

# CHEMICAL ENGINEERING

## College of Engineering

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## Department Office

3001 Ghausi Hall; Fax 530-752-1031; Chemical Engineering (<https://che.engineering.ucdavis.edu/>); Faculty (<https://che.engineering.ucdavis.edu/people/faculty/>)

The Department of Chemical Engineering offers two undergraduate programs: Chemical Engineering (<https://catalog.ucdavis.edu/departments-programs-degrees/chemical-engineering/chemical-engineering-bs/#requirementstext>) and Biochemical Engineering (<https://catalog.ucdavis.edu/departments-programs-degrees/chemical-engineering/biochemical-engineering-bs/>).

## Mission Statement

To advance through teaching and research programs, the frontiers of chemical engineering and biochemical engineering; to educate students with a sense of professionalism and community; and to serve the public of California through outreach efforts.

Our faculty forms the cornerstone of this education and research mission, preparing students for careers in fields that have tremendous impact on key areas of modern life: energy, biotechnology and nanotechnology.

- Biochemical Engineering, Bachelor of Science (<https://catalog.ucdavis.edu/departments-programs-degrees/chemical-engineering/biochemical-engineering-bs/>)
- Chemical Engineering, Bachelor of Science (<https://catalog.ucdavis.edu/departments-programs-degrees/chemical-engineering/chemical-engineering-bs/>)
- Chemical Engineering, Master of Engineering (<https://catalog.ucdavis.edu/departments-programs-degrees/chemical-engineering/chemical-engineering-me/>)
- Chemical Engineering, Master of Science (<https://catalog.ucdavis.edu/departments-programs-degrees/chemical-engineering/-chemical-engineering-ms/>)
- Chemical Engineering, Doctor of Philosophy (<https://catalog.ucdavis.edu/departments-programs-degrees/chemical-engineering/chemical-engineering-phd/>)

## Chemical Engineering (ECH)

### ECH 001 – Design of Coffee–An Introduction to Chemical Engineering (3 units)

*Course Description:* Non-mathematical introduction to how chemical engineers think, illustrated by elucidation of the process of roasting and brewing coffee. Qualitative overview of the basic principles of engineering analysis and design. Corresponding experiments testing design choices on the sensory qualities of coffee.

*Learning Activities:* Lecture 1 hour(s), Laboratory 2 hour(s), Project 1 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 001Y, ECM 001, ECM 005 or ECH 005.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Scientific Literacy (SL); Visual Literacy (VL).

### ECH 001Y – Design of Coffee–An Introduction to Chemical Engineering (3 units)

*Course Description:* Non-mathematical introduction to how chemical engineers think, illustrated by elucidation of the process of roasting and brewing coffee. Qualitative overview of the basic principles of engineering analysis and design. Corresponding experiments testing design choices on the sensory qualities of coffee.

*Learning Activities:* Web Virtual Lecture 1 hour(s), Laboratory 2 hour(s), Project 1 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 001, ECM 001, ECM 005 or ECH 005.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Scientific Literacy (SL); Visual Literacy (VL).

### ECH 005 – Introduction to Analysis & Design in Chemical Engineering (3 units)

*Course Description:* Quantitative introduction to the engineering principles of analysis and design. Applications of differential and integral calculus. Laboratory experiments using coffee to illustrate chemical engineering concepts and to conduct an engineering design competition.

*Prerequisite(s):* MAT 021A; MAT 021B (can be concurrent).

*Learning Activities:* Lecture 2 hour(s), Laboratory 2 hour(s).

*Credit Limitation(s):* Only 2 units of credit to students who have completed ECM 001 or ECH 001; not open for credit to students who have completed ECM 005.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

**ECH 051 – Material Balances (4 units)**

This version has ended; see updated course, below.

*Course Description:* Application of the principle of conservation of mass to single and multicomponent systems in chemical process calculations. Studies of batch, semi-batch, and continuous processes involving mass transfer, phase change, and reaction stoichiometry.

*Prerequisite(s):* MAT 021C C- or better; MAT 021D (can be concurrent).

*Learning Activities:* Lecture 4 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 151.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 051 – Material Balances (4 units)**

*Course Description:* Application of the principle of conservation of mass to single and multicomponent systems in chemical process calculations. Studies of batch, semi-batch, and continuous processes involving mass transfer, phase change, and reaction stoichiometry.

