CHEMICAL ENGINEERING (ECHE)

ECHE 151. Introduction to Chemical Engineering at Case. 1 Unit.
An introduction to the profession of chemical engineering, its practice in industry, and review of the challenges and opportunities for the profession. The academic programs and curricular enhancements available to students majoring in chemical engineering at CWRU, including breadth sequence sequences and concentrations, undergraduate research, international study opportunities, cooperative education and internships, are presented. In addition to introducing the chemical engineering faculty and their research, a number of guest speakers representing the broad professional opportunities discuss career options with the students. Through lectures and discussions, students are also introduced to topics such as professionalism and ethics. Upperclassmen students conduct their co-op debriefing in the class, sharing experiences and initiating networking. In the lab/recitation section, students in smaller groups conduct experiments on chemical processes, spanning different aspects of the profession, and run computer-based simulations of those experiments. Analysis and discussion of the results will follow. Chemical engineering upperclassmen serve as teaching assistants.

ECHE 225. Thermal and Fluid Sciences. 4 Units.
Elementary thermodynamic concepts: first and second laws, and equilibrium. Basic fluid dynamics, and heat transfer Prereq: PHYS 121 and MATH 122.

ECHE 250. Honors Research I. 1 - 3 Units.
A special program which affords a limited number of students the opportunity to conduct research under the guidance of one of the faculty. At the end of the first semester of the sophomore year, students who have a strong interest in research are encouraged to discuss research possibilities with the faculty. Assignments are made based on mutual interest. Subject to the availability of funds, the faculty employs students through the summers of their sophomore and junior years, as members of their research teams.

ECHE 251. Honors Research II. 1 - 3 Units.
(See ECHE 250.) Recommended preparation: ECHE 250.

ECHE 260. Introduction to Chemical Systems. 3 Units.
Material and energy balances. Conservation principles and the elementary laws of physical chemistry applied to chemical processes. Developing skills in quantitative formulation and solution of word problems. Prereq: Sophomore Standing and (CHEM 111 OR CHEM 106). Prereq or Coreq: MATH 122 or MATH 124.

ECHE 305. Topics in Chemical Engineering. 1 - 3 Units.
Topics in chemical engineering will be covered in an independent study mode. Readings and homework assignments will be assigned. Students are graded on the basis of homework assignments and a final exam.

ECHE 313. Statistical Analysis of Chemical Processes. 3 Units.
This course covers the role of statistics in chemical processes. Topics include probability/probability plots, descriptive tools, statistical decision rules, strategies for experimentation with multiple factors, design of experiments, basic factorial experiments, regression analysis, screening designs, and optimization experiments. Basic statistical software will be used throughout the class. Prereq: MATH 126 or MATH 223.

ECHE 330. Design and Production of Fermented Beverages. 3 Units.
Fermented and distilled beverages (including beer, wine, and whiskey) have recently gained new interest as craft products, with significant growth in the craft brewing, wine, and distilling industry. This course provides a technical overview of the design and manufacture of these products, with a particular emphasis on brewing. Specific topics detailed below will include the molecular basis of fermentation, the chemistry of various flavors and styles (alt, kolsch, porter, bock, mead, ale, etc.), the biochemistry of yeast fermentation and hops, as well as mashing, lautering, boiling, conditioning, filtering, and packaging. In addition, the manufacturing process, including the technical features of quality control, statistical analysis, water quality, and hardware choice in the brewing industry will be covered. There is no lab component, but there will be several tours of manufacturing and lab facilities. The course will feature invited speakers from the local brewing and wine making industry. Each student will be expected to have basic background knowledge of chemistry, physics, and biology, but there are no prerequisites for this class. Offered as ECHE 330 and ECHE 430.

ECHE 340. Biochemical Engineering. 3 Units.
Chemical engineering principles applied to biological and biochemical systems and related processes. Microbiology and biochemistry linked with transport phenomena, kinetics, reactor design and analysis, and separations. Specific examples of microbial and enzyme processes of industrial significance. Recommended preparation: BIOC 307, BIOL 343 and ECHE 364, or permission of instructor.

ECHE 350. Undergraduate Research Project I. 3 Units.
This course affords a student the opportunity to conduct research under the guidance of one of the faculty, as part of the Chemical Engineering Research breadth elective sequence. Students who have a strong interest in research are encouraged to discuss research possibilities with the faculty. Assignments are made based on mutual interest.

