# CHEMICAL ENGINEERING (CHEMENG)

**CHEMENG 10. The Chemical Engineering Profession. 1 Unit.**
Open to all undergraduates. Overview of and careers in chemical engineering; opportunities to develop networks with working professionals. Panel discussions on career paths and post-graduation opportunities available. Areas include biotechnology, electronics, energy, environment, management consulting, nanotechnology, and graduate school in business, law, medicine, and engineering.

**CHEMENG 100. Chemical Process Modeling, Dynamics, and Control. 3 Units.**
Mathematical methods applied to engineering problems using chemical engineering examples. The development of mathematical models to describe chemical process dynamic behavior. Analytical and computer simulation techniques for the solution of ordinary differential equations. Dynamic behavior of linear first- and second-order systems. Introduction to process control. Dynamics and stability of controlled systems. Prerequisites: CHEMENG 20 or ENGR 20; CME 102 or MATH 53.

**CHEMENG 110A. Introduction to Chemical Engineering Thermodynamics. 3 Units.**
Thermodynamics of single-component systems: laws of thermodynamics, thermodynamic properties, equations of state, properties of ideal and real fluids, phase transitions and phase equilibrium, design of thermodynamic processes including refrigeration and power cycles. This course is intended for undergraduate sophomores and juniors in engineering and/or the chemical sciences; first-year students require consent of instructor. Pre-/Corequisites: CHEM 33, PHYS 41, MATH 51 or CME 100.

**CHEMENG 110B. Multi-Component and Multi-Phase Thermodynamics. 3 Units.**
Thermodynamic properties, equations of state, properties of non-ideal systems including mixtures, and phase and chemical equilibria. Prerequisite: CHEMENG 110A or equivalent.

**CHEMENG 120A. Fluid Mechanics. 4 Units.**
The flow of isothermal fluids from a momentum transport viewpoint. Continuum hypothesis, scalar and vector fields, fluid statics, non-Newtonian fluids, shell momentum balances, equations of motion and the Navier-Stokes equations, creeping and potential flow, parallel and nearly parallel flows, time-dependent parallel flows, boundary layer theory and separation, introduction to drag correlations. Prerequisites: junior in Chemical Engineering or consent of instructor; CHEMENG 100 and CME 102 or equivalent.

**CHEMENG 120B. Energy and Mass Transport. 4 Units.**
General diffusive transport, heat transport by conduction, Fourier's law, conduction in composites with analogies to electrical circuits, advection-diffusion equations, forced convection, boundary layer heat transport via forced convection in laminar flow, forced convection correlations, free convection, free convection boundary layers, free convection correlations and application to geophysical flows, melting and heat transfer at interfaces, radiation, diffusive transport of mass for dilute and non-dilute transfer, mass and heat transport analogies, mass transport with bulk chemical reaction, mass transport with interfacial chemical reaction, evaporation. Prerequisite CHEMENG 120A or consent of instructor.

**CHEMENG 130A. Microkinetics - Molecular Principles of Chemical Kinetics. 3 Units.**
This course will cover the basis of chemical kinetics that are used to design chemical processes and reactor design. Topics include: origin of rate expression in chemical reactions; experimental generation and analysis of kinetic data; relationship between kinetic and thermodynamic quantities; concepts of elementary steps and reaction orders; reactions in parallel and in sequence; branched reactions; collision theory and introduction to transition state theory; heterogeneous catalysis and surface reactions; enzymatic catalysis; applications of kinetics. Prerequisite CHEMENG 110B or consent of instructor.

**CHEMENG 130B. Introduction to kinetics and reactor design. 3 Units.**
Introduction to kinetics and reactor design. Identification and comparison of different reactors. Application of rate laws, pseudo steady-state, quasi-equilibrium, and other non-reactive components to develop mathematical models describing different types of reactor systems. Analysis of reaction kinetics in the context of reactor design, and determination of rate laws and reaction mechanisms. Assessment and troubleshooting of reactors by identifying sources of deviations. Application of concepts of reactor design to questions in different fields such as ecology and epidemiology. Prerequisites: 130A or equivalent.

**CHEMENG 140. Micro and Nanoscale Fabrication Engineering. 3 Units.**
(Same as CHEMENG 140) Survey of fabrication and processing technologies in industrial sectors, such as semiconductor, biotechnology, and energy. Chemistry and transport of electronic and energy device fabrication. Solid state materials, electronic devices and chemical processes including crystal growth, chemical vapor deposition, etching, oxidation, doping, diffusion, thin film deposition, plasma processing. Micro and nanopatterning involving photolithography, unconventional soft lithography and self assembly. Recommended: CHEM 33, 171, and PHYSICS 55.
Same as: CHEMENG 240