*Prerequisite(s):* MAT 021B C- or better.

*Learning Activities:* Lecture 4 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 151.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

This course version is effective from, and including: Winter Quarter 2023.

**ECH 060 – Engineering Problem Solving Using MATLAB (4 units)**

*Course Description:* Problem solving in chemical, biochemical and materials engineering using MATLAB. Programming styles, data structures, working with lists, functions and rules. Applications drawn from material balances, statistics, numerical methods, bioinformatics, transport phenomena, kinetics, and computational analysis.

*Prerequisite(s):* MAT 021C.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

**ECH 080 – Chemical Engineering Profession (1 unit)**

*Course Description:* Professional opportunities and professional responsibilities of chemical engineers. Opportunities and needs for post-baccalaureate education. Relationship of chemical engineering to contemporary issues.

*Learning Activities:* Lecture/Discussion 1 hour(s), Term Paper.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE) or Social Sciences (SS).

**ECH 090X – Honors Discussion Section (1 unit)**

*Course Description:* Examination of special topics covered in selected lower division courses through additional readings, discussions, collaborative work, or special activities which may include projects, laboratory experience or computer simulations.

*Learning Activities:* Discussion 1 hour(s).

*Enrollment Restriction(s):* Open only to students in the Chemical Engineering or Biochemical Engineering Honors Programs.

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 098 – Directed Group Study (1-5 units)**

*Course Description:* Directed Group Study.

*Prerequisite(s):* Consent of instructor. Lower division standing.

*Learning Activities:* Variable.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

**ECH 099 – Special Study for Undergraduates (1-5 units)**

*Course Description:* Special study for undergraduates.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Variable.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

**ECH 140 – Mathematical Methods in Biochemical & Chemical Engineering (4 units)**

*Course Description:* Mathematical methods for solving problems in chemical and biochemical engineering, with emphasis on transport phenomena. Fourier series and separation of variables. Sturm-Liouville eigenvalue problems. Similarity transformations. Tensor analysis. Finite difference methods for solving time-dependent diffusion problems.

*Prerequisite(s):* MAT 022B; (ECH 060 or ENG 006); or equivalents of ECH 060 or ENG 006.

*Learning Activities:* Lecture/Discussion 3 hour(s), Laboratory 1 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 159.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 141 – Fluid Mechanics for Biochemical & Chemical Engineers (4 units)**

This version has ended; see updated course, below.

*Course Description:* Principles and applications of fluid mechanics in chemical and biochemical engineering. Hydrostatics. Stress tensor and Newton's law of viscosity.

*Prerequisite(s):* ECH 051 C- or better; ECH 140.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 150B.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

**ECH 141 – Fluid Mechanics for Biochemical & Chemical Engineers (4 units)**

*Course Description:* Principles and applications of fluid mechanics in chemical and biochemical engineering. Hydrostatics. Stress tensor and Newton's law of viscosity.

*Prerequisite(s):* ECH 051 (can be concurrent); ECH 140 (can be concurrent).

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 150B.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

This course version is effective from, and including: Winter Quarter 2023.

**ECH 142 – Heat Transfer for Biochemical & Chemical Engineers (4 units)**

*Course Description:* Conduction, convection, and radiation of thermal energy in applications to chemical and biochemical engineering. Derivation of thermal and mechanical energy equations. Thermal boundary layers. Macroscopic balances. Applications: heat transfer in tubes, channels, and integrated circuits, and analysis of heat exchangers.

*Prerequisite(s):* ECH 141.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 153.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

**ECH 143 – Mass Transfer for Biochemical & Chemical Engineers (4 units)**

*Course Description:* Derivation of species conservation equations describing convective and diffusive mass transfer. Fick's law and the Stefan-Maxwell constitutive equations. Mass transfer coefficients. Multicomponent mass transfer across gas/liquid interfaces. Applications include drying, heterogeneous chemical reactions, and membrane separations.

*Prerequisite(s):* ECH 141.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 144 – Rheology & Polymer Processing (3 units)**

*Course Description:* Deformation in steady shear, unsteady shear, and elongational flows. Linear and non-linear viscoelastic constitutive models. The principle of material indifference and admissibility of constitutive equations. Introduction to the unit operations of polymer processing.