ECHE 351. Undergraduate Research Project II. 3 Units.
This course affords a student the opportunity to conduct research under the guidance of one of the faculty, as part of the Chemical Engineering Research breadth elective sequence. Students who have a strong interest in research are encouraged to discuss research possibilities with the faculty. Assignments are made based on mutual interest. Prereq: ECHE 350.

ECHE 355. Quantitative Molecular, Cellular and Tissue Bioengineering. 3 Units.
Physical and chemical principles associated with kinetics and mass transport. Molecular-cellular components incorporated in quantitative analysis of cellular, tissue, and organ systems. Mathematical and computational modeling developed for diagnostic and therapeutic applications. Offered as EBME 350 and ECHE 355.

ECHE 360. Transport Phenomena for Chemical Systems. 4 Units.
Fundamentals of fluid flow, heat and mass transport from the microscopic and macroscopic perspectives. Applications to chemical systems, including steady and transient operations, convective and molecular (conduction and diffusion) effects, and interfacial transport. Design of unit operations (e.g., heat exchangers). Heat and mass transfer analogies. Vector/tensor analysis and dimensional analysis used throughout. Prereq: Junior Standing and (ENGR 225 or ECHE 225 or (Prereq or Coreq: EMAC 352 or EMSE 327)) and (MATH 223 or MATH 227).

ECHE 361. Separation Processes. 4 Units.
Analysis and design of separation processes involving distillation, extraction, absorption, adsorption, and membrane processes. Design problems and the physical and chemical processes involved in separation. Equilibrium stage, degrees of freedom in design, graphical and analytical design techniques, efficiency and capacity of separation processes. Prereq: ECHE 260. Prereq or Coreq: ECHE 363.

ECHE 362. Chemical Engineering Laboratory. 4 Units.
Experiments in the operation of separation and reaction equipment, including design of experiments, technical analysis, and economic analysis. Experiments cover distillation, liquid-liquid extraction, heat transfer, fluidized beds, control, membrane separations, and chemical and electrochemical reactors. Prereq: ECHE 260, ECHE 360, ECHE 361, ECHE 363 and ECHE 364.

ECHE 363. Thermodynamics of Chemical Systems. 4 Units.
First law, second law, phase equilibria, phase rule, chemical reaction equilibria, and applications to engineering problems. Thermodynamic properties of real substances, with emphasis on solutions. Thermodynamic analysis of processes including chemical reactions. Recommended preparation: ECHE 260. Prereq or Coreq: ECHE 225.

ECHE 364. Chemical Reaction Processes. 4 Units.
Design of homogeneous and heterogeneous chemical reactor systems. Relationships between type of reaction and choice of reactor. Methods of obtaining and analyzing kinetic data. Relationship between mechanism and reaction rate and brief introduction to catalysis. Recommended preparation: ECHE 360. Prereq: ECHE 260. Prereq or coreq: MATH 224 or MATH 228.

ECHE 365. Measurements Laboratory. 3 Units.
Laboratory introduction to the measurement process in engineering. Matching measurements to approximate and exact physical models is stressed. Extraction of physical parameters and estimation of the errors in the parameter estimates is an important part of the course. Example projects cover steady and unsteady state heat transfer, momentum transfer, and the first law of thermodynamics. Recommended preparation: ECHE 360. Counts as a Disciplinary Communication course. Prereq: ECHE 260 and ECHE 225. Prereq or Coreq: ECHE 363.

ECHE 366. Colloids and Interfacial Science. 3 Units.
Fundamental aspects of colloidal suspensions, surface tension, wetting, surfactant adsorption, self-assembly, and interparticle interactions. DLVO theory, stability criteria, and coagulation kinetics. Electrokinetic phenomena. Applications to electrophoresis, filtration, floatation, sedimentation, and suspension rheology. Investigation of suspensions, emulsions, gels, and association colloids. Emphasis will be placed on the importance and application of these phenomena to consumer, industrial, and biomedical applications. Recommended preparation: CHEM 335. Offered as ECHE 366 and ECHE 466. Prereq: Junior or Senior student standing.

ECHE 367. Process Control. 4 Units.
Theoretical and practical aspects of feedback control of chemical processes, with a comprehensive, team-based design project integrating these concepts. The course involves extensive use of computer software with exams taken using the computer. Topics include: hardware design and implementation, derivation of unsteady-state mathematical models of simple chemical processes and instrumentation, dynamic simulation of linear and nonlinear models using time domain and Laplace transform methods, design of PID feedback controllers, feed-forward and cascade control. LabVIEW training covers programming basics, interfacing to a data acquisition system and instrumentation, incorporating control algorithms, and simulating dynamic systems. Prereq or Coreq: (MATH 224 or MATH 228) and ECHE 260.

