Department of Chemical & Petroleum Engineering

Chemical and Petroleum Engineering

Chemical engineering has grown out of a combination of chemistry and engineering associated with industrial processes. Today, it comprises knowledge used in processes that change the physical state or composition of materials. Chemical engineers hold key roles in the design, development, production, and purification of materials that are considered essential to human life and well-being, such as food products, fuels and lubricants, pharmaceuticals, fertilizers, synthetic fibers, microelectronic components, and plastics. Chemical engineers are involved in reducing the use of energy to make these products in safe and sustainable ways. They are responsible for minimizing environmental effects of chemical production on the environment.

Petroleum engineering is concerned with the drilling, recovery, production, and distribution of petroleum and natural gas. Petroleum engineers use knowledge of fluid and rock properties in subsurface environments with methods of producing oil and gas safely and economically. At the University of Kansas, the focus is on reservoir engineering to improve production from oil and gas reservoirs. Reservoir engineers use geological detection with computerized mathematical analysis to produce these valuable raw materials. Through such techniques, petroleum engineers continue to extract oil and gas from reservoirs that were considered uneconomical only a few years ago. Petroleum engineering is uniquely challenging in that the raw product must be recovered far from observation.

Undergraduate Programs

The Department of Chemical and Petroleum Engineering offers a Bachelor of Science degree in chemical engineering and a Bachelor of Science degree in petroleum engineering. The Chemical Engineering Bachelor of Science program is accredited by the Engineering Accreditation Commission of ABET. The Petroleum Engineering Bachelor of Science program is accredited by the Engineering Accreditation Commission of ABET.

With Chemical Engineering, students may also choose to complete a concentration: Biomedical, Environmental, Materials Science, Data Science, Premedical, or Petroleum.

Graduate Programs

C&PE graduate programs provide an in-depth academic understanding of chemical engineering and petroleum engineering for students who plan careers in academia, research, or industrial development. The department offers two tracks of Master of Science (M.S.) degree: one in chemical engineering and the other in petroleum engineering, and one Doctor of Philosophy (Ph.D.) degree in chemical and petroleum engineering. This catalog contains detailed information for admissions and degree requirements.

Master of Science

In the master's program, the primary emphasis is on formal course work in engineering and related subjects. Students take a sequence of core courses in heat, mass and momentum transport, thermodynamics, reaction kinetics, applied mathematics, reservoir engineering, phase equilibrium, and petroleum recovery. Students may also conduct independent research, as part of the Master Thesis.

Doctor of Philosophy

In the doctoral program, the student completes an independent and novel research project in a significant engineering area. Specific Ph.D. course work depends on the research area and the specific education needed by the student for the project. The general research area reflects the research interests of the faculty. In addition to specialized courses in the department, advanced courses in mathematics, and computer science, life sciences, physical sciences, and other branches of engineering and technology may be used incorporated to better prepare the Ph.D. student for the research project and for this rapidly changing field.

These guidelines include departmental requirements and are intended to assist the student and advisory committee in preparing a Plan of Study for the graduate degree.

Courses

C&PE 111. Introduction to the Chemical Engineering Profession I. 1 Credits.
The career opportunities for chemical engineers are described and students are introduced to the resources available to them at KU, in the School of Engineering, and in the Chemical and Petroleum Engineering Department. The students are introduced to the curriculum requirements and emphasis options, engineering ethics, basic safety considerations, teamwork, and technical writing. The course includes fundamental calculations and laboratory experiences in material and energy balances and fluid flow. Prerequisite: Corequisite: MATH 104 or MATH 125 or MATH 145.

C&PE 112. Introduction to Chemical Engineering Profession II. 1 Credits.
Students are introduced to engineering ethics, basic safety considerations, teamwork, and technical writing. The course includes fundamental calculations and laboratory experiences in material and energy balances and fluid flow. Prerequisite: Corequisite: CHEM 130 or CHEM 170 or CHEM 190.

C&PE 117. Energy in the Modern World. 1 Credits.
A survey course on global energy supply and demand, production methods and energy economics. Course begins with the matrix of energy supply and demand focusing on fossil fuels and nuclear energy and includes transportation/ distribution patterns and issues and current production technologies. We then analyze alternate energy realities and potentials such as solar energy, wind energy, biomass utilization, hydrogen, fuel cells, hydroelectric, geothermal, wave/tidal, and others based on thermodynamic principles and economics. Course is also open to non-engineering students.

