CHBE - CHEMICAL AND BIOMOLECULAR ENGINEERING

CHBE100 Exploring ChBE (1 Credit)
Overview of the specializations and career paths available in chemical and biomolecular engineering. Academic planning, policies and resources will be covered including introduction to undergraduate research, study abroad, internship and co-op opportunities as well as chemical engineering student groups. A peer mentoring program will enable students to interact with successful upper-class chemical engineering students and build their chemical engineering peer network.
Prerequisite: Permission of instructor; and permission of ENGR-Chemical & Biomolecular Engineering department.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department.

CHBE101 Introduction to Chemical and Biomolecular Engineering (3 Credits)
Introduction to methods of chemical engineering calculations and analysis. Stoichiometric relations, material and energy balances, and behavior of gases, vapors, liquids and solids. Analytical and computer methods.
Prerequisite: CHEM135; or students who have taken courses with comparable content may contact the department.
Corequisite: MATH141.
Restriction: Must be in Engineering: Chemical program; or permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE101 or ENCH215.
Formerly: ENCH215.

CHBE250 Computer Methods in Chemical Engineering (3 Credits)
Algorithm development and application of software to the analysis of chemical engineering problems. File management and editing, graphics and numerical methods. Use of spreadsheets, statistics/math software and process simulators for the design of chemical process equipment.
Prerequisite: CHBE101; and must have completed or be concurrently enrolled in MATH241.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE250 or ENCH250.
Formerly: ENCH250.

CHBE301 Chemical and Biomolecular Engineering Thermodynamics I (3 Credits)
Principles of thermodynamics and their application to engineering problems. First and second laws of thermodynamics, properties of gases, liquids and solids, phase equilibrium, flow and non-flow systems, energy conversion, production of work from heat, thermodynamic analysis of processes, equilibrium stage operations and the thermodynamics of chemically reacting systems.
Prerequisite: CHBE101; and must have completed or be concurrently enrolled in CHBE250 and MATH241.
Restriction: Must be in Engineering: Chemical program; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: ENCH300 or CHBE301.
Formerly: ENCH300.

CHBE302 Chemical and Biomolecular Engineering Thermodynamics II (3 Credits)
Contemporary trends in chemical engineering thermodynamics that bridge the gap between fundamentals and applications. Thermodynamic analysis of non-ideal and structured systems; such as complex fluids, strongly fluctuating and nanoscale systems, dissipative systems, biosystems, and systems under extreme conditions.
Prerequisite: CHBE301.
Corequisite: CHBE250.
Restriction: Must be in a major within ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE302 or ENCH400.
Formerly: ENCH400.

CHBE333 Chemical Engineering Seminar (1 Credit)
To develop oral communication skills through a series of class presentations of current chemical engineering topics.
Restriction: Junior standing; and must be in a major within ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE333 or ENCH333.
Formerly: ENCH333.

CHBE369 Teaching Experiences in Chemical Engineering (1-2 Credits)
Students will obtain pedagogical experience by assisting with the teaching of undergraduate courses in Chemical and Biomolecular Engineering.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Repeatable to: 8 credits.

CHBE409 Undergraduate Honors Seminar (1 Credit)
Students will attend and write summaries of departmental seminars, along with professional development activities
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and Permission of ENGR-Chemical & Biomolecular Engineering department; and Must be in the Chemical Engineering Honors Program.
Repeatable to: 2 credits.

CHBE410 Statistics and Design of Experiments (3 Credits)
An introduction to probability, statistics, and design of experiments for chemical engineers.
Prerequisite: Minimum grade of C- in CHBE250, MATH241, and MATH246.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE410 or ENCH476.
Formerly: ENCH476.

CHBE422 Chemical and Biomolecular Engineering Transport Phenomena I (3 Credits)
Principals of fluid dynamics as applied to model development and process design. Mass, momentum and energy conservation. Statics and surface tension. Equation of Continuity and Navier-Stokes Equation with application to laminar flow. Dimensional analysis. Macroscopic balances, Bernoulli Equation and friction factors with application to turbulent flow.
Prerequisite: Minimum grade of C- in CHBE101, CHBE250, MATH241, and MATH246.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE422 or ENCH422.
Formerly: ENCH422.

