CHEMICAL ENGINEERING

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Courses given in Chemical Engineering have the subject code CHEMENG. For a complete list of subject codes, see Appendix.

Chemical engineers are responsible for the conception and design of processes involved in the production, transformation, and transport of materials. This activity begins with experimentation in the laboratory and is followed by implementation of the technology into full-scale production. The mission of the Department of Chemical Engineering at Stanford is to provide professional training, development, and education for the next generation of leaders in the chemical and biological sciences and engineering. A large number of industries depend on the synthesis and processing of chemicals and materials. In addition to traditional examples such as the chemical and energy industries, there are increasing opportunities in biotechnology, pharmaceuticals, electronic device fabrication and materials, and environmental engineering. Chemical and biological engineering is essential in these and other fields whenever processes involve the chemical, biological, or physical transformation of matter.

UNDERGRADUATE PROGRAMS

The University's basic requirements for the bachelor's degree and coterminal bachelor's and master's degrees are discussed in the "Undergraduate Degrees" section of this bulletin.

BACHELOR OF SCIENCE

The Chemical Engineering depth sequence required for the B.S. degree provides training in applied chemical kinetics, biochemical engineering, electronic materials, engineering thermodynamics, plant design, polymers, process analysis and control, separation processes, and transport phenomena. The B.S. program in Chemical Engineering additionally requires basic courses in biology, chemistry, engineering, mathematics, and physics. Undergraduates who wish to major in Chemical Engineering (CHEMENG) should consult the curriculum outlined in the "School of Engineering" section of this bulletin. Courses taken for the departmental major (math; science; science, technology, and society; engineering fundamentals; and engineering depth) must be taken for a letter grade if this option is offered.

There are several 4-year sequences of courses for a B.S. in Chemical Engineering. While each sequence starts at a different level based on prior preparation, all complete the major at the same level. Sample programs are available from the department's student services and faculty advisers for undergraduates, the Office of Student Affairs in the School of Engineering, and in the *Handbook for Undergraduate Engineering Programs,* available at http://ughb.stanford.edu/. It is recommended that students discuss their prospective programs with chemical engineering advisers, especially if transferring from biology, chemistry, physics, or another engineering major. With advanced planning, students can usually arrange to attend one of the overseas campuses.

For information about the requirements for a Chemical Engineering minor, see the "School of Engineering" section of this bulletin.

BACHELOR OF SCIENCE WITH HONORS

The Department of Chemical Engineering offers a program leading to a Bachelor of Science in Chemical Engineering with honors. Qualified undergraduate majors conduct independent study and research at an advanced level with a faculty mentor, graduate students, and fellow undergraduates. This three quarter sequential program involves research study in an area proposed to and agreed to by a Department of Chemical Engineering faculty adviser, completion of a faculty-approved thesis, and participation in the Chemical Engineering Honors Symposium held annually during Spring Quarter. The last requirement may also be fulfilled through an alternative, public, oral presentation with the approval of the department chair.

Admission to the honors program is by application. Declared Chemical Engineering students with a cumulative grade point average (GPA) of 3.5 or higher are eligible to submit an application. Students should submit their applications by Winter Quarter of their junior year; applications are not accepted later than the first week of Autumn Quarter of the senior year. An application includes a research proposal, sponsored by a research thesis adviser and a second faculty reader. The adviser, or alternatively a sponsor, must be a member of the Chemical Engineering faculty. Students should start honors research in their junior year and are encouraged to consider incorporating research opportunities such as those sponsored by Undergraduate Advising and Research (see http://urp.stanford.edu/StudentGrants/) into their three or four quarter honors research proposal. Subject to faculty approval, it is recommended that students include a writing course in the second quarter of their honors project. See departmental student services for a proposal template and other assistance.

In order to receive departmental honors, students admitted to the honors program must:

1. Maintain an overall grade point average (GPA) of at least 3.5 as calculated on the unofficial transcript.
2. Complete at least three quarters of research with a minimum total of 9 units of CHEMENG 190H for a letter grade. All quarters must focus on the same topic. The same faculty adviser and faculty reader should be maintained throughout if feasible.
3. Participate in the Chemical Engineering Honors Symposium held during Spring Quarter with a poster and oral presentation of thesis work or, at the faculty's discretion, in a comparable public event.
4. Submit a completed draft of thesis simultaneously to the adviser and reader and, if appropriate, to the Chemical Engineering faculty sponsor, no later than May 1, or the first day of the second month of the quarter in which the degree is to be conferred.
5. Complete all work and thesis revisions and obtain indicated faculty approvals on the Certificate of Final Reading of Thesis form by the end of the third week of May, or the second month of the graduation quarter.
6. Submit to Chemical Engineering student services four final copies of the honors thesis as approved by the appropriate faculty and with a certificate form for each copy. The deadline is May 19, 2008, or the Monday at the beginning of the fourth week of the second month of the graduation quarter.