C&PE 127. Introduction to Petroleum Engineering Profession. 1 Credits.
An introduction to principles of reservoir engineering and an application of economic principles will be introduced along with the use of computer spreadsheets. A mini petroleum engineering design project will be assigned to illustrate the integration of petroleum engineering principles and the use of computers. C&PE 127 is required of all Petroleum Engineering freshmen but is optional for others. Course is also open to non-engineering students.

C&PE 211. Material and Energy Balances. 3 Credits.

The application of the laws of chemistry, physics, and mathematics to the solution of material and energy balance problems occurring in the process industries. Prerequisite: MATH 125 or MATH 145; CHEM 135 or CHEM 175 or CHEM 195; or consent of department.

C&PE 221. Chemical Engineering Thermodynamics I. 3 Credits.
Fundamentals and applications of the First and Second Laws of Thermodynamics with strong emphasis on material, energy and entropy balances to solve engineering problems involving pure components. Topics include: Cycles (Rankine, Brayton, refrigeration, etc.), the calculus of thermodynamics, equations of state for realistic thermodynamic properties, departure functions, equilibrium and stability criteria, fugacity, and single component phase equilibrium (vaporization, melting, sublimation). Prerequisite: MATH 126 or MATH 146; and C&PE 211. Corequisite: EPHX 210 or PHSX 211 or PHSX 213; or consent of department.

C&PE 226. Fundamentals of Biomedical and Biomolecular Engineering. 3 Credits.
Introduction to the building blocks of human and other living organisms with a focus on structure/function mechanisms that are critical for design, modeling, and analysis in living systems. Application of chemical engineering principles, including mass, energy, momentum and charge balances and molecular thermodynamics to analysis of living systems. Applies biochemistry, molecular biology and cell biology to fundamental issues in biochemical engineering, biomedical engineering and biotechnology. Prerequisite: C&PE 211, or consent of department. Corequisite: C&PE 221 or ME 212.

C&PE 308. Subsurface Energy Engineering Seminar. 0.25 Credits.

A seminar class conducted every year for all undergraduates in the major. Seminars will be presented in hybrid format using in person lectures as well as distance delivery to in class audiences as well as recorded presentations. Presenters will be from industry and academia including KU faculty. Topics will include recent advances in technology, professional development, career opportunities, sustainability, underground H2/CO2 storage, and other topics of interest. Graded on a satisfactory/unsatisfactory basis.

C&PE 325. Numerical Methods and Statistics for Engineers. 3 Credits.
An introduction to numerical methods and statistics and their application to engineering problems. Numerical methods topics include finding roots of a single nonlinear equation, numerical solution of ordinary differential equations, numerical integration, and solutions of ordinary differential equations. Statistical topics include regression and curve fitting, probability and probability distributions, expected value and hypothesis testing, and optimization of single and multiple-variable systems. Implementing numerical algorithms using computer programming will be emphasized, along with the fundamentals of programming, including data typing, branching, and iteration. Applications specific to chemical and petroleum engineering systems will be considered. Prerequisite: MATH 126 or MATH 146; and CHEM 135 or CHEM 175 or CHEM 195. Corequisite: MATH 220 or MATH 221 or MATH 320 or MATH 321; and MATH 290 or MATH 291; or consent of department.

C&PE 327. Reservoir Engineering. 3 Credits.
Properties of porous rocks, reservoir fluids, and fluid saturated rocks. Introduction to multiphase flow in porous media including concepts of wettability, capillary pressure and relative permeability. Introduction to basic thermodynamics and phase behavior. Prerequisite: CHEM 135 or CHEM 175 or CHEM 195.

C&PE 511. Momentum Transfer. 3 Credits.
Solutions of continuity, momentum, and energy equations applied to fluids in confined flow or flowing past submerged objects. Laminar and turbulent flows of both incompressible and compressible fluids are considered. Engineering applications include pressure drop and network analysis of piping lines, flow measurements, fluid moving equipment including the performance of pumps. Prerequisite: C&PE 221 or ME 212 or C&PE 327; C&PE 325; and a grade of C- or higher in MATH 127 or MATH 147, and MATH 220 or MATH 221 or MATH 320 or MATH 321; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 512. Chemical Engineering Thermodynamics II. 3 Credits.
Further application of the laws of thermodynamics to multi-component mixtures and in multi-phase equilibria with focus on vapor-liquid, liquid-liquid, and solid-liquid equilibria. Mixture Fugacity expressions are developed using equations of state with mixing rules or Excess Gibbs Free Energy/activity coefficient models for data correlation or prediction. Chemical equilibrium of reactions is also discussed. Prerequisite: C&PE 325; C&PE 211; C&PE 221; and CHEM 330 or CHEM 380; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 519. Drilling Fluids Laboratory. 1 Credits.
Laboratory study of formulation and properties of drilling fluids. "Mud" measurements covered include density, solids content, filtration control and viscosity. Other measurements include compressive strength of cement and cuttings transport properties. Prerequisite: Corequisite: C&PE 511.