CHBE424 Chemical and Biomolecular Engineering Transport Phenomena II (3 Credits)
Principles of mass and heat transfer as applied to model development and process design. Species continuity equation with application to diffusion, and convection in laminar flow. Macroscopic balances and mass transfer coefficients with application to turbulent flow. Microscopic equation of energy with application to heat conduction, and convection in laminar flow. Macroscopic energy balance and heat transfer coefficients with application to turbulent flow. Heat exchanger design.
Prerequisite: CHBE422.
Corequisite: CHBE302.
Restriction: Must be in Engineering: Chemical program; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE424 or ENCH424.
Formerly: ENCH424.

CHBE426 Chemical and Biomolecular Separation Processes (3 Credits)
Separation by stages operations. Rate dependent separation processes. Design application in distillation, gas absorption, liquid extraction, drying, adsorption and ion exhange.
Corequisite: CHBE302; and CHBE424.
Restriction: Must be in Engineering: Chemical program; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE426 or ENCH426.
Formerly: ENCH426.

CHBE437 Chemical and Biomolecular Engineering Laboratory (3 Credits)
Application of chemical engineering process and unit operation principals in small-scale semi-commercial equipment. Data from experimental observations are used to evaluate performance and efficiency of operations. Emphasis on correct presentation of results inreport form.
Prerequisite: CHBE424, CHBE426, and CHBE440.
Restriction: Must be in a major within ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE437 or ENCH437.
Formerly: ENCH437.

CHBE440 Chemical Kinetics and Reactor Design (3 Credits)
Fundamentals of chemical reaction kinetics and their application to the design and operation of chemical reactors. Reaction rate theory, homogeneous reactions and catalysis electrochemical reactions. Catalytic reactor design.
Prerequisite: Minimum grade of C- in CHBE301, MATH241, and MATH246.
Restriction: Must be in Engineering: Chemical program; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE440 or ENCH440.
Formerly: ENCH440.

CHBE442 Chemical and Biomolecular Systems Analysis (3 Credits)
Dynamic response applied to process systems. Goals and modes of control, Laplace transformations, analysis and synthesis of simple control systems, closed loop response, dynamic testing.
Prerequisite: CHBE424 and CHBE426.
Credit Only Granted for: CHBE442 or ENCH442.
Formerly: ENCH442.

CHBE444 Process Engineering Economics and Design I (3 Credits)
Principles of chemical engineering economics and process design. Equipment sizing and costing. Economic evaluation of projects. Flowsheet synthesis. Introduction to flowsheet simulators and concepts of flowsheet optimization. Synthesis of Heat Exchanger Networks and Distillation Sequences.
Prerequisite: CHBE424, CHBE426, and CHBE440.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE444 or ENCH444.
Formerly: ENCH444.

CHBE446 Process Engineering Economics and Design II (3 Credits)
Application of chemical engineering principles for the design of chemical processing equipment. Representative problems in the design of chemical plants will be the focus of this capstone design class. Comprehensive reports are required.
Prerequisite: CHBE442 and CHBE444.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE446 or ENCH446.
Formerly: ENCH446.

CHBE451 Photovoltaics: Solar Energy (3 Credits)
The emphasis of the class is on developing a conceptual understanding of the device physics and manufacturing processes of crystalline and thin-film photovoltaic cells, and to develop elementary computational skills necessary to quantify solar cell efficiency. The class material includes detailed, system-level energy balances necessary to understand how solar energy fits into the complete energy generation, conversion, and storage picture. Quantitative comparisons of PV technology to solar chemical conversion processes and biofuels are made.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: ENCH468L or CHBE451.
Formerly: ENCH468L.

CHBE453 Applied Mathematics and Distributive Parameter Systems (3 Credits)
Mathematical techniques applied to the analysis and solution of chemical engineering problems. Use of differentiation, integration, differential equations, partial differential equations and integral transforms. Application of infinite series, numerical and statistical methods.
Credit Only Granted for: CHBE453 or ENCH453.
Formerly: ENCH453.

CHBE454 Chemical Process Analysis and Optimization (3 Credits)
Application of mathematical models to the analysis and optimization of chemical processes. Models based on transport, chemical kinetics and other chemical engineering principles will be employed.
Credit Only Granted for: CHBE454 or ENCH454.
Formerly: ENCH454.