*Prerequisite(s):* ECH 141.

*Learning Activities:* Lecture/Discussion 3 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 150C.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 145A – Chemical Engineering Thermodynamics Laboratory (3 units)**

This version has ended; see updated course, below.

*Course Description:* Laboratory experiments in chemical engineering thermodynamics.

*Prerequisite(s):* ECH 152A; ECH 152B (can be concurrent).

*Learning Activities:* Laboratory 2 hour(s), Discussion 2 hour(s), Extensive Writing.

*Enrollment Restriction(s):* Open to majors in Chemical Engineering, Chemical Engineering/Materials Science, & Biochemical Engineering.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Writing Experience (WE).

**ECH 145A – Chemical Engineering Thermodynamics Laboratory (3 units)**

*Course Description:* Laboratory experiments in chemical engineering thermodynamics.

*Prerequisite(s):* ECH 152A; ECH 152B (can be concurrent); UWP 102E (can be concurrent).

*Learning Activities:* Laboratory 2 hour(s), Discussion 2 hour(s), Extensive Writing.

*Enrollment Restriction(s):* Open to majors in Chemical Engineering, Materials Science & Engineering, and Biochemical Engineering.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Writing Experience (WE).

This course version is effective from, and including: Winter Quarter 2023.

**ECH 145B – Chemical Engineering Transport Lab (3 units)**

This version has ended; see updated course, below.

*Course Description:* Laboratory experiments in chemical engineering transport phenomena.

*Prerequisite(s):* ECH 141; ECH 145A.

*Learning Activities:* Laboratory 2 hour(s), Discussion 2 hour(s), Extensive Writing.

*Enrollment Restriction(s):* Open to majors in Chemical Engineering, Chemical Engineering/Materials Science, & Biochemical Engineering.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Writing Experience (WE).

**ECH 145B – Chemical Engineering Transport Lab (3 units)**

*Course Description:* Laboratory experiments in chemical engineering transport phenomena.

*Prerequisite(s):* ECH 141; ECH 145A; UWP 102E.

*Learning Activities:* Laboratory 2 hour(s), Discussion 2 hour(s), Extensive Writing.

*Enrollment Restriction(s):* Open to majors in Chemical Engineering, Materials Science & Engineering and Biochemical Engineering.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Writing Experience (WE).

This course version is effective from, and including: Spring Quarter 2023.

**ECH 148A – Chemical Kinetics & Reaction Engineering (3 units)**

*Course Description:* Ideal chemical reactors. Rate laws and stoichiometry. Design and analysis of isothermal reactors with multiple reactions.

*Prerequisite(s):* ECH 143; ECH 152B.

*Learning Activities:* Lecture 3 hour(s).

*Credit Limitation(s):* Not open for credit to students who have taken ECH 146.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 148B – Chemical Kinetics & Reaction Engineering (4 units)**

*Course Description:* Design and analysis of non-isothermal reactors. Reactions in packed beds with pressure drop. Adsorption and heterogeneous catalysis. Transport limitations.

*Prerequisite(s):* ECH 148A.

*Learning Activities:* Lecture 3 hour(s), Discussion 1 hour(s).

*Credit Limitation(s):* Not open for credit to students who have taken ECH 146.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 152A – Chemical Engineering Thermodynamics (3 units)**

*Course Description:* Application of principles of thermodynamics to chemical processes.

*Prerequisite(s):* ECH 060 or ENG 006; or equivalents.

*Learning Activities:* Lecture 3 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ENG 105 or ENG 105A.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 152B – Chemical Engineering Thermodynamics (4 units)**

*Course Description:* Continuation of ECH 152A.

*Prerequisite(s):* ECH 152A.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 155 – Chemical Engineering Kinetics & Reactor Design Laboratory (4 units)**

This version has ended; see updated course, below.

*Course Description:* Laboratory experiments in chemical kinetics, reactor design and process control.

*Prerequisite(s):* ECH 145B; ECH 148A; ECH 148B (can be concurrent); ECH 157 (can be concurrent); upper division English composition requirement (can be concurrent).