C&PE 522. Economic Appraisal of Chemical and Petroleum Projects. 2 Credits.
Consideration of the economic factors important in the development of the chemical or petroleum enterprise. Applications of economic evaluation methods to engineering project development. Consideration of risk and uncertainty in project development. Prerequisite: C&PE 325; and a grade of C- or higher in MATH 126 or MATH 146 and PHSX 210 or EPHX 210 or PHSX 211 or PHSX 213; or consent of department.

C&PE 524. Chemical Engineering Kinetics and Reactor Design. 3 Credits.
Development and solution of the material and energy balance equations for continuous and batch reactors. These balance equations are applied in (a) the determination of intrinsic kinetics, (b) the design of reactors and (c) the analysis of reactor behavior. Both homogeneous and heterogeneous reaction systems are considered. Prerequisite: C&PE 511; C&PE 512; and a grade of C- or higher in MATH 220 or MATH 221 or MATH 320 or MATH 321; or consent of department. Corequisite: C&PE 525. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 525. Heat and Mass Transfer. 4 Credits.
An applied study of the various heat and mass transfer mechanisms in solid and fluid systems. Heat transfer mechanisms include conduction and the concept of conductivity at the molecular level, convection, and radiation. Mass transfer fundamentals include diffusion and the concepts of diffusivity at the molecular level and shell mass balances including diffusion, convention, and consumption or generation source terms. Steady state and transient heat and mass transfer engineering applications will be considered. Prerequisite: C&PE 221 or ME 212; C&PE 325; C&PE 511; and a grade of C- or higher in MATH 220 and MATH 127; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 527. Reservoir Engineering II. 3 Credits.

Lectures on fluid flow and pressure distribution in reservoirs. Calculations in drawdown, buildup, multiple rate, fractured systems, gas and injection well testing. Material balance calculations for injection-production processes within subsurface formations. Prerequisite: C&PE 327; a grade of C- or higher in MATH 220 or MATH 221 or MATH 320 or MATH 321; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to junior year courses. Details can be found in the catalog.

C&PE 528. Well Logging. 3 Credits.
Analysis of well logs to estimate properties of subsurface formations, fluid saturations and lithology, and production logging. Prerequisite: C&PE 327 or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the Junior year courses. Details can be found in the catalog.

C&PE 601. Undergraduate Topics in Chemical and Petroleum Engineering. 1-4 Credits.
Undergraduate study in various branches of Chemical and Petroleum Engineering on topics that may vary from year to year. Prerequisite: Varies.

C&PE 611. Design of Unit Operations. 3 Credits.
Application of chemical engineering principles to design pumps, heat exchangers, and separation equipment. Staged separation processes including distillation, extraction and absorption, membrane separations, and modes of operation will be considered. Sizing of equipment, energy consumption and materials of construction will also be addressed. Prerequisite: C&PE 211; C&PE 511; C&PE 512; C&PE 523; C&PE 524; C&PE 525; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 613. Chemical Engineering Design I. 4 Credits.
Synthesis, design and economic analysis of petrochemical, and chemical plants. Applications in computer aided engineering applied to these topics. Prerequisite: C&PE 522, C&PE 611 and C&PE 615; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 615. Introduction to Process Dynamics and Control. 3 Credits.
The behavior of chemical processing equipment in the presence of disturbances in operating conditions is analyzed. Control systems are designed based on the criteria of system stability and optimal system performance. Prerequisite: C&PE 511; C&PE 512; C&PE 524; and C&PE 525; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 616. Chemical Engineering Laboratory I. 3 Credits.
Laboratory study of chemical engineering concepts of thermodynamics, fluid flow, heat transfer, mass transfer, and reaction kinetics. Includes emphasis on technical communication skills. Prerequisite: C&PE 511; C&PE 512; C&PE 524; C&PE 525; and ENGL 102 or ENGL 105; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 617. Drilling and Well Completion. 3 Credits.
Design and analysis of rotary drilling and well completion systems; casing design, cementing, HPHT drilling, MWD, and perforating. Safety and ethical considerations in drilling and fluid disposal operations. Prerequisite: C&PE 519; C&PE 327; C&PE 511; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the senior year courses. Details can be found in the catalog.