**CHEMENG 142. Basic Principles of Heterogeneous Catalysis with Applications in Energy Transformations. 3 Units.**
(Formerly 124/224) Introduction to heterogeneous catalysis, including models of surface reactivity, surface equilibria, kinetics of surface reactions, electronic and geometrical effects in heterogeneous catalysis, trends in reactivity, catalyst structure and composition, electro-catalysis and photo-catalysis. Selected applications and challenges in energy transformations will be discussed. Prerequisites: CHEM 31AB or 31X, CHEM 171, CHEM 175 or CHEMENG 170 or equivalents. Recommended: CHEM 173.
Same as: CHEMENG 242

**CHEMENG 150. Biochemical Engineering. 3 Units.**
Systems-level combination of chemical engineering concepts with biological principles. The production of protein pharmaceuticals as a paradigm to explore quantitative biochemistry and cellular physiology, the elemental stoichiometry of metabolism, recombinant DNA technology, synthetic biology and metabolic engineering, fermentation development and control, product isolation and purification, protein folding and formulation, and biobusiness and regulatory issues. Prerequisite: CHEMENG 181 (formerly 188) or BIOSCI 41 or equivalent.
Same as: BIOE 150, CHEMENG 250

**CHEMENG 160. Polymer Science and Engineering. 3 Units.**
Interrelationships among molecular structure, morphology, and mechanical behavior of polymers. Topics include amorphous and semicrystalline polymers, glass transitions, rubber elasticity, linear viscoelasticity, and rheology. Applications of polymers in biomedical devices and microelectronics. Prerequisites: CHEM 33 and 171, or equivalent.
Same as: CHEMENG 260

**CHEMENG 174. Environmental Microbiology I. 3 Units.**
Basics of microbiology and biochemistry. The biochemical and biophysical principles of biochemical reactions, energetics, and mechanisms of energy conservation. Diversity of microbial catabolism, flow of organic matter in nature: the carbon cycle, and biogeochemical cycles. Bacterial physiology, phylogeny, and the ecology of microbes in soil and marine sediments, bacterial adhesion, and biofilm formation. Microbes in the degradation of pollutants. Prerequisites: CHEM 33,CHEM 121 (formerly CHEM 35), and BIOSCI 83, CHEMENG 181, or equivalents.
Same as: BIO 273A, CEE 274A, CHEMENG 274

**CHEMENG 177. Data Science and Machine Learning Approaches in Chemical and Materials Engineering. 3 Units.**
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Same as: CHEMENG 277, MATSCI 166, MATSCI 176

**CHEMENG 180. Chemical Engineering Plant Design. 4 Units.**
Open to seniors in chemical engineering or by consent of instructor. Application of chemical engineering principles to the design of practical plants for the manufacture of chemicals and related materials. Topics: flow-sheet development from a conceptual design, equipment design for distillation, chemical reactions, heat transfer, pumping, and compression; estimation of capital expenditures and production costs; plant construction.

**CHEMENG 181. Biochemistry I. 4 Units.**
Structure and function of major classes of biomolecules, including proteins, carbohydrates and lipids. Mechanistic analysis of properties of proteins including catalysis, signal transduction and membrane transport. Students will also learn to critically analyze data from the primary biochemical literature. Satisfies Central Menu Area 1 for Bio majors. Prerequisites: Chem 121 (formerly 35).
Same as: CHEM 181, CHEMENG 281

**CHEMENG 183. Biochemistry II. 3 Units.**
Focus on metabolic biochemistry: the study of chemical reactions that provide the cell with the energy and raw materials necessary for life. Topics include glycolysis, gluconeogenesis, the citric acid cycle, oxidative phosphorylation, photosynthesis, the pentose phosphate pathway, and the metabolism of glycogen, fatty acids, amino acids, and nucleotides as well as the macromolecular machines that synthesize RNA, DNA, and proteins. Medical relevance is emphasized throughout. Satisfies Central Menu Area 1 for Bio majors. Prerequisite: CHEM 181 or CHEM 141 or CHEMENG 181/281.
Same as: CHEM 183, CHEMENG 283

**CHEMENG 185A. Chemical Engineering Laboratory A. 5 Units.**
This is the first course in a two-quarter sequence that focuses on critical thinking in experimental aspects of chemical engineering. Critical thinking skills will be developed and practiced through guided lab modules with an emphasis on experimental design, data analysis, and technical communication. In addition to lectures, students are required to attend a weekly lab discussion section (approximately 1 hour each) to be scheduled near the start of the quarter. Due to COVID19 circumstances, all course activities will be held online. TAs will conduct experimental work in the lab based on student input on experimental design, and students will be able to view videos showing the sample preparation and data acquisition processes asynchronously. Students will also work in teams to prepare initial project proposals to be carried out in the following quarter in CHEMENG185B. Satisfies the Writing in the Major (WIM) requirement. Prerequisites: CHEMENG 120A, CHEMENG 120B, CHEMENG 130B, and CHEMENG 181.

