CHEMICAL AND BIOLOGICAL ENGINEERING

Degree Types: MS, PhD

Graduates of the Chemical and Biological Engineering Program (https://www.mccormick.northwestern.edu/chemical-biological/graduate/) develop proficiency in modern chemical and biological engineering theory and practice through a core curriculum. They gain specialized knowledge through elective courses within and outside of the department.

PhD candidates collaborate with a faculty member to develop and pursue a research program that defines and solves a problem at the frontier of chemical engineering. MS candidates are also able to pursue research with the thesis option.

Current areas of research interest by faculty in the department are organized into the broad categories of:

- Sustainability and Energy (https://www.mccormick.northwestern.edu/chemical-biological/research/areas/sustainability-and-energy.html)
- Biotechnology and Synthetic Biology (https://www.mccormick.northwestern.edu/chemical-biological/research/areas/biotechnology-bioengineering-complexity.html)
- Catalysis and Reaction Engineering (https://www.mccormick.northwestern.edu/chemical-biological/research/areas/catalysis-and-reaction-engineering.html)
- Polymers and Soft Materials (https://www.mccormick.northwestern.edu/chemical-biological/research/areas/polymers-and-soft-materials.html)
- Complex Systems and Data Science (https://www.mccormick.northwestern.edu/chemical-biological/research/areas/complex-systems-and-data-science.html)

Additional resources:

- Department website (https://www.mccormick.northwestern.edu/chemical-biological/)
- Program handbook(s)

Degrees Offered

- Chemical and Biological Engineering BS/MS (https://catalogs.northwestern.edu/tgs/chemical-biological-engineering/chemical-biological-engineering-bach-mast/)
- Chemical and Biological Engineering MS (https://catalogs.northwestern.edu/tgs/chemical-biological-engineering/chemical-biological-engineering-ms/)
- Chemical and Biological Engineering PhD (https://catalogs.northwestern.edu/tgs/chemical-biological-engineering/chemical-biological-engineering-phd/)

Chemical and Biological Engineering: MS

Learning objective(s)/Students should be able to…

- Demonstrate achievement through coursework in the fundamentals of thermodynamics, kinetics and reactor design, and transport phenomena, when approached from the perspective of a chemical engineer.
- Demonstrate achievement through additional coursework in a topical area related to chemical engineering of the students choosing.
- Contribute to new knowledge in the field of chemical engineering.

Chemical and Biological Engineering: PhD

Learning objective(s)/Students should be able to…

- Demonstrate achievement through coursework in the fundamentals of thermodynamics, kinetics and reactor design, and transport phenomena, when approached from the perspective of a chemical engineer.
- Demonstrate achievement through additional coursework in a topical area related to chemical engineering of the students choosing.
- Develop excellence in teaching of chemical engineering concepts.
- Cultivate an interest in lifelong learning in the field of chemical engineering.
- Contribute to new knowledge in the field of chemical engineering.
- Excel in their career of choice following graduation.
- Gain an understanding of the concepts of Anti-Racism, Diversity, Equity, and Inclusion (ARDEI) and consider these concepts in relation to their research and the field of chemical engineering.

Chemical and Biological Engineering Courses

CHEM_ENG 307-0 Kinetics and Reactor Engineering (1 Unit)
Chemical reaction kinetics with application to the design of chemical reactors.
Prerequisites: CHEM_ENG 210-0, CHEM_ENG 211-0, CHEM_ENG 321-0, CHEM_ENG 322-0.

CHEM_ENG 312-0 Probability and Statistics for Chemical Engineering (1 Unit)
Introduction to probability theory and statistical methods necessary for analyzing the behavior of processes and experiments. Statistical tests for detecting significant changes in process parameters relevant to engineering problems. Students are encouraged but not required to be familiar with coding prior to taking this course.
Prerequisites: MATH 220-1, 220-2, 228-1, 228-2 or equivalent, and COMP_SCI 150-0.

CHEM_ENG 321-0 Fluid Mechanics (1 Unit)
Derivation and applications of continuity and Navier-Stokes equations. Macroscopic mass, momentum, and energy balance. Dimensional analysis: friction factors in pipes and packed beds; drag coefficients.
Prerequisites: completion of mathematics requirements with no grades of D; GEN_ENG 205-4 (C- or better).

CHEM_ENG 322-0 Heat Transfer (1 Unit)
The differential equations of energy transport. Solutions for various applications.
Prerequisites: completion of mathematics requirements with no grades of D; GEN_ENG 205-4 (C- or better); CHEM_ENG 321-0 recommended.

CHEM_ENG 323-0 Mass Transfer (1 Unit)
Diffusion and rate concepts; application to distillation, extraction, absorption, humidification, drying.
Prerequisites: CHEM_ENG 321-0, CHEM_ENG 322-0.