ECHE 372. Electrochemical Energy Storage. 3 Units.
Batteries and supercapacitors as part of renewable energy systems are introduced. Related fundamental electrochemistry concepts, materials and techniques are described. Challenges, current literature and future opportunities in energy storage will be discussed. Offered as ECHE 372 and ECHE 472. Prereq: Junior or Senior standing or Requisites Not Met permission.

ECHE 381. Electrochemical Engineering. 3 Units.
Engineering aspects of electrochemical processes including current and potential distribution, mass transport and fluid mechanical effects. Examples from industrial processes including electroplating, industrial electrolysis, corrosion, and batteries. Recommended preparation: ECHE 260 or permission of instructor. Offered as ECHE 381 and ECHE 480.

ECHE 383. Chemical Engineering Applied to Microfabrication and Devices. 3 Units.
Silicon based microfabrication and micromachining require many chemical engineering technologies. Microfabricated devices such as sensors are also directly related to chemical engineering. The applications of chemical engineering principles to microfabrication and micromachining are introduced. Oxidation processing, chemical vapor deposition, etching and patterning techniques, electroplating and other technologies are discussed. Graduate students will submit an additional final project on some technical aspect of microfabrication technology or devices. Recommended preparation: ECHE 363. Offered as ECHE 383 and ECHE 483.

ECHE 384. Corrosion Fundamentals. 3 Units.
This course will cover fundamentals of corrosion, including thermodynamic and kinetic aspects of the electrochemical reactions leading to corrosion. Salient features of the various types of corrosion will be reviewed, with an emphasis on fundamental mechanisms. Electrochemical testing, corrosion monitoring and techniques to stifle corrosion will be discussed. After completion of this course, students will be able to classify corrosion systems, understand the mechanisms underlying corrosion, and outline strategies to design corrosion-resistant systems. Offered as ECHE 384 and ECHE 481.

ECHE 386. Protein Engineering. 3 Units.
This course will provide an in-depth examination of protein engineering topics and their applications. In particular, this class will cover the design and expression of recombinant proteins, purification strategies, and the incorporation of non-natural amino acids using a bacterial system. Specifically, amino acid sequences that dictate well-defined secondary structures such as beta-sheets, alpha-helices, and leucine zippers will be studied. Tissue engineering examples from the literature such as incorporation of bioactive sequences to promote specific cell response (e.g., cell adhesion sites and protease degradation sequences). In addition, this course will explore the application of protein engineering in drug delivery, electrochemical technology, sensors, and nanoparticle assembly. Current computational techniques for protein design and directed evolution methods will also be explored. Offered as ECHE 386 and ECHE 486.

ECHE 398. Process Analysis, Design and Safety. 4 Units.
Economic analysis and cost estimation of chemical processes. Equipment and materials selection in the chemical process industry. Scale consideration, plant layout and plant site selection. Process analysis, heuristics and optimization. Environmental and plant safety issues. Prereq: ECHE 225 and ECHE 260 and ECHE 361 and ECHE 363 and ECHE 364. Prereq or Coreq: ECHE 360.

ECHE 399. Chemical Engineering Design Project. 3 Units.
Students work in small groups on projects in conjunction with external companies. The projects are defined by the company, and involve real issues current at the company. All projects will involve design (i.e., open ended problems with no one solution or route), an economic analysis, and will account for possible safety and environmental issues. The nature of the projects varies, depending on the needs of each company. There are no lectures for this course, and students are expected to work on their project for an amount appropriate for a 3-credit course (10 hrs/week). Recommended preparation: ECHE 362, ECHE 365, and ECHE 398. Counts as a SAGES Senior Capstone course. Prereq: ECHE 360, ECHE 361, ECHE 364, and ECHE 367.

ECHE 400T. Graduate Teaching I. 0 Unit.
All Ph.D. students are required to take this course. The experience includes elements from the following tasks: development of teaching or lecture materials, teaching recitation groups, providing laboratory assistance, tutoring, exam/quiz/homework preparation and grading, mentoring students. Recommended preparation: Entering Ph.D. student in Chemical Engineering.

ECHE 401. Chemical Engineering Communications. 1 Unit.
Introductory course in communication for Chemical Engineering graduate students: preparation of first proposal for thesis, preparation of technical reports and scientific papers, literature sources, reviewing proposals, and manuscripts for professional journals, and making effective technical presentations.