**CHEMENG 185B. Chemical Engineering Laboratory B. 5 Units.**
Second quarter of two-quarter sequence. Experimental aspects of chemical engineering. Emphasizes experimental design, project execution, team organization, and communication skills. Lab section times will not be assigned, though students should expect to spend at least 5 hours per week on average in the lab working on their team research projects. Labs will typically be available M-F between 9am-6pm; to be arranged separately. Prerequisite: CHEMENG 185A. Corequisite: CHEMENG 150.

**CHEMENG 190. Undergraduate Research in Chemical Engineering. 1-6 Unit.**
Laboratory or theoretical work for undergraduates under the supervision of a faculty member. Research in one of the graduate research groups or other special projects in the undergraduate chemical engineering lab. Students should consult advisers for information on available projects. Course may be repeated.

**CHEMENG 190H. Undergraduate Honors Research in Chemical Engineering. 1-5 Unit.**
For Chemical Engineering majors pursuing a B.S. with Honors degree who have submitted an approved research proposal to the department. Unofficial transcript must document BSH status and at least 9 units of 190H research for a minimum of 3 quarters May be repeated for credit.

**CHEMENG 191H. Undergraduate Honors Seminar. 1 Unit.**
For Chemical Engineering majors approved for B.S. with Honors research program. Honors research proposal must be submitted and unofficial transcript document BSH status prior to required concurrent registration in 190H and 191H. May be repeated for credit. Corequisite: 190H.

**CHEMENG 193. Interdisciplinary Approaches to Human Health Research. 1 Unit.**
For undergraduate students participating in the Stanford ChEM-H Undergraduate Scholars Program. This course will expose students to interdisciplinary research questions and approaches that span chemistry, engineering, biology, and medicine. Focus is on the development and practice of scientific reading, writing, and presentation skills intended to complement hands-on laboratory research. Students will read scientific articles, write research proposals, make posters, and give presentations.
Same as: BIO 193, BIOE 193, CHEM 193

**CHEMENG 196. Creating and Leading New Ventures in Engineering and Science-based Industries. 3 Units.**
Open to seniors and graduate students interested in the creation of new ventures and entrepreneurship in engineering and science intensive industries such as chemical, energy, materials, bioengineering, environmental, clean-tech, pharmaceuticals, medical, and biotechnology. Exploration of the dynamics, complexity, and challenges that define creating new ventures, particularly in industries that require long development times, large investments, integration across a wide range of technical and non-technical disciplines, and the creation and protection of intellectual property. Covers business basics, opportunity viability, creating start-ups, entrepreneurial leadership, and entrepreneurship as a career. Teaching methods include lectures, case studies, guest speakers, and individual and team projects.
Same as: CHEM 196, CHEM 296, CHEMENG 296

**CHEMENG 199. Undergraduate Practical Training. 1 Unit.**
Only for undergraduate students majoring in Chemical Engineering. Students obtain employment in a relevant industrial or research activity to enhance their professional experience. Students submit a concise report detailing work activities, problems worked on, and key results. May be repeated for credit up to 3 units. Prerequisite: qualified offer of employment and consent of department. Prior approval by the Chemical Engineering Department is required; you must contact the Chemical Engineering Department's Student Services staff for instructions before being granted permission to enroll.

**CHEMENG 20. Introduction to Chemical Engineering. 4 Units.**
Overview of chemical engineering through discussion and engineering analysis of physical and chemical processes. Topics: overall staged separations, material and energy balances, concepts of rate processes, energy and mass transport, and kinetics of chemical reactions. Applications of these concepts to areas of current technological importance: biotechnology, energy, production of chemicals, materials processing, and purification. Prerequisite: CHEM 31.
Same as: ENGR 20

**CHEMENG 240. Micro and Nanoscale Fabrication Engineering. 3 Units.**
(Same as CHEMENG 140) Survey of fabrication and processing technologies in industrial sectors, such as semiconductor, biotechnology, and energy. Chemistry and transport of electronic and energy device fabrication. Solid state materials, electronic devices and chemical processes including crystal growth, chemical vapor deposition, etching, oxidation, doping, diffusion, thin film deposition, plasma processing. Micro and nanopatterning involving photolithography, unconventional soft lithography and self assembly. Recommended: CHEM 33, 171, and PHYSICS 55.
Same as: CHEMENG 140