C&PE 618. Improved Oil Recovery. 3 Credits.
Improved Oil Recovery processes will be presented in this course. This includes design of waterfloods, miscible/immiscible displacement, chemical processes such as polymer flood, surfactant flood, and thermal recovery techniques such as steam flooding, in-situ combustion, and other EOR techniques. CO2 injection for the purpose of carbon capture, utilizations and storage (CCUS) will be covered in this class. Prerequisite: C&PE 527; or consent of the department. The Petroleum major has a GPA requirement for specific courses to progress to the Junior year courses. Details can be found in the catalog.

C&PE 619. Petroleum Engineering Laboratory. 3 Credits.
Laboratory study of methods to determine rock and fluid properties related to subsurface engineering including phase behavior, viscosity, permeability, porosity, capillary pressure, oil recovery, water/oil displacement, fluid flow, rock compaction, heat transfer coefficients and analysis of experimental uncertainty. Oral and written presentations are required. Prerequisite: C&PE 519; C&PE 327; C&PE 511; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to junior year courses. Details can be found in the catalog.

C&PE 620. Enhanced Oil Recovery. 3 Credits.
Enhanced Oil Recovery processes such as primary, secondary, and tertiary oil recovery techniques will be presented. This includes miscible/immiscible displacement, chemical processes such as polymerflood, surfactant and micellar flood, and thermal recovery techniques such as steam flooding, in-situ combustion, and other EOR techniques. Prerequisite: C&PE 527 and C&PE 618 or consent of instructor.

C&PE 624. Process Safety and Sustainability. 3 Credits.
An introductory course designed to acquaint students with the necessary global aspects and ethics of risk-based process safety and sustainability. Topics will include elements of process safety, process safety management, historical and contemporary case studies of major accidents in the chemical and petroleum industry, overview of current government regulation (e.g. OSHA, EPA, etc.), and ethics. Students will receive an introduction to sustainable ("green") chemistry and engineering followed by more quantitative Life Cycle Analysis (LCA) to compare technologies and products. Prerequisite: C&PE 511 or ME 510. The department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 625. Unconventional Reservoirs. 3 Credits.
Principles of unconventional reservoir engineering including properties of unconventional reservoirs, hydraulic fracturing, geomechanical and relevant environmental and economic factors. The course will also cover contributing factors of these rocks in new energy ventures such as CO2 and hydrogen storage. Prerequisite: C&PE 511; C&PE 527; C&PE 528; ME 211; GEOL 332; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the senior year courses. Details can be found in the catalog.

C&PE 626. Chemical Engineering Laboratory II. 3 Credits.
Laboratory study of chemical engineering concepts of thermodynamics, fluid flow, heat transfer, mass transfer, reaction kinetics, and process control. Includes emphasis on technical communication skills. Prerequisite: ENGL 102 or ENGL 105; C&PE 511; C&PE 512; C&PE 524; C&PE 525; C&PE 615; and C&PE 616; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog.

C&PE 627. Petroleum Production. 3 Credits.
Design and analysis of natural production and artificial lift systems, including beam pumping, gas lift, and submersible pumps. Vertical and horizontal two-phase flow, compression, metering, acidizing, fracturing,

and pipe line flow systems. Additionally, the operational aspects of CO2 injection for permanent underground storage (CCUS) will be covered. Treatment of ethics considerations in production contracts and leasing arrangements. Prerequisite: C&PE 327; C&PE 511; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the senior year courses. Details can be found in the catalog.

C&PE 628. Petroleum Engineering Design. 3 Credits.
Design problems related to subsurface reservoir challenges with respect to development of conventional and unconventional reservoirs as well as new energy venture projects such as CO2 storage, hydrogen storage and enhanced geothermal. Designs consider economic, uncertainty analysis, as well as conservation, environmental, and professional ethics factors. Prerequisite: C&PE 522; C&PE 527; C&PE 528; C&PE 618; C&PE 619; GEOL 535; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the senior year courses. Details can be found in the catalog.