CHEM_ENG 330-0 Molecular Engineering and Statistical Mechanics (1 Unit)
Basic statistical mechanics. Applications to thermodynamics, kinetics, and transport of various engineering systems, including frontier areas

of chemical and biological engineering. Not open to students who have taken CHEM_ENG 406-0, CHEM 342-3, or PHYSICS 332-0.
Prerequisite: CHEM_ENG 211-0 or another thermodynamics course; courses in probability and statistics, heat transfer, or other transport recommended.

CHEM_ENG 341-0 Dynamics and Control of Chemical and Biological Processes (1 Unit)
Dynamic behavior of chemical process components. Feedback control principles.
Prerequisites: CHEM_ENG 307-0; senior standing.

CHEM_ENG 342-0 Chemical Engineering Laboratory (1 Unit)
Operation and control of process equipment for the determination of operating data. Analysis and written presentation of results.
Prerequisites: CHEM_ENG 212-0, CHEM_ENG 307-0, CHEM_ENG 321-0, CHEM_ENG 322-0, CHEM_ENG 323-0.

CHEM_ENG 345-0 Process Optimization for Energy and Sustainability (1 Unit)
Modern techniques and application to the design and operation of chemical process systems. Steady-state and dynamic methods. Experimental search for the optimum.
Prerequisite: junior standing.

CHEM_ENG 351-0 Process Economics, Design, & Evaluation (1 Unit)
Preliminary design of industrial processes for the production of chemical and allied products by the application of the engineering sciences and economics.
Prerequisites: CHEM_ENG 212-0, CHEM_ENG 307-0, CHEM_ENG 321-0, CHEM_ENG 322-0, CHEM_ENG 323-0.

CHEM_ENG 352-0 Chemical Engineering Design Projects (1 Unit)
Design of chemical and process plants applying the principles of unit operations, thermodynamics, reaction kinetics, and economics. Mechanical design and selection of chemical process equipment.
Prerequisite: CHEM_ENG 351-0.

CHEM_ENG 355-0 Chemical Product Design (1 Unit)
Properties and selection of chemicals for products from single-molecule pharmaceuticals to devices to manufactured products such as food and consumer goods.
Prerequisite: junior standing.

CHEM_ENG 361-0 Introduction to Polymers (1 Unit)
Polymerization mechanisms and their relation to molecular structure, polymerization processes, and the mechanical properties of polymers, especially flow behavior.
Prerequisites: CHEM_ENG 211-0 or other thermodynamics course; CHEM 210-1.

CHEM_ENG 364-0 Chemical Processing and the Environment (1 Unit)
Application of chemical engineering fundamentals to environmental problems. Chemistry and mechanisms, chemical reaction and rate, and transport emphasized. Risk assessment and analysis revealed through case studies.
Prerequisites: CHEM_ENG 212-0, CHEM_ENG 307-0.

CHEM_ENG 365-0 Sustainability, Technology, and Society (1 Unit)
Technical discussion of selected topics related to sustainability, sustainable development, global climate changes, natural and renewal resources and utilization, industrial ecology, eco-efficiency, technology related to sustainability such as biofuel, electrification of transportation, and water purification, and role of policy and business risk assessment.
Prerequisites: junior standing in science or engineering; familiarity with process system analysis, energy and material balances (such as found in CHEM_ENG 210-0 or CIV_ENV 260-0).

CHEM_ENG 367-0 Quantitative Methods in Life Cycle Analysis (1 Unit)
Lifecycle analysis (LCA) framework for environmental assessment of technology systems, focusing on modeling methods for systems mass and energy flows, process and input-output-based systems inventories, environmental impact analysis, and methods for robust engineering decisions. MECH_ENG 367-0 is taught with CHEM_ENG 367-0; may not receive credit for both courses.

CHEM_ENG 372-0 Bionanotechnology (1 Unit)
Physical biology of the cell and its implications for nanotechnology, with a focus on the quantitative description of sizes, shapes, times, and energies at the nanoscale.
Prerequisite: MATH 228-1 (formerly listed as MATH 230-0).

CHEM_ENG 373-0 Biotechnology and Global Health (1 Unit)
Recent advances in synthetic biology and genetic, metabolic, and tissue engineering. Design, development, and commercialization of healthcare technologies for countries in the developing world and the challenges of deploying preventative, diagnostic, and therapeutic products in these settings.

CHEM_ENG 375-0 Biochemical Engineering (1 Unit)
Modern biochemical engineering. Life sciences: microbiology, biochemistry, and molecular genetics. Metabolic stoichiometry, energetics, growth kinetics, transport phenomena in bioreactors, and product recovery.
Prerequisite: CHEM_ENG 307-0, CHEM_ENG 323-0, or consent of instructor.