**CHEMENG 242. Basic Principles of Heterogeneous Catalysis with Applications in Energy Transformations. 3 Units.**
(Formerly 124/224) Introduction to heterogeneous catalysis, including models of surface reactivity, surface equilibria, kinetics of surface reactions, electronic and geometrical effects in heterogeneous catalysis, trends in reactivity, catalyst structure and composition, electro-catalysis and photo-catalysis. Selected applications and challenges in energy transformations will be discussed. Prerequisites: CHEM 31AB or 31X, CHEM 171, CHEM 175 or CHEMENG 170 or equivalents. Recommended: CHEM 173.
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**CHEMENG 250. Biochemical Engineering. 3 Units.**
Systems-level combination of chemical engineering concepts with biological principles. The production of protein pharmaceuticals as a paradigm to explore quantitative biochemistry and cellular physiology, the elemental stoichiometry of metabolism, recombinant DNA technology, synthetic biology and metabolic engineering, fermentation development and control, product isolation and purification, protein folding and formulation, and biobusiness and regulatory issues. Prerequisite: CHEMENG 181 (formerly 188) or BIOSCI 41 or equivalent.
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**CHEMENG 260. Polymer Science and Engineering. 3 Units.**
Interrelationships among molecular structure, morphology, and mechanical behavior of polymers. Topics include amorphous and semicrystalline polymers, glass transitions, rubber elasticity, linear viscoelasticity, and rheology. Applications of polymers in biomedical devices and microelectronics. Prerequisites: CHEM 33 and 171, or equivalent.
Same as: CHEMENG 160

**CHEMENG 270. Mechanics of Soft Matter: Rheology. 3 Units.**
Soft matter comes in many forms and includes polymeric materials, suspensions, emulsions, foams, gels, and living tissue. These materials are characterized by being easily deformed and possessing internal relaxation time spectra. They are viscoelastic with responses that are intermediate between purely viscous liquids and perfectly elastic solids. This course provides an introduction to the subject of rheology, which concerns the deformation and flow of complex liquids and solids. Rheological testing is aimed at determining the relationships between the applied stresses in these materials and the resulting deformations. These are characterized by material functions, such as viscosity (shear and extensional), moduli, and compliances. These functions reflect the microstructure of the material being tested and microstructural models of polymers (single chain theories and reptation-based models), suspensions, emulsions, and foams will be presented. Experimental methods to measure materials subjected to both shearing and elongational deformations will be described. Many soft matter systems are influenced by interfacial phenomena (foams, emulsions, thin films in the human body) and interfacial rheological techniques will be discussed. Advanced undergraduates register for 270; graduates register for 470. Prerequisites: ChE 120A or its equivalent (concurrent enrollment is permissible).
Same as: CHEMENG 470

**CHEMENG 274. Environmental Microbiology I. 3 Units.**
Basics of microbiology and biochemistry. The biochemical and biophysical principles of biochemical reactions, energetics, and mechanisms of energy conservation. Diversity of microbial catabolism, flow of organic matter in nature: the carbon cycle, and biogeochemical cycles. Bacterial physiology, phylogeny, and the ecology of microbes in soil and marine sediments, bacterial adhesion, and biofilm formation. Microbes in the degradation of pollutants. Prerequisites: CHEM 33,CHEM 121 (formerly CHEM 35), and BIOSCI 83, CHEMENG 181, or equivalents.
Same as: BIO 273A, CEE 274A, CHEMENG 174

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Same as: CHEM 183, CHEMENG 183

**CHEMENG 296. Creating and Leading New Ventures in Engineering and Science-based Industries. 3 Units.**
Open to seniors and graduate students interested in the creation of new ventures and entrepreneurship in engineering and science intensive industries such as chemical, energy, materials, bioengineering, environmental, clean-tech, pharmaceuticals, medical, and biotechnology. Exploration of the dynamics, complexity, and challenges that define creating new ventures, particularly in industries that require long development times, large investments, integration across a wide range of technical and non-technical disciplines, and the creation and protection of intellectual property. Covers business basics, opportunity viability, creating start-ups, entrepreneurial leadership, and entrepreneurship as a career. Teaching methods include lectures, case studies, guest speakers, and individual and team projects.
Same as: CHEM 196, CHEM 296, CHEMENG 196

**CHEMENG 299. Graduate Practical Training. 1 Unit.**
Only for graduate students majoring in Chemical Engineering. Students obtain employment in a relevant industrial or research activity to enhance their professional experience. Students submit a concise report detailing work activities, problems worked on, and key results. May be repeated for credit up to 3 units. Prerequisite: qualified offer of employment and consent of department. Prior approval by the Chemical Engineering Department is required; you must contact the Chemical Engineering Department's Student Services staff for instructions before being granted permission to enroll.

