN 4820 and BIEN 4830 (all minimum grade C-). Restricted to College of Engineering majors only.

BIEN 4820 (3) Biochemical Separations

Lect. and lab. Presents purification methods, mass transfer coefficients, problems specific to biologicals, and scale-up of processes. Also covers chromatography, phase extraction, supercritical fluids, sedimentation, precipitation, electrophoresis, dialysis, affinity techniques, cell separation, application of separations to bioreactors, and comparison of batch and continuous processes. Formerly CHEN 4820.

Requisites: Requires prerequisite course of CHEN 3210 and prereq or coreq of CHEN 4330 or BIEN 4830 (all minimum grade C-). Restricted to College of Engineering majors only.

BIEN 4830 (3) Biokinetics and Reactor Design

Introduces chemical kinetics, chemical reactor design, and biological kinetics. Involves mass and energy balances for steady-state and transient reactor systems. Also covers residence time distribution, mass transfer, catalytic reactions, multiple steady states in reactors, enzyme kinetics, metabolic networks, and cell growth kinetics.

Requisites: Requires prerequisite courses of CHEN 3320 and CHEN 3210 and (CHEN 4521 or CHEM 4531) (all minimum grade C-). Restricted to College of Engineering majors only.

BIEN 4838 (1-3) Special Topics in Biological Engineering

Examines a special topic in Biological Engineering.

Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to College of Engineering (ENGRU) undergraduates only.

BIEN 4840 (1-4) Independent Study

Available to seniors with approval of Chemical and Biological Engineering department. Subject arranged to fit needs of student.

Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.

CHEN 1000 (3) Creative Technology

Delve into cutting-edge topics such as the science of climate change, biotechnology, biomedical devices, advanced materials, renewable energy, and environmental sustainability! This course will introduce undergraduate students to the most recent concepts in technology and how these concepts impact all aspects of life, including human health and the health of the planet.

Additional Information: Arts Sci Core Curr: Natural Science Non-Sequence Arts Sci Gen Ed: Distribution-Natural Sciences

CHEN 1100 (3) Gourmet Science: Exploring Chemistry, Biology, and Technology through Food

This course explores chemistry, biology, and technology fundamentals through food. Ingredients utilized in cooking and baking processes demonstrate a breadth of key science and engineering concepts, intertwined with social significance and historical context. Students will learn about the chemical behaviors and biological interactions of molecules in food, understand critical ratios and reactions in baking and cooking, survey techniques and relevant technology, evaluate industrial and agricultural developments, and analyze global impacts of trade and policy on food science and engineering.

CHEN 1201 (4) General Chemistry for Engineers 1

Designed to meet the general chemistry requirement for some engineering students and serve as part one for students whose academic plans require advanced work in chemistry. Topics include components of matter, stoichiometry, electron configuration, chemical bonding, molecular shapes, covalent bonding, classes of reactions, thermochemistry, gases, atomic structure, organic compounds, intermolecular forces, and phase equilibria. Examples and problems illustrate the application of chemistry to engineering sub-disciplines. Department enforced prerequisites: High school Algebra, one year of high school Chemistry or CHEM 1021 (minimum grade C-).

Equivalent - Duplicate Degree Credit Not Granted: CHEN 1211, CHEM 1113, CHEM 1400 and MCEN 1024

Requisites: Restricted to College of Engineering (ENGRU) undergraduates and IUT On Track applicants only.

Recommended: Not recommended for students with grade below B- in CHEM 1021.

CHEN 1203 (2) General Chemistry for Engineers 2

Designed for students whose academic plans require advanced work in chemistry. Topics include kinetics, solubility/solubility equilibria, acid-bases, buffers and titrations, thermodynamics, and electrochemistry. Examples and problems illustrate the application of chemistry to engineering sub-disciplines. AP Chemistry credit not accepted in lieu of any of these prereq classes.

Equivalent - Duplicate Degree Credit Not Granted: CHEN 1211 or CHEM 1133 or CHEM 2100

Requisites: Requires prerequisite courses of CHEN 1201 or CHEM 1113 or MCEN 1024 (all minimum grade C-). Restricted to College of Engineering undergraduates (ENGRU) and IUT On Track applicants only.