ECHE 402. Chemical Engineering Communications II. 2 Units.
This course is a continuation of ECHE 401 and is designed to develop skills in writing proposals for funding research projects. The federal requirements are reviewed for submitting proposals to the major granting agents including NSF, NIH and DoD. We will study strategies for developing fundable projects. Each student will submit a research proposal for a thesis project and do an oral presentation of the project.

ECHE 430. Design and Production of Fermented Beverages. 3 Units.
Fermented and distilled beverages (including beer, wine, and whiskey) have recently gained new interest as craft products, with significant growth in the craft brewing, wine, and distilling industry. This course provides a technical overview of the design and manufacture of these products, with a particular emphasis on brewing. Specific topics detailed below will include the molecular basis of fermentation, the chemistry of various flavors and styles (alt, kolsch, porter, bock, mead, ale, etc.), the biochemistry of yeast fermentation and hops, as well as mashing, lautering, boiling, conditioning, filtering, and packaging. In addition, the manufacturing process, including the technical features of quality control, statistical analysis, water quality, and hardware choice in the brewing industry will be covered. There is no lab component, but there will be several tours of manufacturing and lab facilities. The course will feature invited speakers from the local brewing and wine making industry. Each student will be expected to have basic background knowledge of chemistry, physics, and biology, but there are no prerequisites for this class. Offered as ECHE 330 and ECHE 430.

ECHE 431. Design of Chemical Engineering Systems: Material Analysis. 3 Units.
Applying fundamental mass-balance related analysis to industrial separations processes (distillation, absorption, membranes; both plate and packed columns), reactors (CSTR, PFR), and process control (PID feedback controllers). Utilizing relevant thermodynamics theory including liquid-vapor and solid-liquid phase diagrams and azeotropes as needed for separations. Fundamental theory will be integrated in comprehensive design applications including economic analysis (equipment costing, net-present value and return on investment). Process simulation software will be used to introduce students to advanced design tools. Outcome goal will be to have the students learn to integrate fundamental knowledge from different chemical engineering topics to the comprehensive design of processes of industrial relevance. Prereq: Graduate student standing.

ECHE 432. Design of Chemical Engineering Systems: Energy Analysis. 3 Units.
Applying energy balance analysis to the design of comprehensive engineering processes. Fluid-flow fundamentals including mechanical energy balance and Bernoulli's equation, viscous flow in conduits and around submerged objects, Newton's law of viscosity and Navier-Stokes equation, among others, will be applied to the analysis and design of systems of industrial significance. Scaling analysis will elucidate critical process parameters. Thermodynamics first and second laws will be applied together with heat transfer models based on differential and integral analysis to the design of heat transfer systems including heat exchangers. Fluid-flow and heat transport analysis will be combined with economic considerations to analyze comprehensive problems and optimize designs. Emphasis will be placed on green and sustainable energy processes. An outcome goal of the course is to have the students develop skills of integrating fundamental knowledge from the fields of fluid flow, heat transfer, and engineering economics to the analysis and design of comprehensive systems of practical interest. Prereq: Graduate student standing.

ECHE 460. Thermodynamics of Chemical Systems. 3 Units.
Phase equilibria, phase rule, chemical reaction equilibria in homogeneous and heterogeneous systems, ideal and non-ideal behavior of fluids and solutions, thermodynamic analysis of closed and open chemical systems with applications. Recommended preparation: ECHE 363.

ECHE 461. Transport Phenomena. 3 Units.
Mechanisms of heat, mass, and momentum transport on both molecular and continuum basis. Generalized equations of transport. Techniques of solution for boundary value problems in systems of conduction, diffusion, and laminar flow. Boundary layer and turbulent systems. Recommended preparation: ECHE 360.

ECHE 462. Chemical Reaction Engineering. 3 Units.
Steady and unsteady state mathematical modeling of chemical reactors from conservation principles. Interrelation of reaction kinetics, mass and heat transfer, flow phenomena. Catalytic and chemical vapor deposition reactors. Determination of kinetic parameters. Includes catalytic and chemical vapor deposition reactors. Recommended preparation: ECHE 364.