**CHEMENG 300. Applied Mathematics in the Chemical and Biological Sciences. 3 Units.**
Mathematical solution methods via applied problems including chemical reaction sequences, mass and heat transfer in chemical reactors, quantum mechanics, fluid mechanics of reacting systems, and chromatography. Topics include generalized vector space theory, linear operator theory with eigenvalue methods, phase plane methods, perturbation theory (regular and singular), solution of parabolic and elliptic partial differential equations, and transform methods (Laplace and Fourier). Prerequisites: CME 102/ENGR 155A and CME 104/ENGR 155B, or equivalents.
Same as: CME 330

**CHEMENG 310. Microhydrodynamics. 3 Units.**
Transport phenomena on small-length scales appropriate to applications in microfluidics, complex fluids, and biology. The basic equations of mass, momentum, and energy, derived for incompressible fluids and simplified to the slow-flow limit. Topics: solution techniques utilizing expansions of harmonic and Green's functions; singularity solutions; flows involving rigid particles and fluid droplets; applications to suspensions; lubrication theory for flows in confined geometries; slender body theory; and capillarity and wetting. Prerequisites: 120A,B, 300, or equivalents.
Same as: ME 451D

**CHEMENG 31N. When Chemistry Meets Engineering. 3 Units.**
Preference to freshmen. Chemistry and engineering are subjects that are ubiquitous around us. But what happens when the two meet? Students will explore this question by diving into experimental problems that scientists and engineers have to face on a daily basis. Many processes that are taken for granted have been developed by understanding science at a very fundamental level and then applying it to large and important industrial processes. In this seminar, students will explore some of the basic concepts that are important to address chemical engineering problems through experimental work. Students will build materials for energy and environmental applications, understand how to separate mixtures into pure compounds, produce fuels, and will learn to look at the chemical properties of molecules that are part of daily life with a different eye.

**CHEMENG 320. Chemical Kinetics and Reaction Engineering. 3 Units.**
Theoretical and experimental tools useful in understanding and manipulating reactions mediated by small-molecules and biological catalysts. Theoretical: first classical chemical kinetics and transition state theory; then RRKM theory and Monte Carlo simulations. Experimental approaches include practical application of modern spectroscopic techniques, stopped-flow measurements, temperature-jump experiments, and single-molecule approaches to chemical and biological systems. Both theory and application are framed with regard to systems of particular interest, including industrially relevant enzymes, organometallic catalysts, heterogeneous catalysis, electron transfer reactions, and chemical kinetics within living cells.

**CHEMENG 340. Molecular Thermodynamics. 3 Units.**
Classical thermodynamics and quantum mechanics. Development of statistical thermodynamics to address the collective behavior of molecules. Establishment of theories for gas, liquid, and solid phases, including phase transitions and critical behavior. Applications include electrolytes, ion channels, surface adsorption, ligand binding to proteins, hydrogen bonding in water, hydrophobicity, polymers, and proteins.

**CHEMENG 345. Fundamentals and Applications of Spectroscopy. 3 Units.**
Theoretical basis and experimental aspects of atomic and molecular spectroscopy, including spectroscopic transitions, transition probabilities, and selection rules. Applications of rotational, vibrational, and electronic spectroscopies emphasize the use of spectroscopy in modern research. Specific topics include but are not limited to microwave spectroscopy, infrared spectroscopy and Raman scattering, and photoelectron and fluorescence spectroscopies. Prerequisites: CME 104 or an equivalent intro to partial differential equations; CHEMENG 110A or CHEM 171 or an equivalent intro to physical chemistry.
Same as: PHOTON 345

**CHEMENG 355. Advanced Biochemical Engineering. 3 Units.**
Combines biological knowledge and methods with quantitative engineering principles. Quantitative review of biochemistry and metabolism; recombinant DNA technology and synthetic biology (metabolic engineering). The production of protein pharaceuticals as a paradigm for the application of chemical engineering principles to advanced process development within the framework of current business and regulatory requirements. Prerequisite: CHEMENG 181 (formerly 188) or BIOSCI 41, or equivalent.
Same as: BIOE 355

**CHEMENG 399. Graduate Research Rotation in Chemical Engineering. 1 Unit.**
Introduction to graduate level laboratory and theoretical work. Performance in this course comprises part of the mandatory evaluation for pre-candidacy standing and suitability to continue in the chemical engineering Ph.D. program.

**CHEMENG 420. Growth and Form. 3 Units.**
Advanced topics course examining the role of physical forces in shaping living cells, tissues, and organs, making use of D'Arcy Thompson's classic text On Growth and Form. The course begins with a review of relevant physical principles drawn from statistical physics, polymer theory, rheology and materials science. We then examine current knowledge of cellular mechanotransduction pathways, the roles of physical forces in guiding embryonic development, and the contribution of aberrant cellular response to mechanical cues in heart disease and cancer. The course concludes by examining current frontiers in stem cell biology and tissue engineering.

**CHEMENG 424. Structure and Reactivity of Solid Surfaces. 3 Units.**
The structure of solid surfaces including experimental methods for determining the structure of single crystal surfaces. The adsorption of molecules on these surfaces including the thermodynamics of adsorption processes, surface diffusion, and surface reactions. Molecular structure of adsorbates. Current topics in surface structure and reactivity, including systems for heterogeneous catalysis and electronic materials.