CHBE455 Model Predictive Control (3 Credits)
Empirical model identification from process data. Step and impulse response models. Linearization of nonlinear first principles models. Single variable Model Predictive Control. Robustness with respect to modeling error. MPC based tuning of PID controllers. Feedforward control. Multi-input multi-output processes. Multi-loop decentralized control. Centralized multivariable Model Predictive Control via on-line optimization.
Credit Only Granted for: CHBE455 or ENCH455.
Formerly: ENCH455.

CHBE457 Design and Processing of Polymers for Biomedical Devices (3 Credits)
An overview of the design and processing of polymers used in medical applications. Following a discussion of the physical and mechanical properties of polymers, important classes of polymeric biomaterials will be surveyed, discussing material synthesis, processing techniques and equipment, as well as properties and performance in biomedical applications. Topics will include silicone elastomers, hydrogels, ultra-high molecular weight polyethylene, polyurethanes, polyureas, polyesters, degradable and resorbable polymeric biomaterial designs used in surgery and drug delivery, polymers for ophthalmologic and orthopedic applications, and biopolymers such as silks and collagen. Finally, the design of major industrial polymer processing equipment will be covered, and the fundamentals of extrusion, calendering, coating, fiber spinning, film blowing, and injection molding processes will be presented.
Prerequisite: MATH246; and CHEM231; and (CHBE301, ENMA461, or BIOE232).
Recommended: Knowledge of basic fluid dynamics: CHBE422/BIOE331 or equivalent.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: BIOE453, CHBE457, or ENMA425.

CHBE468 Research (1-3 Credits)
Investigation of a research project under the direction of a faculty member. Comprehensive reports are required.
Restriction: Permission of Chemical and Biomolecular Engineering Department; and must be third or fourth year student; and must have minimum GPA of 3.0; and must have successfully completed all lower level engineering, science and mathematics courses for the major.
Repeatable to: 6 credits.
Formerly: ENCH468.

CHBE469 Special Projects (1-3 Credits)
Special project under the direction of a faculty member. Comprehensive reports are required.
Restriction: Permission of Chemical and Biomolecular Engineering Department; and must be third or fourth year student; and must have minimum GPA of 3.0; and must have successfully completed all lower level engineering, science and mathematics courses for the major.
Repeatable to: 6 credits if content differs.

CHBE470 Colloid and Interface Science (3 Credits)
Introduction to colloidal systems and interfacial science. Topics include preparation, stability and coagulation kinetics of colloidal suspensions. Introduction to DLVO theory, electrokinetic phenomena, colloidal aggregation, interfacial phenomena, double layer theory, surface chemistry. Discussion of interfacial thermodynamics and interfacial forces for solid-liquid interfaces. Applications to nanomaterial synthesis, nanomaterial and polymer self-assembly, protein-protein interactions, and protein aggregation will be discussed.
Prerequisite: CHBE424 and CHBE426.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.

CHBE471 Particle Science and Technology (3 Credits)
Particles are everywhere. We breathe them, eat them, and use them to make many non-particulate materials. Knowledge of particle science and technology is important for manufacturing, for occupational health and safety, as well as environmental considerations. In this multidisciplinary course, the focus will be on the study of science and technology relevant to multiphase systems consisting of solid and/or liquid particles surrounded by a gas. These topics fall loosely under the headings of powder and aerosol technology. Team design projects will be an integral component.
Prerequisite: Knowledge of undergraduate engineering thermodynamics, and transport phenomena; knowledge of numerical methods for solving systems of ordinary differential equations.
Restriction: Must be in a major within ENGR-Chemical & Biomolecular Engineering department; or permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE471 or ENCH471.
Formerly: ENCH471.

CHBE472 Control of Air Pollution Sources (3 Credits)
Sources and effects of air pollutants, regulatory trends, atmospheric dispersion models, fundamentals of two-phase flow as applied to air pollution and air pollution control systems, design of systems for control of gases and particulate matter.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.

CHBE473 Electrochemical Energy Engineering (3 Credits)
The lecture will start from the basic electrochemical thermodynamics and kinetics, with emphasis on electrochemical techniques, fundamental principle and performance of batteries, and supercapacitors.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: ENCH468K or CHBE473.
Formerly: ENCH468K.