C&PE 640. Natural Gas Engineering. 3 Credits.
Principles of natural gas engineering including resource distribution and evaluation, composition and properties, production, processing, transportation, storage and relevant environmental and economic aspects. Prerequisite: C&PE 625 and C&PE 627, or consent of department.

C&PE 641. Introduction to AI and Machine Learning for Subsurface Energy Engineering. 3 Credits.
This course will introduce different applications of AI/ML techniques to address subsurface problems through case studies that will be presented in the class. Additionally, students will learn some AI/ML concepts and algorithms that have been used in the presented case studies with applications in Reservoir Engineering, Production Engineering, Drilling Engineering, and subsurface characterization. Prerequisite: C&PE 325 (or EECS 138--Python), C&PE 327, and C&PE 527.

C&PE 642. New Energy Ventures. 3 Credits.
This course covers the necessary fundamentals required for new energy venture topics such as Carbon Capture, Utilization and Storage (CCUS), Subsurface Hydrogen Storage and Production, and Enhanced Geothermal Systems. Prerequisite: C&PE 527, C&PE 528, GEOL 332; Corequisite: C&PE 625.

C&PE 651. Undergraduate Problems. 1-4 Credits.
Investigation of a particular problem in the field of chemical or petroleum engineering. The problem or research topic is identified jointly by the student and the faculty research supervisor. A final report is required.

C&PE 655. Introduction to Semiconductor Processing. 3 Credits.
An overview of various processes to fabricate semiconductor devices and integrated circuits. Topics covered include crystal growth, oxidation, solid-state diffusion, ion implantation, photolithography, chemical vapor deposition, epitaxial growth, metalization, and plasma etching of thin films. (Same as EECS 670.) Prerequisite: Junior or senior standing in C&PE or EECS, or consent of department.

C&PE 656. Introduction to Biomedical Engineering. 3 Credits.
An interdisciplinary introduction to the field of biomedical engineering. This course covers a breadth of topics including biotransport, biomechanics, biomaterials, tissue engineering, drug delivery, biomedical imaging, computational biology, and biotechnology. Students are exposed to these broad topics, and go further in depth in a topic of their choice with the semester project. Prerequisite: Junior or Senior-level standing in Engineering or consent of department.

C&PE 657. Polymer Science and Technology. 3 Credits.
Introduction to polymer chemistry, science, technology, and processing. The course covers the principles of polymer synthesis and the structure-property relationships in the solid state and in solution, such as solubility, rheology and mechanical properties. Principles of polymer processing are introduced. Students will learn to understand from an engineering perspective how polymers are created and used. Prerequisite: Senior or graduate student standing in chemical engineering, chemistry, or consent of instructor.

C&PE 661. Undergraduate Honors Research. 1-3 Credits.
This course involves the investigation of a particular problem in the field of chemical or petroleum engineering. C&PE 661 should be taken, rather than C&PE 651, for students seeking Departmental Honors in Chemical Petroleum Engineering. C&PE 661 may also be used by students in the Honors Program to help satisfy the course requirement of this program. The design or research topic is identified jointly by the student and faculty research supervisor. Prerequisite: C&PE 325; C&PE 211; C&PE 511; C&PE 512; overall GPA >3.5; and engineering GPA >3.5; or consent of the department.

C&PE 676. Principles of Biomolecular Engineering. 3 Credits.
Application of chemical engineering principles, including transport phenomena, reaction kinetics and thermodynamics, to analysis of living systems. Applies biochemistry, molecular biology and cell biology to fundamental issues in biochemical engineering, biomedical engineering and biotechnology. Prerequisite: C&PE 511, C&PE 512, or consent of instructor. Corequisite: C&PE 524, C&PE 525, or consent of instructor.

C&PE 678. Applied Optimization Methods. 3 Credits.
Study of methods for solving optimization problems encountered in engineering and the natural sciences, with specific applications illustrating analytical and numerical techniques. Topics covered include methods, penalty functions, linear programming, nonlinear and integer programming, stochastic optimization approaches, and treatment of constrained problems. A semester project is required. Prerequisite: Senior standing or consent of instructor.