**CHEMENG 432. Electrochemical Energy Conversion. 3 Units.**
Electrochemistry is playing an increasingly important role in renewable energy. This course aims to cover the fundamentals of electrochemistry, and then build on that knowledge to cover applications of electrochemistry in energy conversion. Topics to be covered include fuel cells, solar water-splitting, CO2 conversion to fuels and chemicals, batteries, redox flow cells, and supercapacitors. Prerequisites: CHEM 31AB or 31 X, CHEM 33, CHEM 171, CHEM 175 or CHEMENG 170, or equivalents. Recommended: CHEM 173.

**CHEMENG 442. Suspension Mechanics. 3-4 Units.**
The course will begin with a brief recap of low-Reynolds number hydrodynamics and the analytical foundations for the study of pair-level particle interactions in a Newtonian solvent. Extension to many-body interactions will be covered in detail, with an introductory overview of computational methods. Brownian motion, thermodynamic forces, and other interparticle forces will be discussed, and various approaches for theoretical modeling will be covered, including Fokker-Planck / Smoluchowski analysis and Langevin analysis. Theoretical and computational modeling of material properties via averaging techniques will be studied, in the context of micromechanical and continuum models. Landmark results in the microrheology and rheology of complex fluids will be covered, including sedimentation, non-Newtonian rheology (including shear thinning and thickening; viscoelasticity and memory behaviors; yield-stress behavior; glassy aging; diffusion; normal stress differences).

**CHEMENG 443. Principles and practice of heterogeneous catalysis. 3 Units.**
Pre-Reqs: UG physical chemistry (171), thermodynamics (110) and kinetics (130) or equivalents.

**CHEMENG 444. Electronic Structure Theory and Applications to Chemical Kinetics. 3 Units.**
Fundamentals of electronic structure theory to describe materials properties and chemical reactivity. nLearning objectives: Understand the basis for modern electronic structure calculations, understand the relationship between electronic structure, materials properties, and chemical kinetics, be able to read the current literature, be able to do own calculations. nImportant components of the lectures: An overview of quantum chemical methods, introduction to methods for periodic systems, density functional theory and current approximations to describe exchange and correlation effects, methods to describe excited states, transition state theory and methods to calculate partition functions. nThe Lab: Leaning to do DFT calculations.

**CHEMENG 450. Advances in Biotechnology. 3 Units.**
Overview of cutting edge advances in biotechnology with a focus on therapeutic and health-related topics. Academic and industrial speakers from a range of areas including protein engineering, immuno-oncology, DNA sequencing, the microbiome, phamacogenomics, industrial enzymes, synthetic biology, and more. Course is designed for students interested in pursuing a career in the biotech industry.
Same as: BIOE 450

**CHEMENG 454. Synthetic Biology and Metabolic Engineering. 3 Units.**
Principles for the design and optimization of new biological systems. Development of new enzymes, metabolic pathways, other metabolic systems, and communication systems among organisms. Example applications include the production of central metabolites, amino acids, pharmaceutical proteins, and isoprenoids. Economic challenges and quantitative assessment of metabolic performance. Pre- or corequisite: CHEMENG 355 or equivalent.
Same as: BIOE 454

**CHEMENG 456. Microbial Bioenergy Systems. 3 Units.**
Introduction to microbial metabolic pathways and to the pathway logic with a special focus on microbial bioenergy systems. The first part of the course emphasizes the metabolic and biochemical principles of pathways, whereas the second part is more specifically directed toward using this knowledge to understand existing systems and to design innovative microbial bioenergy systems for biofuel, biorefinery, and environmental applications. There also is an emphasis on the implications of rerouting of energy and reducing equivalents for the fitness and ecology of the organism. Prerequisites: CHEMENG 174 or 181 and organic chemistry, or equivalents.
Same as: BIO 273B, CEE 274B

**CHEMENG 459. Frontiers in Interdisciplinary Biosciences. 1 Unit.**
Students register through their affiliated department; otherwise register for CHEMENG 459. For specialists and non-specialists. Sponsored by the Stanford BioX Program. Three seminars per quarter address scientific and technical themes related to interdisciplinary approaches in bioengineering, medicine, and the chemical, physical, and biological sciences. Leading investigators from Stanford and the world present breakthroughs and endeavors that cut across core disciplines. Pre-seminars introduce basic concepts and background for non-experts. Registered students attend all pre-seminars; others welcome. See http://biox.stanford.edu/courses/459.html. Recommended: basic mathematics, biology, chemistry, and physics.
Same as: BIO 459, BIOC 459, BIOE 459, CHEM 459, PSYCH 459