*Learning Activities:* Laboratory 6 hour(s), Discussion 1 hour(s), Term Paper.

*Enrollment Restriction(s):* Open to majors in Chemical Engineering, Chemical Engineering/Materials Science, and Biochemical Engineering.

*Credit Limitation(s):* Not open for credit to students who have taken ECH 155B.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Visual Literacy (VL); Writing Experience (WE).

**ECH 155 – Chemical Engineering Kinetics & Reactor Design Laboratory (4 units)**

*Course Description:* Laboratory experiments in chemical kinetics, reactor design and process control.

*Prerequisite(s):* ECH 145B; ECH 148A; ECH 148B (can be concurrent); ECH 157 (can be concurrent).

*Learning Activities:* Laboratory 6 hour(s), Discussion 1 hour(s), Term Paper.

*Enrollment Restriction(s):* Open to majors in Chemical Engineering, Materials Science & Engineering, and Biochemical Engineering.

*Credit Limitation(s):* Not open for credit to students who have taken ECH 155B.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Visual Literacy (VL); Writing Experience (WE).

This course version is effective from, and including: Winter Quarter 2023.

**ECH 157 – Process Dynamics & Control (4 units)**

*Course Description:* Fundamentals of dynamics and modeling of chemical processes. Design and analysis of feedback control of chemical processes.

*Prerequisite(s):* ECH 140.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

**ECH 158A – Process Economics & Green Design (4 units)**

*Course Description:* Senior design experience in process and product creation and design with multiple realistic constraints. Cost accounting and capital investment estimation. Profitability analysis techniques. Green chemistry, health risk assessment and life cycle assessment concepts.

*Prerequisite(s):* ECH 142; ECH 143.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE) or Social Sciences (SS); Scientific Literacy (SL); Visual Literacy (VL).

**ECH 158B – Separations & Unit Operations (4 units)**

*Course Description:* Senior design experience with multiple realistic constraints. Heuristic and rigorous design of chemical process equipment. Separation by filtration, distillation and extraction. Synthesis of reactor and separation networks, heat and power integration.

*Prerequisite(s):* ECH 158A.

*Learning Activities:* Lecture 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

**ECH 158C – Plant Design Project (4 units)**

*Course Description:* Senior design experience for chemical and biochemical processes. Impact of multiple realistic constraints. Design, costing and profitability analysis of complete plants. Use of computer-aided design techniques.

*Prerequisite(s):* ECH 158B or ECH 161C.

*Learning Activities:* Discussion/Laboratory 2 hour(s), Project 2 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE) or Social Sciences (SS); Visual Literacy (VL).

**ECH 160 – Fundamentals of Biomanufacturing (3 units)**

*Course Description:* Principles of large scale bioreactor production of metabolites, enzymes, and recombinant proteins including the development of strains/cell lines, fermentor/bioreactor design, monitoring and operation, product recovery and purification, and biomanufacturing economics.

*Prerequisite(s):* MIC 102 or BIS 102 or ABI 102.

*Learning Activities:* Lecture 3 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed ECH 161C or both ECH 161A and ECH 161B; only 2 units of credit to students who have completed either ECH 161A or ECH 161B.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL); Visual Literacy (VL).

**ECH 161A – Biochemical Engineering Fundamentals (4 units)**

*Course Description:* Biokinetics; bioreactor design and operation; transport phenomena in bioreactors; microbial, plant, and animal cell cultures.

*Prerequisite(s):* ECH 148A.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL); Visual Literacy (VL).

**ECH 161B – Bioseparations (4 units)**

*Course Description:* Product recovery and purification of biochemicals. Cell disruption, centrifugation, filtration, membrane separations, extraction, and chromatographic separation.

*Prerequisite(s):* ECH 143.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

**ECH 161C – Biotechnology Facility Design & Regulatory Compliance (4 units)**

*Course Description:* Design of biotechnology manufacturing facilities. Fermentation and purification equipment, and utility systems.

Introduction to current good manufacturing practices, regulatory compliance, and documentation.

*Prerequisite(s):* (ECH 158A, ECH 161A (can be concurrent), ECH 161B (can be concurrent)) or DEB 263 (can be concurrent).