C&PE 686. Bioprocess Engineering. 3 Credits.
Provides students with essential knowledge and understanding of biochemical engineering fundamentals to the design, development, operation and control of biologically based industrial processes. The course will cover unit operations key to the production of chemicals and pharmaceuticals using cultured cells, such as bioreactors, separations, centrifuges, chromatography and lyophilizers. Issues unique to biologically-based processes such as the need for aseptic conditions, clean-in-place procedures, containment, material handling, sequencing, safety and biohazard, multi-purpose plant design, and process measurement and control. Prerequisite: Senior or graduate student standing in Chemical Engineering, or consent of the instructor.

C&PE 701. Methods of Chemical and Petroleum Calculations. 3 Credits.
The utilization of advanced mathematical methods and computing techniques in the solution of problems in these fields.

C&PE 715. Topics in Chemical and Petroleum Engineering: _____. 3 Credits.
Study in various branches of Chemical and Petroleum Engineering on topics that may vary from year to year.

C&PE 721. Chemical Engineering Thermodynamics. 3 Credits.
Chemical engineering applications of advanced thermodynamics and physical chemistry. Prerequisite: C&PE 512.

C&PE 722. Kinetics and Catalysis. 3 Credits.
Modeling and analysis of chemical reactors with emphasis on heterogenous catalytic reaction systems. Prerequisite: C&PE 524.

C&PE 725. Cellular and Molecular Pharmaceutics. 3 Credits.

The pharmaceutical relevance of fundamental and advanced concepts in cell biology and the molecular interactions responsible for cell and tissue functions, homeostasis in health and disease will be presented. Current analytical methods for examining cells and tissues, and molecular components important in understanding drug and protein biodistribution and metabolism will be discussed. Discussion topics will include the chemical and physical properties of small molecules, proteins, nucleic acids and lipids and their impact on cellular and subcellular structures and ultimately of either adverse or therapeutic benefit. (Same as PHCH 725.) Prerequisite: Graduate standing or consent of instructor.

C&PE 731. Convective Heat and Momentum Transfer. 3 Credits.
The formulation and solution of steady- and unsteady-state convective heat and momentum transfer problems. Applications of boundary layer equations to free and forced convection with study of similarity and integral methods of solution for laminar and turbulent flow; development of analogies; transport properties from kinetic theory of gases viewpoint; introduction to numerical methods. Prerequisite: C&PE 511 and C&PE 525 or equivalent.

C&PE 732. Advanced Transport Phenomena II. 3 Credits.
The formulation and solution of steady- and unsteady-state mass transfer problems (including those complicated by momentum and heat transfer).The mathematical approach predominates and the methods available for determining suitable mass transfer coefficients are covered. Prerequisite: C&PE 731.

C&PE 751. Basic Rheology. 3 Credits.
Basic rheology including classification of classical bodies based on their stress and strain tensors, rheological equation of state, material functions, generalized Newtonian and general linear viscoelastic fluids, mechanical models such as those of Jeffreys and Maxwell. Prerequisite: C&PE 511 or an equivalent course in fluid mechanics.

C&PE 752. Tissue Engineering. 3 Credits.
An introduction to the rapidly growing and continuously evolving field of tissue engineering. Tissue engineering applies principles and methods of engineering and life sciences toward understanding and development of biological substitutes to restore, maintain and improve tissues functions. In this course, students study the basic science, engineering and medicine required for tissue engineering, learn state-of-the-art technology and practice, and create a literature-based proposal for a tissue engineered medical product. Prerequisite: Senior or graduate standing in engineering; or consent of instructor.

C&PE 753. Introduction to Electrochemical Engineering. 3 Credits.

Basic principles of electrochemical engineering as they are applied to energy conversion and storage devices, industrial electrolytic processes and corrosion. Areas covered range from electrochemical thermodynamics, ionic phase equilibria, electro-kinetics and ionic mass transport to mathematical modeling of electrochemical systems. Prerequisite: Graduate standing; C&PE 511, C&PE 512, C&PE 524 or equivalent; knowledge of a programming language.

C&PE 755. Introduction to Semiconductor Processing. 3 Credits.
An overview of various processes to fabricate semiconductor devices and integrated circuits. Topics covered include crystal growth, oxidation, solid-state diffusion, ion implantation, photolithography, chemical vapor deposition, eqitaxial growth, metallization, and plasma etching of thin films. A term paper on an approved topic of fabrication referencing current peer reviewed literature is required.