COTERMINAL BACHELOR'S AND MASTER'S DEGREES

Undergraduates with strong academic records may apply to study for a master's degree while completing their bachelor's degree(s). Further details are in the "Undergraduate Degrees" section of this bulletin. Interested students should discuss their educational goals with their faculty advisers and departmental student services.

For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

GRADUATE PROGRAMS

The University's requirements, including residency requirements, for the M.S., Engineer, and Ph.D. degrees are outlined in the "Graduate Degrees" section of this bulletin.

MASTER OF SCIENCE

An M.S. program comprising appropriate course work is available to accommodate students wishing to obtain further academic preparation, after receiving a B.S. degree, before pursuing a professional chemical engineering career. This degree is not a prerequisite for nor does it lead directly into the department's Ph.D. program. For conferral of an M.S. degree, a formal thesis is not required, but the following departmental requirements must be met.

Unit and Course Requirements—For students terminating their graduate work with the M.S. degree in Chemical Engineering, a graduate-level, thematic program consisting of a minimum of 45 units of academic work is required, including (1) four Chemical Engineering lecture courses selected from the 300 series; (2) 3 units of 699 Colloquia; (3) an additional 30 units, selected from graduate-level science or engineering lecture courses in any department and, by petition to the Chair of the Department of Chemical Engineering, from upper-division undergraduate lecture courses in science and engineering. Alternatively, for terminal M.S. degree students, up to 6 units of research may be used in lieu of up to 6 units of the additional 30 lecture units to partially satisfy the 45-unit minimum requirement. Another option for terminal M.S. students is an up-to-six-units combination of research units and no more than 3 units of 459 or other 1- or 2-unit graduate seminar courses in other departments, used in lieu of up to 6 units of the required additional 30 lecture units. Credit toward the M.S. degree is not given for Chemical Engineering special topics courses numbered in the 500 series nor for similar courses in other departments.

To ensure that an appropriate Chemical Engineering graduate program is pursued by all M.S. candidates, students who first matriculate at Stanford at the graduate level must (a) submit during the first quarter, no later than the ninth week, an adviser-approved Program Proposal for a Master's Degree form to departmental student services for review by the department chair, and (b) obtain approval from the M.S. adviser and the department chair for any subsequent program change or changes. Stanford undergraduates admitted to the coterminal master's program must (a) submit an adviser-approved Program Proposal for a Master's Degree (a graduate degree progress form) either during their first quarter of graduate standing or upon the completion of 15 units of graduate work (whichever occurs first), and (b) document with student services their M.S. adviser's review and approval of their graduate program when they have accrued 30 units toward the degree in Chemical Engineering. All M.S. programs must be reviewed and given final approval by the Chemical Engineering M.S. adviser and the department chair no later than the quarter before the quarter of M.S. degree conferral, in order to permit amendment of the final quarter's study list if the faculty deem this necessary. Students with questions should contact student services.

Minimum Grade Requirement—Any course used to satisfy the 45-unit minimum for the M.S. degree must be taken for a letter grade, if offered. An overall grade point average (GPA) of 3.0 must be maintained for these courses.

Research Experience—Students in the M.S. program wishing to obtain research experience should work with the M.S. adviser on the choice of research adviser in advance of the quarter(s) of research, and, upon approval, then enroll in the appropriate section of CHEMENG 600. A written report describing the results of the research undertaken must be submitted to and approved by the research adviser. CHEMENG 600 may not be taken in lieu of any of the required four 300-level lecture courses.

ENGINEER

The degree of Engineer is awarded after completion of a minimum of 90 units of graduate work beyond the B.S. degree and satisfactory completion of all University requirements plus the following departmental requirements. (This degree is not required to enter the Ph.D. program.)

Unit and Course Requirements—A minimum of 90 total units (including research) within which 45 units of lecture course work is required for the Engineer degree, including (1) 300, 310A, 340, 345, 355 and (2) 3 units of 699. The remaining lecture courses, to total at least 45 units, may be chosen from the basic sciences and engineering according to the guidelines given in the Master of Science section and with the consent of the graduate adviser and the department chair. An aggregate of 6 units maximum of the required 45-unit minimum of course work may include such courses as 459 and 699. Students seeking the Engineer degree may apply for the M.S. degree once the requirements for that degree have been fulfilled (see General Requirements in the "Graduate Degrees" section of this bulletin and Chemical Engineering's "Master of Science" section above).

Minimum Grade Requirement—Any course intended to satisfy the degree requirements must be taken for a letter grade, if offered. An overall grade point average (GPA) of 3.0 must be maintained for these courses.