Recommended: Corequisite CHEM 1221.

CHEN 1211 (4) Accelerated Chemistry for Engineers

One-semester lecture and recitation course designed for engineering students with more advanced chemistry backgrounds. Topics include stoichiometry; thermodynamics; gases, liquids, and solids; equilibrium; acids and bases; bonding concepts; kinetics; reactions; and materials science. Examples and problems illustrate the application of chemistry to engineering sub-disciplines. Department enforced prerequisite of 3, 4 or 5 on the AP Chemistry exam or equivalent IB scores or a passing score on the "Chemistry Readiness Exam for Engineers." Degree credit not granted for this course and CHEM 1113 and CHEM 1400 and CHEN 1201 and MCEN 1024.

Requisites: Restricted to College of Engineering (ENGRU) undergraduates and IUT On Track applicants only.

Recommended: Corequisite CHEM 1221.

CHEN 1300 (1) Introduction to Chemical and Biological Engineering

Meets for one lecture per week. Examines the different fields of chemical engineering and chemical & biological engineering including energy, materials, pharma, and biomedical; addresses how to be successful in college and engineering; and showcases some of the opportunities here at CU.

Requisites: Restricted to Chemical Engineering, Chemical Biological Engineering, Biological Engineering, and open option (XXEN) majors only with a maximum of 50 credit hours.

CHEN 1310 (3) Introduction to Engineering Computing

Introduces the use of computers in engineering problem solving, including elementary numerical methods. Teaches programming fundamentals, including data and algorithm structure, and modular programming. Software vehicles include Excel/Vba and Matlab. Formerly GEEN 1300 and COEN 1300.

Requisites: Requires prerequisite or corequisite course of APPM 1340 or 1345 or 1350 or GEEN 3830 or MATH 1300 (all minimum grade C-). Restricted to College of Engineering majors and IUT On Track applicants only

CHEN 1400 (3) Drugs, Driving and Dynamic Processes

Project-based course that applies the principles of chemistry, biology, mechanics and electronics to the production and application of sustainable commodities (fuels, drugs, chemicals, and energy). Examples include student-developed green vehicles, sustainable nutraceuticals, or renewable electrical generation.

Requisites: Restricted to Chemical Engineering (CHEN) and Chemical and Biological Engineering (CBEN), and open option (XXEN) majors only with a maximum of 70 credit hours.

CHEN 2120 (3) Chemical Engineering Material and Energy Balances

Provides a basic understanding of chemical engineering calculations involving material and energy balances around simple chemical processes.

Requisites: Requires prerequisite courses of CHEN 1211 or CHEN 1201 or CHEM 1400 or CHEM 1113 or MCEN 1024 (all min grade C-). Requires corequisite courses of CHEN 1310 (CHEN 1203 or CHEM 1133). Restricted to Coll of Engineering mjrs IUT On Track applicants onl

CHEN 2840 (1-4) Independent Study

Available to sophomores with approval of Department of Chemical Engineering. Subject arranged to fit needs of student.

Repeatable: Repeatable for up to 6.00 total credit hours.

CHEN 3010 (3) Applied Data Analysis

Teaches students to analyze and interpret data. Topics include engineering measurements, graphical presentation and numerical treatment of data, statistical inference, and regression analysis.

Requisites: Requires prerequisite course of CHEN 1310 and APPM 2360 or MATH 2130 and MATH 3430 (all minimum grade C-). Restricted to College of Engineering students only.

CHEN 3200 (3) Chemical Engineering Fluid Mechanics

Introduces fluid mechanics and momentum transfer, emphasizing the application of these principles to chemical engineering systems.

Equivalent - Duplicate Degree Credit Not Granted: CVEN 3313 and MCEN 3021

Requisites: Requires prereq courses of PHYS 1110 and (APPM 2350 or MATH 2400) and (CHEN 2120 or CVEN 2121 or GEEN 2851 or MCEN 2023) (all min grade C-). Requires prereq or coreq courses of APPM 2360 or (MATH 2130 and MATH 3430) (min grade C-). Restricted to ENGR mjr

CHEN 3210 (4) Chemical Engineering Heat and Mass Transfer

Examines conservation and transfer of mass and thermal energy. Focuses on conduction and convection of heat in the context of chemical processes and heat exchangers. Addresses radiation. Also studies mass transfer rate processes, including diffusion, microscopic material balances, and correlations for mass transfer coefficients.