C&PE 756. Introduction to Biomedical Engineering. 3 Credits.
The graduate elective form of C&PE 656. Additional assignments commensurate with the graduate-level course designation are required for this section. Prerequisite: Graduate-level standing in Engineering, or consent of department.

C&PE 757. Polymer Science and Technology. 3 Credits.
The graduate elective form of C&PE 657. Additional assignments on current research directions in the field commensurate with the graduate-level course designation are required for this section. Prerequisite: Graduate-level standing in engineering, or consent of department.

C&PE 765. Corrosion Engineering. 3 Credits.
Electrochemical basis of corrosion. Estimating probability and rate of corrosion. Identifying different conditions likely to cause specific types of corrosion. Corrosion mitigation techniques. Prerequisite: CHEM 135 or CHEM 175 or CHEM 195. Same course as CE 715.

C&PE 771. Advanced Reservoir Engineering. 3 Credits.
Physical principles of petroleum production; gas drive performance; partial water drive performance; pressure maintenance through gas and water injection. Prerequisite: C&PE 527.

C&PE 778. Applied Optimization Methods. 3 Credits.
Study of methods for solving optimization problems encountered in engineering and the natural sciences, with specific applications illustrating analytical and numerical techniques. Topics covered include gradient methods, penalty functions, linear programming, nonlinear and integer programming, stochastic optimization approaches, and treatment of constrained problems. Homework problems involving theoretical concepts and a theoretically-based semester project are required.

C&PE 790. Introduction to Flow in Porous Media. 3 Credits.
Generalized Darcy's law, vector equations, solutions of partial differential equations with various boundary conditions as applied to the flow of fluids in porous media. Prerequisite: C&PE 527.

C&PE 795. Enhanced Petroleum Recovery. 3 Credits.
A study of improved oil recovery processes such as miscible displacement, microemulsion displacement, and thermal methods. Prerequisite: C&PE 618 or permission of instructor.

C&PE 798. Phase Equilibrium. 3 Credits.
A study of phase behavior and equilibrium from a molecular perspective. Focus will be on vapor-liquid, liquid-liquid and solid-liquid equilibrium with advanced topics in compressed and supercritical fluids, petroleum applications, ionic solutions and others.

C&PE 800. Seminar. 1 Credits.
Every fall, five to six seminar sessions will be devoted to providing incoming students information on available thesis/dissertation research projects, library resources, computing environment and topics related to the issues of responsible scholarship in the fields of Chemical and Petroleum Engineering. For the remainder of the semester, the seminar will involve three presentations on current research and other topics of interest to chemical and petroleum engineers given by invited guest experts from the field. Other presentations are given by faculty and advanced graduate students. Student attendance is required. Graded on a satisfactory/unsatisfactory basis.

C&PE 802. CEBC Colloquium. 0.5-1 Credits.
A forum in which graduate and postdoctoral students, and faculty present the results of CEBC research and literature surveys that support the mission of CEBC.

C&PE 803. Research. 1-6 Credits.
For M.S. candidates.

C&PE 804. Petroleum Management Seminar. 1 Credits.

Structure, operation, and problems of the petroleum industry from a management viewpoint. Presentations will be made by faculty, advanced students, and invited guests. Prerequisite: Permission of instructor.

C&PE 825. Graduate Problems in Chemical and Petroleum Engineering. 1-5 Credits.
Advanced laboratory problems, special research problems, or library reading problems. Three hours maximum acceptable for master's degree.

C&PE 902. Preparation for the Ph.D. Comprehensive Examination. 3 Credits.
Preparation of a research proposal in an area assigned by the student's advisory committee. The grade received on the Ph.D. comprehensive examination will apply to this credit.

C&PE 904. Research. 1-12 Credits.
For Ph.D. candidates.

C&PE 910. Industrial Development of Catalytic Processes. 3 Credits.
Students adopt an interdisciplinary team approach to developing strategies for the design and optimization of catalytic processes. Examples of case studies will be derived from industry or from research testbeds. Students collaborate in multiscale process development involving catalyst and reactor design, reaction system design, modeling and optimization, economic analysis and environmental assessment needed for the development of a catalytic process at either the pilot or production scale.

C&PE 911. Industrial Practicum. 1-3 Credits.
Graduate students engage in an industrial research internship experience with collaborators in industry.

C&PE 919. Advanced Topics in Process Modeling Simulation or Control: _____. 1-4 Credits.
Advanced study in process modeling, simulation or control on topics which may vary from year to year.