CHEM_ENG 376-0 Principles of Synthetic Biology (1 Unit)
Overview of synthetic biology's foundations in the natural sciences and engineering and its applications in medicine, biotechnology, and green chemistry. How engineering driven approaches may be used to accelerate design-build-test loops required for reprogramming existing biological systems and constructing new ones.
Prerequisite: CHEM_ENG 275-0 or BIOL_SCI 201-0 or BIOL_SCI 202-0 (formerly BIOL_SCI 215-0 or BIOL_SCI 219-0).

CHEM_ENG 377-0 Bioseparations (1 Unit)
Downstream process in biotechnology. Separation and lysis of cells. Recovery of organelles and proteins. Protein separation and purification.
Prerequisites: CHEM_ENG 323-0 (may be taken concurrently); CHEM_ENG 275-0 or BIOL_SCI 201-0 or BIOL_SCI 202-0 (formerly BIOL_SCI 215-0 or BIOL_SCI 219-0).

CHEM_ENG 378-0 Deconstructing Synthetic Biology – Biotechnology Case Studies Across Scales (1 Unit)
Synthetic biology uses concepts across STEM fields to reuse, repurpose and redesign biological systems to solve important global challenges. Here, we break down how synthetic biology solutions integrate concepts across five spatiotemporal scales—molecular, network, cell/cell-free systems, biological communities and societal—using case studies in sustainability, biomanufacturing and human health. The deconstruction approach enables students to better tackle scientific challenges.

CHEM_ENG 379-0 Computational Biology: Analysis and Design of Living Systems (1 Unit)
This course provides an introduction to fundamental principles and methods for computational and mathematical analysis of natural and engineered biological systems. Emphasis is placed upon understanding and designing biological systems based upon conceptual framings including multi-scale networks, dynamic control, genetic circuits, and biological programs.

CHEM_ENG 381-0 Practical Biological Imaging (1 Unit)

Theory and practice of biological microscopy in a lab setting; image acquisition, analysis, and the ethics of image manipulation.

CHEM_ENG 382-0 Regulatory Sciences in Biotechnology (1 Unit)
Course on topics at the intersection of science, engineering, and biotech regulatory compliance. Federal regulations for drug product development; regulatory compliance processes and organizational structure; interface between biotechnology processes and regulatory sciences; global harmonization of regulations; regulatory documentation.

CHEM_ENG 395-0 Special Topics in Chemical Engineering (1 Unit)
Topics suggested by students or faculty and approved by the department.

CHEM_ENG 401-0 Mathematical Methods for Chemical Engineering (1 Unit)
Foundation for mathematical and programming techniques that will be common in chemical engineering, particularly related to research. Topics include probability and statistics; differential equations; vectors, tensors, linear algebra; and conservation equations for momentum, heat, and mass transport.

CHEM_ENG 404-0 Advanced Thermodynamics (1 Unit)
Quantitative study of the fundamental principles of thermodynamics. Application of the laws of thermodynamics, concepts of equilibrium, equations of state, and properties of solutions to problems of engineering significance, including phase and chemical reaction equilibria.

CHEM_ENG 406-0 Selected Topics in Thermodynamics (1 Unit)
Selected topics from recent literature in thermodynamics.

CHEM_ENG 408-0 Chemical Engineering Kinetics and Reactor Design (1 Unit)
Interpretation of chemical rate selectivity data in homogeneous and heterogeneous reaction systems. Development and application of the theory of chemical kinetics, including collision, transition state, and surface reactivity approaches. Theory and analysis of reaction in heterogeneous phases. Reactor design with applications to and extension of ideal and nonideal reactor models: gas-solid, gas-liquid, and three-phase reactor design.

CHEM_ENG 409-0 Advanced Reactor Design (1 Unit)
Advanced engineering aspects of reactor design. Analysis of coupled transport processes and chemical reaction in application to realistic design and scale-up of various types of chemical reactors. Optimization problems in reactor design and operation.

CHEM_ENG 410-0 Principles of Heterogeneous Catalysis (1 Unit)
Recent publications in heterogeneous catalysis are reviewed along with formal lectures on fundamentals. Topics include kinetics and mechanisms of surface reactions, catalyst characterization, structure of solids, surface reactivity trends, active site concepts, importance of mass transfer, and examples of catalysis by metals, oxides, sulfides and zeolites.

CHEM_ENG 420-0 Transport Phenomena (1 Unit)
Momentum, Heat, and Mass transfer derivations and applications. Topics include Navier-Stokes equations and their application for solution of fluid mechanics problems in the inviscid fluid, creeping flow and boundary layer approximations; linear Heat and Mass transfer by heat conduction, diffusion, and convection; steady-state and transient processes; general formulation, approximations, and model building; emphasis on developing physical insight.