Requisites: Requires prerequisite courses of (CHEN 3200 or MCEN 3021) and (APPM 2360 or MATH 3430) (minimum grade C-). Restricted to College of Engineering majors only

CHEN 3211 (1) Chemical Engineering Mass Transfer

Study of mass-transfer rate processes, including diffusion, convection, microscopic material balances, and correlations for mass-transfer coefficients. Requires department approval and a department-approved heat transfer course.

Requisites: Requires prerequisite course of either CHEN 3200 or MCEN 3021 (minimum grade C-). Restricted to College of Engineering (ENGRU) undergraduates only.

CHEN 3220 (3) Chemical Engineering Separations

Studies separation methods including distillation, absorption, extraction, and membranes, and graphical and computer-based solutions to separation problems. Applies mass transfer rate theory to packed and tray columns.

Requisites: Requires prerequisite courses of CHEN 3210 and CHEN 3320 and (CHEN 4521 or a prerequisite or corequisite of CHEM 4531) (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 3320 (3) Chemical Engineering Thermodynamics

Applies thermodynamic principles to nonideal systems, phase equilibrium, chemical equilibrium, power generation, refrigeration, and chemical processes.

Requisites: Requires prerequisite courses of CHEN 2120 and (CHEN 4521 or a prerequisite or corequisite of CHEM 4531) and (APPM 2360 or MATH 3430) (all minimum grade C-). Restricted to College of Engineering majors only

CHEN 3660 (3) Energy Fundamentals

Explains the most important energy technologies and systems; provides tools to analyze performance using science and engineering principles. This course will investigate important energy concepts from sources and extraction to utilization, storage and efficiency. Topics include fossil fuels, hydropower, renewable energy, biofuels, carbon capture and waste disposal.

Requisites: Requires prerequisite courses of CHEN 1201 or CHEN 1211 or CHEM 1113 or MCEN 1024 and PHYS 1110 and APPM 1360 or MATH 2300 (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 3670 (3) Sustainable Design of Chemical and Materials Systems

Explains the principles of green engineering and provides tools to analyze sustainability of engineered processes and materials. This course will investigate important sustainability concepts from utilization of renewable feedstocks for chemicals and materials manufacturing to recycling, waste elimination, and toxicology. Topics include analysis of environmental effects of chemical processes and products, mechanical and chemical recycling of plastics and other materials, minimizing fossil energy demands in manufacturing processes, and approaches to life cycle assessment of candidate technologies.

Requisites: Requires prerequisite courses of PHYS 1110 and (CHEN 1211 or CHEN 1201 or CHEM 1113 or MCEN 1024) and (APPM 1360 or MATH 2300) (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 3840 (1-4) Independent Study

Available to juniors with approval of the Department of Chemical Engineering. Subject arranged to fit needs of the student.

Repeatable: Repeatable for up to 6.00 total credit hours.

Requisites: Restricted to College of Engineering (ENGRU) undergraduates only.

CHEN 3930 (6) Chemical Engineering Cooperative Education

Students enrolled in this course participate in a previously arranged, department-sponsored cooperative education program.

Requisites: Requires prerequisite course of CHEN 2120 (minimum grade C-). At least a 2.85 cumulative GPA is required. Restricted to College of Engineering majors only.

Recommended: Prerequisite 3.00 GPA or higher.

CHEN 4010 (2) Chemical Engineering Senior Thesis 1

Provides an opportunity for advanced students to conduct exploratory research in chemical engineering.

Requisites: Restricted to College of Engineering (ENGRU) undergraduates only.

CHEN 4020 (2) Chemical Engineering Senior Thesis 2

Continuation of CHEN 4010. This course and CHEN 4020 can substitute for CHEN 4130.