**CHEMENG 460. Interfacial Engineering of Soft Matter. 3 Units.**
Interfacial engineering is a culmination of a century of interdisciplinary science and engineering. The foundation is provided by the thermodynamics of surface tension, surface chemistry and adsorption, which govern the properties of catalysts, colloids and surfactants. Microminiaturization of soft and hard materials and the growth of nanotechnology have led to dramatic increases in the surface-to-volume ratio. Knowledge of the principles of interfacial engineering can be used in the application domains of microelectronics chips and packaging, polymer composites, advanced ceramics, biomedical implants and bioanalytical devices. This course will cover the fundamentals of interface physics and chemistry, with an emphasis on soft matter, including phospholipids, proteins and synthetic polymers at interfaces. Specific topics will include intermolecular forces and potentials; solvation, structural and hydration forces; particle-particle interactions; interfacial thermodynamics; Poisson-Boltzmann theory of the diffuse electric double layer; electrokinetic phenomena; colloidal aggregation; and molecular assemblies.

**CHEMENG 462. Complex Fluids and Non-Newtonian Flows. 3 Units.**
Definition of a complex liquid and microrheology. Division of complex fluids into suspensions, solutions, and melts. Suspensions as colloidal and non-colloidal. Extra stress and relation to the stresslet. Suspension rheology including Brownian and non-Brownian fibers. Microhydrodynamics and the Fokker-Planck equation. Linear viscoelasticity and the weak flow limit. Polymer solutions including single mode (dumbbell) and multimode models. Nonlinear viscoelasticity. Intermolecular effects in nondilute solutions and melts and the concept of reptation. Prerequisites: low Reynolds number hydrodynamics or consent of instructor.
Same as: ME 455

**CHEMENG 464. Polymer Chemistry. 3 Units.**
Polymer material design, synthesis, characterization, and application. Topics include organic and kinetic aspects of polymerization, polymer characterization techniques, and structure and properties of bulk polymers for commercial applications and emerging technologies.

**CHEMENG 466. Polymer Physics. 3 Units.**
Concepts and applications in the equilibrium and dynamic behavior of complex fluids. Topics include solution thermodynamics, scaling concepts, semiflexibility, characterization of polymer size (light scattering, osmotic pressure, size-exclusion chromatography, intrinsic viscosity), viscoelasticity, rheological measurements, polyelectrolytes, liquid crystals, biopolymers, and gels.

**CHEMENG 469. Solid Structure and Properties of Polymers. 3 Units.**
Fundamental structure-properties relationships of solid polymers in bulk and thin films. Topics include chain conformations in bulk amorphous polymers, glass transition, crystallization, semi-crystalline morphology, liquid crystalline order, polymer blends, block copolymers, polymer networks/gels, polymers of high current interest, and experimental methods of characterizing polymer structure.

**CHEMENG 470. Mechanics of Soft Matter: Rheology. 3 Units.**
Soft matter comes in many forms and includes polymeric materials, suspensions, emulsions, foams, gels, and living tissue. These materials are characterized by being easily deformed and possessing internal relaxation time spectra. They are viscoelastic with responses that are intermediate between purely viscous liquids and perfectly elastic solids. This course provides an introduction to the subject of rheology, which concerns the deformation and flow of complex liquids and solids. Rheological testing is aimed at determining the relationships between the applied stresses in these materials and the resulting deformations. These are characterized by material functions, such as viscosity (shear and extensional), moduli, and compliances. These functions reflect the microstructure of the material being tested and microstructural models of polymers (single chain theories and reptation-based models), suspensions, emulsions, and foams will be presented. Experimental methods to measure materials subjected to both shearing and elongational deformations will be described. Many soft matter systems are influenced by interfacial phenomena (foams, emulsions, thin films in the human body) and interfacial rheological techniques will be discussed. Advanced undergraduates register for 270; graduates register for 470. Prerequisites: ChE 120A or its equivalent (concurrent enrollment is permissible).
Same as: CHEMENG 270

**CHEMENG 482. The Startup Garage: Design. 4 Units.**
(Same as STRAMGT 356) The Startup Garage is an experiential lab course that focuses on the design, testing and launch of a new venture. Multidisciplinary student teams work through an iterative process of understanding user needs, creating a point of view statement, ideating and prototyping new product and services and their business models, and communicating the user need, product, service and business models to end-users, partners, and investors. In the autumn quarter, teams will: identify and validate a compelling user need and develop very preliminary prototypes for a new product or service and business models. Students form teams, conduct field work and iterate on the combination of business model -- product -- market. Teams will present their first prototypes (business model - product - market) at the end of the quarter to a panel of entrepreneurs, venture capitalists, angel investors and faculty.
Same as: SOMGEN 282