ECHE 466. Colloids and Interfacial Science. 3 Units.
Fundamental aspects of colloidal suspensions, surface tension, wetting, surfactant adsorption, self-assembly, and interparticle interactions. DLVO theory, stability criteria, and coagulation kinetics. Electrokinetic phenomena. Applications to electrophoresis, filtration, floatation, sedimentation, and suspension rheology. Investigation of suspensions, emulsions, gels, and association colloids. Emphasis will be placed on the importance and application of these phenomena to consumer, industrial, and biomedical applications. Recommended preparation: CHEM 335. Offered as ECHE 366 and ECHE 466. Prereq: Graduate student standing.

ECHE 469. Chemical Engineering Seminar. 0 Unit.
Distinguished outside speakers present current research in various topics of chemical engineering science. Graduate students also present technical papers based on thesis research.

ECHE 470. Graduate Research Colloquium. .5 Unit.
Outside speakers present lectures on their current research. Various topics in the areas of chemical engineering science , basic and applied chemistry, bioengineering, material science, and applied mathematics are covered in the lectures. Graduate students also present technical papers based on their own research. Students are graded on the submission of one- page summary reports on any two lectures.

ECHE 472. Electrochemical Energy Storage. 3 Units.
Batteries and supercapacitors as part of renewable energy systems are introduced. Related fundamental electrochemistry concepts, materials and techniques are described. Challenges, current literature and future opportunities in energy storage will be discussed. Offered as ECHE 372 and ECHE 472. Prereq: Graduate standing or Requisites Not Met permission.

ECHE 474. Biotransport Processes. 3 Units.
Biomedical mass transport and chemical reaction processes. Basic mechanisms and mathematical models based on thermodynamics, mass and momentum conservation. Analytical and numerical methods to simulate in vivo processes as well as to develop diagnostic and therapeutic methods. Applications include transport across membranes, transport in blood, tumor processes, bioreactors, cell differentiation, chemotaxis, drug delivery systems, tissue engineering processes. Recommended preparation: EBME 350 or equivalent. Offered as EBME 474 and ECHE 474.

ECHE 475. Chemical Engineering Analysis. 3 Units.
Mathematical analysis of problems in transport processes, chemical kinetics, and control systems. Examines vector spaces and matrices and their relation to differential transforms, series techniques (Fourier, Bessel functions, Legendre polynomials). Recommended preparation: MATH 224.

ECHE 478. Membrane Separations. 3 Units.
Membrane-based separations provide a low-energy technique for performing chemical engineering separations and have applications in water treatment, energy, and human health. This course will provide an introduction to membrane transport mechanisms including solution diffusion, pore-flow and active transport. The course will also cover membrane fabrication methods, analytical techniques for membrane characterization and performance metrics. Fundamental concepts will be discussed in the context of particle filtration, nanofiltration, reverse osmosis, gas separations processes and emerging applications like membrane chromatography. Prereq: Graduate Standing or Requisites Not Met permission.

ECHE 479. Radiochemistry. 3 Units.
This course is intended to provide students with a basic understanding of fundamental chemical and physical properties of radioactive elements. The course will begin with a review of radioactive decay modes and nuclear chemistry. The majority of the course will focus on the solution chemistry, bonding, kinetics and thermodynamics of actinides in the context of analytical purification processes such as liquid-liquid extraction and resin-based chromatography. Common radioanalytical techniques such as gamma spectroscopy, alpha spectroscopy and liquid scintillation counting will also be discussed. Prereq: Graduate student standing.

ECHE 480. Electrochemical Engineering. 3 Units.
Engineering aspects of electrochemical processes including current and potential distribution, mass transport and fluid mechanical effects. Examples from industrial processes including electroplating, industrial electrolysis, corrosion, and batteries. Recommended preparation: ECHE 260 or permission of instructor. Offered as ECHE 381 and ECHE 480.

ECHE 481. Corrosion Fundamentals. 3 Units.
This course will cover fundamentals of corrosion, including thermodynamic and kinetic aspects of the electrochemical reactions leading to corrosion. Salient features of the various types of corrosion will be reviewed, with an emphasis on fundamental mechanisms. Electrochemical testing, corrosion monitoring and techniques to stifle corrosion will be discussed. After completion of this course, students will be able to classify corrosion systems, understand the mechanisms underlying corrosion, and outline strategies to design corrosion-resistant systems. Offered as ECHE 384 and ECHE 481.

ECHE 483. Chemical Engineering Applied to Microfabrication and Devices. 3 Units.
Silicon based microfabrication and micromachining require many chemical engineering technologies. Microfabricated devices such as sensors are also directly related to chemical engineering. The applications of chemical engineering principles to microfabrication and micromachining are introduced. Oxidation processing, chemical vapor deposition, etching and patterning techniques, electroplating and other technologies are discussed. Graduate students will submit an additional final project on some technical aspect of microfabrication technology or devices. Recommended preparation: ECHE 363. Offered as ECHE 383 and ECHE 483.