Requisites: Requires prerequisite course of CHEN 4010 (minimum grade C-). Restricted to College of Engineering students only.

CHEN 4090 (1) Undergraduate Seminar

Provides chemical engineering career and professional information, facilitates contact with faculty and industry representatives, and improves communication and leadership skills. Consists of a series of seminars and field trips and requires a research project involving a written and oral report.

Requisites: Restricted to Chemical (CHEN) Engineering or Chemical and Biological (CBEN) Engineering or Biological (BIEN) Engineering majors only.

CHEN 4130 (3) Chemical Engineering Laboratory

Involves planning and execution of chemical engineering experiments on mass transfer operations, separations, and chemical reactors. Interprets experimental data with theoretical principles and statistical analysis. Emphasizes communication with written memos, full reports, and oral presentations.

Requisites: Requires prerequisite courses of CHEN 3010 and CHEN 3220 and CHEN 3320 and CHEN 4330 (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4330 (3) Kinetics and Reactor Design

Introduces chemical kinetics and chemical reactor design. Involves mass and energy balances for steady-state and transient reactor systems. Also covers residence time distribution, mass transfer, catalytic reactions, and multiple steady states in reactors.

Requisites: Requires prerequisite courses of CHEN 3320 and CHEN 3210 and (CHEN 4521 or CHEM 4531) (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4440 (3) Chemical Engineering Materials

Introduces materials engineering, including properties of polymers, metals, ceramics, and semiconductors, especially as related to chemical engineering processes.

Requisites: Requires prerequisite courses of CHEN 3320 and CHEM 3311 (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4450 (3) Polymer Chemistry

Introduces polymer science with a focus on polymer chemistry and polymerization reactions. Focuses on polymerization reaction engineering and how polymer properties depend on structure.

Equivalent - Duplicate Degree Credit Not Granted: CHEN 5450

Requisites: Requires prerequisite courses of CHEN 4830 or CHEN 4330 and CHEM 3311 (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4460 (3) Polymer Engineering

Introductory polymer engineering course reviewing basic terminology and definitions; the properties and synthetic routes of important industrial polymers; and processing of polymers and their applications.

Equivalent - Duplicate Degree Credit Not Granted: CHEN 5460

Requisites: Requires prerequisite courses of CHEM 3311 and CHEN 3320 (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4480 (3) Solar Cells and Optical Devices for Sustainable Buildings

This course assumes no background in electronic materials and explains how silicon and cutting-edge metal halide perovskite solar cells are designed, fabricated and characterized. Topics will include optics, band diagrams, wafer fabrication, most thin film deposition techniques, module design and economics. Other optical devices that can help the world rapidly reduce its carbon emissions, such as light-emitting diodes and energy saving windows with dynamic tinting, will also be covered.

Equivalent - Duplicate Degree Credit Not Granted: CHEN 5480

Recommended: Prerequisite a course in materials science (for example CHEN 4440), the physics of electromagnetism and optics at a very basic level.

CHEN 4490 (3) Electrochemical Engineering

This course discusses fundamentals and applications of electrochemical systems from an engineering perspective. Aspects of thermodynamics, reaction kinetics, and transport phenomena relevant to the description of electrode/electrolyte interfaces and charge transfer reactions are covered. Topics include cell equilibrium (Nernst equation), reactions rates within Butler-Volmer and Marcus theory, electrochemical double layer structure, ion transport (Poisson-Nernst-Planck equation), potential and current distributions in electrochemical cells, and experimental electroanalytical techniques. Applications include fuel cells, electrolyzers, batteries, sensors, and corrosion. Contact instructor to request to take prerequisites as corequisites.

Equivalent - Duplicate Degree Credit Not Granted: CHEN 5490

Requisites: Requires prerequisite courses of (CHEN 4330 or CHEN 4830) and PHYS 1120 (minimum grade C-). Restricted to College of Engineering (ENGRU) undergraduates only.

CHEN 4520 (3) Chemical Process Design

Studies applied chemical process design including equipment specification and economic evaluation.