*Learning Activities:* Lecture 3 hour(s), Discussion 1 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE) or Social Sciences (SS); Quantitative Literacy (QL); Scientific Literacy (SL); Visual Literacy (VL).

**ECH 161L – Bioprocess Engineering Laboratory (4 units)**

*Course Description:* Laboratory experiments in the operation and analysis of bioreactors; determination of oxygen mass transfer coefficients in bioreactors and ion exchange chromatography.

*Prerequisite(s):* (ECH 145B, ECH 161A, ECH 161B) or VEN 186 or (BIS 103, MCB 120L).

*Learning Activities:* Laboratory 9 hour(s), Discussion 1 hour(s), Term Paper.

*Enrollment Restriction(s):* Pass One restricted to chemical/biochemical engineering majors.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL); Visual Literacy (VL); Writing Experience (WE).

**ECH 166 – Catalysis (3 units)**

*Course Description:* Principles of catalysis based on an integration of principles of physical, organic, and inorganic chemistry and chemical kinetics and chemical reaction engineering. Catalysis in solution; catalysis by enzymes; catalysis in swellable polymers; catalysis in microscopic cages (zeolites); catalysis on surfaces.

*Prerequisite(s):* ECH 148A; consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**ECH 168 – Chemical & Engineering Principles in Whisky & Fuel Alcohol Production (3 units)**

*Course Description:* Chemical & engineering principles underlying the manufacture of whisky & fuel alcohol. Biochemistry of malting.

Assessment of grain modification & diastatic power, and of the phenol content of peated malt. Lautering as a problem of fluidized bed compaction. Fermentation and its assessment. Fractional distillation and the Rayleigh equation. The fate of congeners in pot and column distillation. Chemical reactions affecting flavor from kilning to maturation.

*Prerequisite(s):* CHE 128A; CHE 128B (can be concurrent); or consent of instructor.

*Learning Activities:* Laboratory 3 hour(s), Discussion 1 hour(s).

*Enrollment Restriction(s):* Limited to students aged 21 years or older; open to seniors in chemical engineering and seniors in chemistry; non-majors require consent of instructor.

*Cross Listing:* CHE 168.

*Grade Mode:* Letter.

### **ECH 169 – The Design of Cocktails: Applied Thermodynamics & Transport Phenomena in Mixed Drinks (1 unit)**

*Course Description:* Scientific and engineering principles underlying the preparation of mixed drinks. Thermodynamics and kinetics of ice crystallization; phase diagram of ethanol-water-ice mixtures; mass transfer of aromatics; solubility of sucrose and carbon dioxide; colloidal behavior of dispersed solids and emulsified oils. Corresponding laboratory experiments testing the effect of design choices on the sensory quality of cocktails.

*Prerequisite(s):* ECH 145B; ECH 152B; consent of instructor.

*Learning Activities:* Discussion/Laboratory 1 hour(s).

*Enrollment Restriction(s):* Enrollment by permission of instructors only; limited to students over 21 years old.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

### **ECH 170 – Introduction to Colloid & Surface Phenomena (3 units)**

*Course Description:* Introduction to the behavior of surfaces and disperse systems. Fundamentals will be applied to the solution of practical problems in colloid science. Should be of value to engineers, chemists, biologists, soil scientists, and related disciplines.

*Prerequisite(s):* CHE 110A.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### **ECH 190C – Research Group Conference (1 unit)**

*Course Description:* Research group conferences.

*Prerequisite(s):* Consent of instructor; upper division standing in Chemical Engineering.

*Learning Activities:* Discussion 1 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

### **ECH 190X – Honors Discussion Section (1 unit)**

*Course Description:* Examination of special topics covered in selected upper division courses through additional readings, discussions, collaborative work, or special activities which may include projects, laboratory experience or computer simulations.

*Learning Activities:* Discussion 1 hour(s).

*Enrollment Restriction(s):* Open only to students in the Chemical Engineering or Biochemical Engineering Honors Programs.

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

### **ECH 192 – Internship in Chemical or Biochemical Engineering (1-5 units)**

*Course Description:* Supervised work experience in Chemical or Biochemical Engineering.

*Prerequisite(s):* Consent of instructor; completion of a minimum of 84 units; project approval before period of internship.

*Learning Activities:* Internship 3-15 hour(s).