CHBE474 Biopharmaceutical Process Development and Manufacturing (3 Credits)
Covers the fundamental steps involved in process development and manufacturing of biopharmaceuticals. An overview of different classes of biopharmaceuticals as well as manufacturing requirements for clinical development and regulatory approval will be provided. In depth coverage of manufacturing steps including cell culture, purification and formulation as well as drug product manufacturing, analysis and stability will be covered. Scientific literature will be used to highlight current challenges and novel solutions in each step of the manufacturing process. Scale up considerations, GMP requirements and process economics will also be introduced.
Prerequisite: BIOE120; and permission of instructor.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE474, BIOE489T, or ENCH648D.

CHBE475 Ethics in Science and Engineering (3 Credits)
Ethical issues in science and engineering and their resolutions are examined. The main topics will be ethics and scientific truth (including issues of proper data analysis, proper data presentation, and record-keeping), ethics and other scientists and engineers (including issues of attribution, confidentiality, conflicts of interest, mentoring, and inclusion of under-represented groups), ethics and the practice of engineering (including responsibilities of engineers to clients, ecological issues, and conflicts of interest), and ethics and society (including funding priorities, moral issues, and human and animal subjects). Class meetings will be organized around discussions, case studies, and student reports. The course is aimed at postdoctoral students, graduate students and advanced undergraduate students who wish to ponder the important contemporary questions about the ethics of how science and engineering get done.
Credit Only Granted for: CHBE475 or ENCH475.
Formerly: ENCH475.

CHBE476 Molecular Modeling Methods (3 Credits)
Statistical mechanics will be introduced to give the fundamental background for atomic to mesoscale molecular modeling. Classical atomic-level simulations methods (Monte Carlo and Molecular Dynamics) and the procedures to develop intra- and intermolecular potentials will be covered. This course will also discuss the theory and application of coarse-grained molecular simulations, mesoscale simulations and other modern simulation techniques. A broad range of applications will be included throughout the semester, e.g., phase behavior of small molecules, kinetics, and biophysics.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: ENCH468P or CHBE476.
Formerly: ENCH468P.

CHBE477 Mesoscopic and Nanoscale Thermodynamics (3 Credits)
Interdisciplinary course primarily for graduate and senior undergraduate students from engineering or science departments. New emerging technologies deal with bio-membrane and gene engineering, microreactor chemistry and microcapsule drug delivery, micro-fluids and porous media, nanoparticles and nanostructures, supercritical fluid extraction and artifical organs. Engineers often design processes where classical thermodynamics may be insufficient, e.g., strongly fluctuating and nanoscale systems, or dissipative systems under conditions far away from equilibrium.
Prerequisite: A prior course in classical thermodynamics.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE477 or ENCH468Q.
Formerly: ENCH468Q.

CHBE480 Bionanotechnology: Physical Principles (3 Credits)
Physics at nano/micro scales. Biomolecular building blocks. Simplest biomolecular assembly: protein folding. Nanoscale intermolecular interactions important for biology. Protein-ligand binding. Protein higher-order assembly: filaments, networks. Protein filaments and motility. DNA, RNA and their assembly assisted by proteins. Viral capsid assembly. Lipid assembly into micelles, bilayers. Lipid-protein co-assembly in membranes. Lipid and polymer structures useful in medicine. Targeted delivery of drugs, genes by nano/micro structures. Cellular assembly in the eye, in insect wings. Cellular assembly at surfaces: gecko feet, duck feathers. Cellular assembly in the presence of crystals: biomineralization.
Prerequisite: BIOE120; or students who have taken courses with comparable content may contact the department.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.

CHBE481 Transport Phenomena in Small and Biological Systems (3 Credits)
Interdisciplinary course primarily for senior undergraduate and graduate students from engineering or science departments. The course's main goal is to make the students familiar with the fundamental physics and modeling of transport phenomena in small and biological systems, and their current scientific and engineering utilization in microfluidics, nanofluidics and biological systems.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: ENCH468W or CHBE481.
Formerly: ENCH468W.

CHBE482 Biochemical Engineering (3 Credits)
Introduction to biochemical and microbiological applications to commericail and engineering processes, including industrial fermentation, enzymology, ultrafiltration, food and pharmaceutical processing and resulting waste treatment. Enzyme kinetics, cell growth, energetics and mass transfer.
Prerequisite: CHBE440.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE482 or ENCH482.
Formerly: ENCH482.

CHBE483 Bioseparations (3 Credits)
Engineering fundamentals of separations and purification of biological molecules. Case studies and examples illustrate principles and practice of centrifugation, precipitation, crystallization, filtration, membrane separations, chromatography, and affinity separation of recombinant proteins and other biomolecules. Process scale-up and economics of biotechnology products and processes.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: ENCH483 or CHBE483.
Formerly: ENCH483.