Requisites: Requires prerequisite courses of CHEN 3010 and CHEN 3210 and CHEN 3220 and CHEN 4330 or CHEN 4830 (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4521 (3) Physical Chemistry for Engineers

Examines the laws of classical thermodynamics followed by physical transformations of pure substances, the thermodynamics of simple mixtures and chemical equilibrium. Applies quantum theory to atomic and molecular structure. Presents the concepts and applications of statistical thermodynamics. Introduces rates of chemical reactions, reaction dynamics and catalysis.

Requisites: Requires prereq courses of APPM 2350 or MATH 2400 and CHEN 1211 or CHEN 1203 or CHEM 1133 (all min. grade C-). Requires a prereq or coreq course of APPM 2360 or MATH 2130 and MATH 3430 (min. grade C-). Restricted to College of Engineering majors only.

CHEN 4530 (2) Chemical Engineering Design Project

Provides a team-based capstone design experience for chemical engineering students. Projects are sponsored by industry and student design teams collaborate with industrial consultants. Projects consider chemical process and product design with emphasis on economic analysis. Deliverables include an oral mid-project design review, a final oral presentation and final written design report.

Requisites: Requires prerequisite course of CHEN 4520 (minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4570 (4) Process Dynamics and Control

Examines principles of controls theory and controls application to chemical processes. Focuses on feedback, feedforward and distributed control systems. Laboratory sessions cover measurement fundamentals, signal transmission, dynamic testing, control system synthesis, and implementation and adjustment.

Requisites: Requires prerequisite courses of CHEN 3220 and CHEN 4330 or BIEN 4830 and PHYS 1120 and APPM 2360 or MATH 2130 and MATH 3430 (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4630 (1) Intellectual Property Law and Engineering

Learn the fundamentals of the various types of intellectual property, obtain the ability to search the USPTO database for patents, learn the difference between provisional patents, utility patents and foreign patents and learn the timing requirements related to the filing of patents and public disclosure, use, and/or sale of an invention.

Equivalent - Duplicate Degree Credit Not Granted: CHEN 5630

Requisites: Restricted to students with 87-180 credits (Senior, Fifth Year Senior) College of Engineering majors only.

CHEN 4650 (3) Particle Technology

Aims to identify the important physical mechanisms occurring in processes involving particles, formulate and solve mathematical descriptions of such processes, and analyze experimental and theoretical results in both a qualitative and quantitative manner. Teaches students to apply this knowledge to the design of particulate systems. Conveys the breadth and depth of natural and industrial applications involving particulates.

Equivalent - Duplicate Degree Credit Not Granted: CHEN 5650

Requisites: Requires prerequisite courses of APPM 2360 or MATH 2130 and MATH 3430 and CHEN 3200 or MCEN 3021 (all minimum grade C-). Restricted to College of Engineering majors only.

CHEN 4831 (1) Biokinetics and Bioreactors Module

Study of biokinetics of enzyme reactions, cell growth and bioproduct formation. Design of batch, semi-batch and continuous bioreactors. Overview of biotechnology industry. Introduction to pharmacokinetics and drug delivery. Requires department approval and a department-approved kinetics and reactor design course.

Requisites: Requires prerequisite course CHEN 3210 (minimum grade C-). Restricted to College of Engineering (ENGRU) undergraduates only.

CHEN 4836 (3) Nanomaterials

Presents fundamental chemical and physical concepts that give rise to the unique optical, electronic and magnetic properties of nanoscale materials. Introduces important synthetic routes for producing nanomaterials, and interparticle forces governing colloidal behavior and self-assembly. Discusses current and potential applications in catalysis, biomedicine, renewable energy, and other fields.

Equivalent - Duplicate Degree Credit Not Granted: CHEN 5836

Requisites: Require prerequisite or corequisite of CHEN 3320 (minimum grade C-). Restricted to College of Engineering students only.

CHEN 4838 (1-3) Special Topics in Chemical Engineering

Examines a special topic in Chemical Engineering.

Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to College of Engineering (ENGRU) undergraduates only.

CHEN 4840 (1-4) Independent Study

Available to seniors with approval of chemical engineering department. Subject arranged to fit needs of student.

Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to students with 87-180 credits (Senior, Fifth Year Senior) College of Engineering majors only.