*Repeat Credit:* May be repeated when project differs.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

### **ECH 198 – Group Study (1-5 units)**

*Course Description:* Group study.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Variable.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

### **ECH 199 – Special Study for Advanced Undergraduates (1-5 units)**

*Course Description:* Special study.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Variable.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

### **ECH 200 – Preparing for Graduate Student Success (1 unit)**

*Course Description:* Introduction to the soft-skills and campus resources needed to succeed in graduate school. Emphasis on the student-mentor relationship and the process of selecting a research mentor.

*Learning Activities:* Seminar 1.50 hour(s).

*Enrollment Restriction(s):* Restricted to graduate students in Chemical Engineering.

*Cross Listing:* EMS 200.

*Grade Mode:* Satisfactory/Unsatisfactory only.

### **ECH 206 – Biochemical Engineering (3 units)**

*Course Description:* Interaction of chemical engineering, biochemistry, and microbiology. Mathematical representations of microbial systems. Kinetics of growth, death, and metabolism. Continuous fermentation, agitation, mass transfer and scale-up in fermentation systems, product recovery, enzyme technology.

*Prerequisite(s):* MIC 102; MIC 102L; BIS 101; BIS 102; BIS 103; MCB 120L; MCB 200A; or consent of instructor; FST 205 recommended.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

### **ECH 226 – Enzyme Engineering (3 units)**

*Course Description:* Application of basic biochemical and engineering principles of practical enzymatic processes. Lectures cover large scale production and separation of enzymes, immobilized enzyme systems, enzyme related biotechnology, reactor design and optimization, and new application of enzymes in genetic engineering.

*Prerequisite(s):* MIC 102; MIC 102L; BIS 102; BIS 103; MCB 122; MCB 120L; MCB 200A; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

### **ECH 245 – Micro- & Nano-Technology in Life Sciences (4 units)**

*Course Description:* Survey of biodevice design from engineering and biological perspectives; micro-/nano-fabrication techniques; surface science and mass transport; essential biological processes and models; proposal development skills on merging aforementioned themes.

*Prerequisite(s):* Graduate standing or consent of instructor.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Cross Listing:* EEC 245, EMS 245, MAE 245.

*Grade Mode:* Letter.

**ECH 246 – Advanced Biochemical Engineering (2 units)**

*Course Description:* Advances in the field of biotechnology including genetic engineering, enzyme engineering, fermentation science, and renewable resources development. The important results of original research will be evaluated for understanding of the fundamental principles and for potential practical application.

*Prerequisite(s):* ECH 206; or consent of instructor.

*Learning Activities:* Lecture 2 hour(s).

*Grade Mode:* Letter.

**ECH 252 – Statistical Thermodynamics (4 units)**

*Course Description:* A treatment of the statistical basis of thermodynamics; introduction to statistical mechanics; discussion of the laws of thermodynamics; application of thermodynamic relationships to phase and chemical reaction equilibrium; introduction to molecular simulations and the evaluation of thermodynamic properties from molecular simulations.

*Prerequisite(s):* ECH 152B; ENG 105B or the equivalent.

*Learning Activities:* Lecture 3 hour(s), Discussion 1 hour(s).

*Grade Mode:* Letter.

**ECH 253A – Advanced Fluid Mechanics (4 units)**

*Course Description:* Kinematics and basic principles of fluid flow. Principles of constitutive equations. Navier-Stokes equations for Newtonian fluids. Survey of rectilinear creeping flow, lubrication flow and boundary layer theory.

*Prerequisite(s):* ECH 141; ECH 259.

*Learning Activities:* Lecture 4 hour(s).

*Grade Mode:* Letter.

**ECH 253B – Advanced Heat Transport (4 units)**

*Course Description:* Fundamental energy postulates and derivation of microscopic and macroscopic energy equations. Mechanisms of conduction. Isotropic, thermoelastic and anisotropic materials solution problems using Greens functions and perturbation theory.

*Prerequisite(s):* ECH 142; ECH 259; or the equivalent.

*Learning Activities:* Lecture 4 hour(s).

*Grade Mode:* Letter.