ECHE 485. Computational Materials Modeling. 3 Units.
This course will survey computational methods used for the atomic-level modeling of materials. Topics will include quantum mechanics, density functional theory, surface thermodynamics and phase diagrams, transition state theory and surface kinetics, microkinetic modeling, and interfacial electrochemistry. Examples utilizing these methods will be tailored toward applications in heterogeneous catalysis (thermal and electrochemical). This class will also involve hands-on computational exercises and a research-based term project. Prereq: Graduate standing.

ECHE 486. Protein Engineering. 3 Units.
This course will provide an in-depth examination of protein engineering topics and their applications. In particular, this class will cover the design and expression of recombinant proteins, purification strategies, and the incorporation of non-natural amino acids using a bacterial system. Specifically, amino acid sequences that dictate well-defined secondary structures such as beta-sheets, alpha-helices, and leucine zippers will be studied. Tissue engineering examples from the literature such as incorporation of bioactive sequences to promote specific cell response (e.g., cell adhesion sites and protease degradation sequences). In addition, this course will explore the application of protein engineering in drug delivery, electrochemical technology, sensors, and nanoparticle assembly. Current computational techniques for protein design and directed evolution methods will also be explored. Offered as ECHE 386 and ECHE 486. Prereq: Graduate standing or requisites not met permission.

ECHE 488. Electrochemical Engineering Measurement Techniques. 3 Units.
The course explores the theory and assumptions of measurement techniques and electrode design in electrochemical engineering, including rotating disk electrodes, ultramicroelectrodes, porous electrodes, voltammetry, and impedance. The course includes laboratory experiments to demonstrate measurement techniques, and simulations that explore design and assumption limits. Students will have an opportunity to explore theory/measurements of a technique or system of their own system of interest. Prereq: ECHE 381 or ECHE 480.

ECHE 500T. Graduate Teaching II. 0 Unit.
All Ph.D. students are required to take this course. The experience will include elements from the following tasks: development of teaching or lecture materials, teaching recitation groups, providing laboratory assistance, tutoring, exam/quiz/homework preparation and grading, mentoring students. Recommended preparation: Ph.D. student in Chemical Engineering.

ECHE 508. Seminar on Review of Literature on Research Topic. 3 Units.
Impactful research requires a deep and comprehensive understanding of the current state of research on the topic. A critical review of relevant background literature will help determine what is already known on the topic, how extensively the topic has already been studied, who are the experts active in the field, and the relevant key questions that deserve further exploration. A review of the literature that describes methodologies (both experimental and theoretical) used in prior studies or new approaches that could be adapted from other research areas can also lead to the effective pursuit of the research topic. Through this course, students will learn how to develop a plan for a literature review, conduct the literature review and monitor continuing developments in the field, and create an annotated bibliography appropriate to the research project.

ECHE 509. Seminar on Preparation of Articles for Publication in Journals. 3 Units.
This course is intended for advanced graduate students who have generated results at the stage of being ready to be written up for a journal article. The course will cover: understanding what findings warrant publication, factors affecting journal selection, formatting requirements of journals, publication-quality figures, appropriate material for each of the sections of the paper. During the course students will be putting together a manuscript based on their research that would eventually be submitted to a journal.

ECHE 580. Special Topics. 3 Units.
Special topics in chemical engineering. Prereq: Consent of instructor.

ECHE 600T. Graduate Teaching III. 0 Unit.
All Ph.D. students are required to take this course. The experience will include elements from the following tasks: development of teaching or lecture materials, teaching recitation groups, providing laboratory assistance, tutoring, exam/quiz/homework preparation and grading, mentoring students. Recommended preparation: Ph.D. student in Chemical Engineering.

ECHE 601. Independent Study. 1 - 18 Units.

ECHE 651. Thesis M.S.. 1 - 18 Units.
(Credit as arranged.)

ECHE 660. Special Problems. 1 - 18 Units.
Research course taken by Plan B M.S. students.

ECHE 695. Project M.S.. 1 - 9 Units.
Research course taken by Plan B M.S. students. Prereq: Enrolled in ECHE Plan B Program.

ECHE 701. Dissertation Ph.D.. 1 - 9 Units.
(Credit as arranged.) Prereq: Predoctoral research consent or advanced to Ph.D. candidacy milestone.