CHBE484 Metabolic Pathway Engineering (3 Credits)
The state-of-the-art in metabolic engineering, with a focus on the analysis and engineering of metabolic pathways through (chemical) engineering principles, will be covered. Topics covered include: (1) overview of biochemistry and metabolism; (2) metabolic flux analysis and isotope labeling illustrated with examples from the recent scientific literature; (3) technologies for engineering metabolic pathways; (4) metabolic control analysis and pathway regulation; (5) applications of metabolic engineering to synthesis of biofuels and therapeutics; (6) specialized and related subjects such as protein engineering and synthetic biology.
Prerequisite: CHBE101 and CHBE440.
Restriction: Permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: ENCH468M or CHBE484.
Formerly: ENCH468M.

CHBE485 Biochemical Engineering Laboratory (3 Credits)
Techniques of measuring pertinent parameters in fermentation reactors, quantification of production variables for primary and secondary metabolites such as enzymes and antibiotics, the insolubilization of enzymes for reactors, and the demonstration of separation techniques such as ultrafiltration and affinity chromatography.
Credit Only Granted for: CHBE485 or ENCH485.
Formerly: ENCH485.

CHBE486 Heterogeneous Catalysis for Energy Applications (3 Credits)
Introduction to heterogeneous catalytic science and technology for energy conversion and hydocarbon processing. Preparation and mechanistic characterization of catalyst systems, kinetics of catalyzed reactions, adsorption and diffusion influences in heterogenious reactions. An overview of heterogeneous catalysis in various energy-related applications, including petroleum refining, chemicals from biomass, valorization of shale gas, and CO2 utilization will be introduced.
Prerequisite: Minimum grade of C- in CHBE302, CHBE424, and CHBE440; and permission of instructor.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: CHBE486 or ENCH686.

CHBE487 Tissue Engineering (3 Credits)
A review of the fundamental principles involved in the design of engineered tissues and organs. Both biological and engineering fundamentals will be considered.
Prerequisite: Must have completed at least one biology course; and MATH241.
Recommended: BSCI330 and BIOE340.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; or permission of ENGR-Chemical & Biomolecular Engineering department.
Credit Only Granted for: BIOE411, CHBE487, or ENCH468T.
Formerly: ENCH468T.

CHBE490 Polymer Science (3 Credits)
The elements of the polymer chemistry and industrial polymerization, polymer structures and physics, thermodynamics of polymer solutions, polymer processing methods, and engineering applications of polymers.
Credit Only Granted for: CHBE490, ENCH490, or ENMA495.
Formerly: ENCH490.

CHBE495 Nanoparticle Aerosol Dynamics and Particle Technology (3 Credits)
NanoParticles (NA) (< 100 nm), and their science and technology play an important role in nature and industry. From air quality standards, nuclear reactor safety, inhalation therapy, workplace exposure, global climate change, to counterterrorism, aerosols play a central role in our environment. On the industrial side, NA plays an integral part of reinforcing fillers, pigments and catalysts, and the new emerging field of nanotechnology, they are the building blocks to new materials, which encompass, electronic, photonic and magnetic devices, and bio and chemical sensors.
Restriction: Must be in a major within the ENGR-Chemical & Biomolecular Engineering department; and permission of ENGR-Chemical & Biomolecular Engineering department.

CHBE496 Processing and Engineering of Polymers (3 Credits)
A comprehensive analysis of processing and engineering techniques for the conversion of polymeric materials into useful products. Evaluation of the performance of polymer processes, design of polymer processing equipment.
Credit Only Granted for: CHBE496 or ENCH496.
Formerly: ENCH496.

CHBE497 Protein Engineering (3 Credits)
This course will cover the fundamentals of protein engineering and its applications in medicine, chemical processes, and energy. Topics will include the structure and function of biological molecules, rational design and directed evolution, construction of protein and peptide libraries, protein screening platforms, methods for characterizing structure and function of biological molecules. Scientific literature will be used to highlight key discoveries and current work in protein engineering.
Prerequisite: BIOE120, CHBE302, and CHBE440; and permission of instructor.
Credit Only Granted for: CHBE497, BIOE489R, or ENCH 648P.