**ECH 253C – Advanced Mass Transfer (4 units)**

*Course Description:* Kinematics and basic conservation principles for multicomponent systems. Constitutive equations for momentum, heat and mass transfer, applications to binary and ternary systems. Details of diffusion with reaction, and the effects of concentration.

*Prerequisite(s):* ECH 253A; or the equivalent.

*Learning Activities:* Lecture 4 hour(s).

*Grade Mode:* Letter.

**ECH 254 – Colloid & Surface Phenomena (4 units)**

*Course Description:* Thermodynamics and rate processes at interfaces. These fundamental processes will be applied to determine the collective properties of thin films and membranes, self-assembled systems, liquid crystals and colloidal systems. Experimental techniques in surface analysis.

*Prerequisite(s):* Graduate standing in science or engineering or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Discussion 1 hour(s).

*Grade Mode:* Letter.

**ECH 256 – Chemical Kinetics & Reaction Engineering (4 units)**

*Course Description:* Analysis of the performance of chemical reactors and design of chemical reactors based on the principles of chemical kinetics and transport phenomena. Consideration of noncatalytic/catalytic reactions in single fluid phases and emphasis on reactions in multiphase mixtures, especially gas-solid reactors.

*Prerequisite(s):* ECH 146; or the equivalent.

*Learning Activities:* Lecture 4 hour(s).

*Grade Mode:* Letter.

**ECH 259 – Advanced Engineering Mathematics (4 units)**

*Course Description:* Applications of methods of applied mathematics to the analytical and numerical solution of linear and nonlinear ordinary and partial differential equations arising in the study of transport phenomena.

*Prerequisite(s):* MAT 021D; MAT 022A; MAT 022B.

*Learning Activities:* Lecture 4 hour(s).

*Grade Mode:* Letter.

**ECH 261 – Molecular Modelling of Soft & Biological Matter (4 units)**

*Course Description:* Modern molecular simulation techniques with a focus on soft matter like polymers, biologically relevant systems, and glasses.

*Prerequisite(s):* EMS 247 or ECH 252; or equivalent course in advanced thermodynamics/statistical mechanics.

*Learning Activities:* Lecture/Discussion 4 hour(s).

*Grade Mode:* Letter.

**ECH 262 – Transport Phenomena in Multiphase Systems (3 units)**

*Course Description:* Heat, mass and momentum transfer in multiphase, multicomponent systems with special emphasis on transport processes in porous media. Derivation of the averaging theorem and application of the method of volume averaging to multicomponent, reacting systems.

*Prerequisite(s):* ECH 253C.

*Learning Activities:* Discussion/Laboratory 3 hour(s).

*Grade Mode:* Letter.

**ECH 263 – Rheology & Mechanics of Non-Newtonian Fluids (3 units)**

*Course Description:* Mechanics of polymer solutions and suspension, especially the development of properly invariant constitutive equations.

Topics include: viscometry, linear and nonlinear viscoelasticity, continuum mechanics, kinetic theory.

*Prerequisite(s):* ECH 253A; ECH 259; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**ECH 265 – Emulsions, Microemulsions & Bilayers (3 units)**

*Course Description:* Thermodynamic and mechanical descriptions of surfactant-laden interfaces. Forces between and within interfaces.

Physics of micelle and microemulsion formation. Structure and stability of emulsions. Properties of phospholipid bilayers, with emphasis on vesicles.

*Prerequisite(s):* An undergraduate course in physical chemistry.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**ECH 267 – Advanced Process Control (3 units)**

*Course Description:* Advanced course in analysis and synthesis of linear multivariable systems. Emphasis on frequency domain techniques and applications to chemical processes. Topics include singular value analysis, internal model control, robust controller design methods as well as self-tuning control techniques.

*Prerequisite(s):* ECH 157; or the equivalent.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**ECH 268 – Polysaccharides Surface Interactions (3 units)**

*Course Description:* Study of fundamental surface science theories as applied to physical and chemical interactions of carbohydrates and polysaccharides.

*Prerequisite(s):* Graduate students in science or engineering.

*Learning Activities:* Lecture 3 hour(s).

*Cross Listing:* EBS 268.

*Grade Mode:* Letter.

**ECH 269 – Cell & Molecular Biophysics for Bioengineers (4 units)**

*Course Description:* Introduction to fundamental mechanisms governing the structure, function, and assembly of bio-macromolecules. Emphasis is on a quantitative understanding of the nano-to-microscale interactions between and within individual molecules, as well as of their assemblies, in particular membranes.