CHEM_ENG 421-0 Fluid Mechanics (1 Unit)
Derivation of Navier-Stokes equations and their application for solution of fluid mechanics problems in the inviscid fluid, creeping flow and boundary layer approximations.

CHEM_ENG 422-0 Heat and Mass Transfer (1 Unit)
Heat and Mass transfer by heat conduction, diffusion, and convection. (Linear phenomena only; heat transfer by radiation, natural convection, and mass transfer in concentrated solutions are not discussed.) Steady-state and transient processes. General formulation, approximations, and model building. Emphasis on developing physical insight.

CHEM_ENG 441-0 Electrocatalysis for Sustainable Fuels and Chemicals (1 Unit)
This class presents the fundamentals of electrochemistry and applies these principles to a variety of electrocatalytic processes, especially those with relevance to sustainable chemical and fuel production or consumption technologies. Overall aim of the course is to provide the student with both the technical foundation and high-level overview needed to assess up-and-coming electrochemical energy conversion technologies. Recommended.
prerequisite: undergraduate level thermodynamics (such as CHEM_ENG 211-0 or General Chemistry courses).

CHEM_ENG 451-0 Applied Molecular Modeling (1 Unit)
Introduction to modern computational methods for calculating properties of reaction systems, as well as thermodynamics, transport, and structural properties of materials.

CHEM_ENG 462-0 Viscoelasticity & Flow in Polymer Systems (1 Unit)
Fundamental aspects of polymer rheology, including the theory of linear viscoelasticity, measurement of fundamental flow properties, constitutive equations, the kinetic- molecular theories of viscoelasticity, and polymer processing behavior.

CHEM_ENG 463-0 Polymerization Reaction Engineering (1 Unit)
Polymerization reactions and resulting molecular weight distributions; modeling of polymerization kinetics; batch, continuous stirred tank and tubular flow reactor design for optimal polymerizations; emulsion and catalyzed polymerizations; photoresist technology.

CHEM_ENG 470-0 Molecular Folding and Function (1 Unit)
This course is an in-depth study of the current methods used to design and engineer biomolecules, with a focus on proteins and RNA. Emphasis on how strategies can be applied in the laboratory. Relevant case studies presented to illustrate method variations and applications. Intended for graduate students and upper-level undergraduates with some familiarity with basic biological concepts.
Prerequisites: BIOL_SCI 201-0 or CHEM_ENG 275-0, or equivalent with consent of instructor; recommended: BIOL_SCI 301-0 or equivalent.

CHEM_ENG 477-0 Bioseparations (1 Unit)
Downstream processing in biotechnology. Separation and lysis of cells. Recovery of organelles and proteins. Protein separation and purification.
Prerequisites: CHEM_ENG 321-0, CHEM_ENG 323-0 (or equivalent), CHEM_ENG 375-0.

CHEM_ENG 478-0 Advances in Biotechnology (1 Unit)
The emergence of new tools and ideas in biotechnology continues to accelerate, and this course is an introduction to a range of topics at the forefront of this field. The objective of this class is to expose students to the multidisciplinary research, and provide technical and intellectual skills from fields such as biochemical engineering, biochemistry, bioengineering, biomaterials, metabolic engineering, molecular biology, nanobiotechnology, pharmacology, and tissue engineering.

CHEM_ENG 489-0 Selected Topics in Chemical Engineering (1 Unit)
Selected topics from recent literature.

CHEM_ENG 499-0 Projects (1-3 Units)
Thorough study and submission of a report on a chemical engineering problem. Permission of instructor and department required. May be repeated for credit.

CHEM_ENG 510-0 Seminar (0 Unit)
Department seminar.

CHEM_ENG 520-0 Professional Development in Chemical and Biological Engineering 1 (0 Unit)
A required class for all graduate students in Chemical and Biological Engineering. This class covers skills and best practices for research, including expectations; developing and maintaining networks; effective meeting, communication, and collaboration; and data/literature management. This will also introduce students to anti-racism, diversity, equity, and inclusion (ARDEI) concepts and their relationship to students' research, academic/professional settings, engineering, and daily lives.

CHEM_ENG 520-1 Professional Development in Chemical and Biological Engineering 2 (0 Unit)
A required class for Ph.D. students and an optional class for MS students in Chemical and Biological Engineering. This class covers skills and best practices for research, including expectations; developing and maintaining networks; effective meeting, communication, and collaboration; and data/literature management. This will also introduce students to anti-racism, diversity, equity, and inclusion (ARDEI) concepts and their relationship to students' research, academic/professional settings, engineering, and daily lives.

CHEM_ENG 590-0 Research (1-4 Units)
Independent investigation of selected problems pertaining to thesis or dissertation. May be repeated for credit.