**CHEMENG 484. The Startup Garage: Testing and Launch. 4 Units.**
This is the second quarter of the two-quarter series. In this quarter, student teams expand the field work they started in the fall quarter. They get out of the building to talk to potential customers, partners, distributors, and investors to test and refine their business model, product/service and market. This quarter the teams will be expected to develop and test a minimally viable product, iterate, and focus on validated lessons on: the market opportunity, user need and behavior, user interactions with the product or service, business unit economics, sale and distribution models, partnerships, value proposition, and funding strategies. Teams will interact with customers, partners, distributors, investors and mentors with the end goal of developing and delivering a funding pitch to a panel of entrepreneurs, venture capitalists, angel investors and faculty.
Same as: SOMGEN 284

**CHEMENG 500. Special Topics in Protein Biotechnology. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 501. Special Topics in Semiconductor Processing. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 503. Special Topics in Biocatalysis. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 505. Special Topics in Microrheology. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 507. Special Topics in Polymer Physics and Molecular Assemblies. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 510. Special Topics in Transport Mechanics. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 513. Special Topics in Functional Organic Materials for Electronic and Optical Devices. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 514. Special Topics in Biopolymer Physics. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 515. Special Topics in Molecular and Systems Biology. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 516. Special Topics in Energy and Catalysis. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 517. Special Topics in Microbial Physiology and Metabolism. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 518. Special Topics in Advanced Biophysics and Protein Design. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 519. Special Topics in Interface Science and Catalysis. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 520. Special Topics in Biological Chemistry. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 521. Special Topics in Nanostructured Materials for Energy and the Environment. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 522. Special Topics in Soft Matter and Molecular Physics. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 523. Special Topics in Suspension Dynamics. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 524. Special Topics in Electrochemistry and Water Treatment. 1 Unit.**
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

**CHEMENG 600. Graduate Research in Chemical Engineering. 1-12 Unit.**
Laboratory and theoretical work leading to partial fulfillment of requirements for an advanced degree. Course may be repeated for credit.

**CHEMENG 60Q. Environmental Regulation and Policy. 3 Units.**
Preference to sophomores. How does government, politics and science affect environmental policy? We examine environmental policy including the precautionary principal, acceptable risks, mathematical models, and cost-effectiveness of regulation. You will learn how data is changing environmental regulation and how different administrations mold environmental policy in real-time. We examine the use of science and engineering, its media presentation and misrepresentation, and the effect of public scientific and technical literacy. You will learn how to participate in the process and effect change.

**CHEMENG 699. Colloquium. 1 Unit.**
Weekly lectures by experts from academia and industry in the field of chemical engineering. Course may be repeated for credit.

**CHEMENG 70Q. Masters of Disaster. 3 Units.**
Preference to sophomores. For students interested in science, engineering, politics, and the law. Learn from past disasters to avoid future ones. How disasters can be tracked to failures in the design process. The roles of engineers, artisans, politicians, lawyers, and scientists in the design of products. Failure as rooted in oversight in adhering to the design process. Student teams analyze real disasters and design new products presumably free from the potential for disastrous outcomes.

**CHEMENG 801. TGR Project. 0 Units.**
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**CHEMENG 802. TGR Dissertation. 0 Units.**
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**CHEMENG 80Q. Art, Chemistry, and Madness: The Science of Art Materials. 3 Units.**
Preference to sophomores. Chemistry of natural and synthetic pigments in five historical palettes: earth (paleolithic), classical (Egyptian, Greco-Roman), medieval European (Middle Ages), Renaissance (old masters), and synthetic (contemporary). Composite nature of paints using scanning electron microscopy images; analytical techniques used in art conservation, restoration, and determination of provenance; and inherent health hazards. Paintings as mechanical structures. Hands-on laboratory includes stretching canvas, applying gesso grounds, grinding pigments, preparing egg tempera paint, bamboo and quill pens, gilding and illumination, and papermaking.

**CHEMENG 90Q. Dare to Care: Compassionate Design. 3 Units.**
Imagine yourself with your abundant creativity, intellect, and passion, but your ability to move or speak is diminished. How would you face the world, how would you thrive at Stanford, how would you relay to people your ideas and creations? How would you share yourself and your ideas with the world? nThere are more than 50 million individuals in America with at least one disability, and in the current world of design, these differences are often overlooked. How do we as designers empower people of diverse physical abilities and provide them with means of self-expression?nnIn Compassionate Design, students from any prospective major are invited to explore the engineering design process by examining the needs of persons with disabilities. Through invited guests, students will have the opportunity to directly engage people with different types of disabilities as a foundation to design products that address problems of motion and mobility, vision, speech and hearing. For example, in class, students will interview people who are deaf, blind, have cerebral palsy, or other disabling conditions. Students will then be asked, using the design tools they have been exposed to as part of the seminar, to create a particular component or device that enhances the quality of life for that user or users with similar limitations.nnPresentation skills are taught and emphasized as students will convey their designs to the class and instructors. Students will complete this seminar with a compassionate view toward design for the disabled, they will acquire a set of design tools that they can use to empower themselves and others in whatever direction they choose to go, and they will have increased confidence and abilities in presenting in front of an audience.