*Prerequisite(s):* BIM 284; or equivalent; graduate standing; undergraduate students by consent of instructor.

*Learning Activities:* Lecture 4 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed BIM 162.

*Cross Listing:* BIM 262.

*Grade Mode:* Letter.

**ECH 282 – Organic Electronic Materials, Processing & Devices (3 units)**

*Course Description:* Organic electronic materials synthesis and molecular design, methods for device fabrication, optical and electrical characteristics of the devices, discussion of the technology readiness, and a broad survey of methods used to characterize organic electronic materials and devices.

*Prerequisite(s):* Graduate major in Chemistry, Physics or Engineering discipline or consent of instructor.

*Learning Activities:* Lecture/Discussion 3 hour(s).

*Grade Mode:* Letter.

**ECH 289A – Special Topics in Chemical Engineering: Fluid Mechanics (1-5 units)**

*Course Description:* Special topics in Fluid Mechanics.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289B – Special Topics in Chemical Engineering: Nonlinear Analysis & Numerical Methods (1-5 units)**

*Course Description:* Special topics in Nonlinear Analysis and Numerical Methods.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289C – Special Topics in Chemical Engineering: Process Control (1-5 units)**

*Course Description:* Special topics in Process Control.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289D – Special Topics in Chemical Engineering: Chemistry of Catalytic Processes (1-5 units)**

*Course Description:* Special topics in Chemistry of Catalytic Processes.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289E – Special Topics in Chemical Engineering: Biotechnology (1-5 units)**

*Course Description:* Special topics in Biotechnology.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289F – Special Topics in Chemical Engineering: Interfacial Engineering (1-5 units)**

*Course Description:* Special topics in Interfacial Engineering.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289G – Special Topics in Chemical Engineering: Molecular Thermodynamics (1-5 units)**

*Course Description:* Special topics in Molecular Thermodynamics.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289H – Special Topics in Chemical Engineering: Membrane Separations (1-5 units)**

*Course Description:* Special topics in Membrane Separations.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.



**ECH 289I – Special Topics in Chemical Engineering: Advanced Materials Processing (1-5 units)**

*Course Description:* Special topics in Advanced Materials Processing.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289J – Special Topics in Chemical Engineering: Novel Experimental Methods (1-5 units)**

*Course Description:* Special topics in Novel Experimental Methods.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289K – Special Topics in Chemical Engineering: Advanced Transport Phenomena (1-5 units)**

*Course Description:* Special topics in Advanced Transport Phenomena.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 289L – Special Topics in Chemical Engineering: Biomolecular Engineering (1-5 units)**

*Course Description:* Special topics in Biomolecular Engineering.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1-5 hour(s), Laboratory 1-5 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**ECH 290 – Seminar (1 unit)**

*Course Description:* Seminar.

*Learning Activities:* Seminar 1 hour(s).

*Grade Mode:* Satisfactory/Unsatisfactory only.

**ECH 290C – Graduate Research Group Conference (1 unit)**

*Course Description:* Research problems, progress and techniques in chemical engineering.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Discussion 1 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**ECH 294 – Current Progress in Biotechnology (1 unit)**

*Course Description:* Seminars presented by guest lecturers on subjects of their own research activities.

*Prerequisite(s):* Graduate standing.

*Learning Activities:* Seminar 1 hour(s).

*Repeat Credit:* May be repeated.

*Cross Listing:* DEB 294.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**ECH 298 – Group Study (1-5 units)**

*Course Description:* Group study.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Variable.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**ECH 299 – Research (1-12 units)**

*Course Description:* Research.

*Learning Activities:* Variable.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**ECH 390 – Teaching of Chemical Engineering (1 unit)**

*Course Description:* Participation as a teaching assistant or associate-in in a designated engineering course. Methods of leading discussion groups or laboratory sections, writing and grading quizzes, use of laboratory equipment, and grading laboratory reports.

*Prerequisite(s):* Consent of instructor; qualifications and acceptance as teaching assistant and/or associate-in in chemical engineering.

*Learning Activities:* Discussion 1 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.