Reading Committee Requirement—All candidates are required to have an initial meeting with their reading committees consisting of two members of the Chemical Engineering faculty, by the end of their seventh quarter. Following this initial meeting, additional committee meetings must occur no less than once a year until all the requirements for the degree are satisfied. Students are encouraged to hold meetings on a more frequent basis to help focus and guide the thesis project. It is each student's responsibility to schedule meetings and to inform student services of meeting dates.

Thesis Requirement—The thesis must represent a substantial piece of research equivalent to nine months of full-time effort and must be approved by the reading committee.

Qualification for the Ph.D. Program by Students Ready to Receive the Degree of Engineer—After completing the requirements for the Engineer degree, a student may request to be examined on the Engineer research work for the purpose of qualifying for the Ph.D. degree. If the request is granted, the student's thesis must have been approved by the reading committee and be available in its final form for inspection by the entire faculty at least two weeks prior to the scheduled date of the examination.

DOCTOR OF PHILOSOPHY

The Ph.D. degree is awarded after the completion of a minimum of 135 units of graduate work as well as satisfactory completion of any additional University requirements and the following departmental requirements. Completion of an M.S. degree is not a prerequisite for beginning, pursuing, or completing doctoral work.

Unit and Course Requirements—A minimum of 135 completed units, including a minimum of 45 units of lecture course work, is required for the Ph.D. degree. The following courses are required: 300, 310A, 340, 345, and 355, plus two courses in the 440, 450, or 460 series. These must be taken at Stanford, and any petition to substitute another graduate-level course for any of these core courses must be approved by the chair. The remaining lecture courses may be chosen from graduate-level science and engineering lecture courses in any department and, by petition to the chair, from upper-division undergraduate lecture courses in the sciences and engineering. 3 units of 699 may be included in the required 45 units of lecture courses. Additionally, 1, 2, or 3 units of seminar courses such as 459 may be substituted for up to 3 units of the lecture course work requirement, but not for any of the specified CHEMENG courses above. All proposals for Ph.D. course work must be approved by the student's adviser and the department chair. Students admitted to Ph.D. candidacy should enroll each quarter in the 500 series, 600, and 699 as appropriate and as study list unit limits permit. Predoctoral students have the option of petitioning for a M.S. degree program to be added to their graduate record. When the petition is approved, students may apply for M.S. degree conferral once the requirements for that degree have been fulfilled (see the "Master of Science" section above). The M.S. degree must be awarded within the University's time limit for completion of a master's degree.

Minimum Grade Requirement—Any course intended to satisfy the Ph.D. degree requirements must be taken for a letter grade, if offered. An overall grade point average (GPA) of 3.0 must be maintained for these courses.

Qualifying Examination—To be advanced to candidacy for the Ph.D. degree, the student must pass both parts of the qualifying examination. The first part is held at the beginning of Spring Quarter, or the third quarter of study, and the first-year student is asked to make an oral presentation to the faculty of a critical review of a published paper. This preliminary examination, in addition to performance in courses and during research rotations, is the basis for determining whether or not a first-year student may be allowed to choose a research adviser and to begin doctoral research work immediately. Failure in this first part of the qualifying examination leads to termination of a student's study towards the Ph.D. degree; however, the student may continue to work toward an M.S. degree (see "Master of Science" section above). It also precludes any financial aid beyond that already awarded. Students who pass the preliminary examination take the second part of the qualifying examination at the beginning of their second year, or the fifth quarter. This second examination before the faculty is an oral presentation and defense of their current research work. Students who pass both examinations must promptly submit Application for Candidacy for Doctoral Degree forms approved by their research advisers and at the same time establish and meet with their doctoral dissertation reading committees.

Reading Committee Requirement—All Ph.D. candidates are required to assemble reading committees and to have an initial committee meeting by the end of their seventh quarter. Reading committee meetings are not examinations; they are intended to be discussion sessions, to help focus and guide the dissertation project. Following the initial committee meeting, additional meetings must take place no less than once per year until all the requirements for the Ph.D. degree are satisfied. The department encourages students to take advantage of the benefits of more frequent meetings with their entire reading committee as a group. It is the student's responsibility to schedule committee meetings and to report the meeting dates to the student services manager.

Teaching Requirement—Teaching experience is considered an essential component of doctoral training. All Ph.D. candidates, regardless of the source of their financial support, are required to assist in the teaching of a minimum of two chemical engineering courses.

Dissertation and Oral Defense Requirements—A dissertation based on a successful investigation of a fundamental problem in chemical engineering is required. Within approximately five calendar years after enrolling in the department, students are expected to have fulfilled all the requirements for this degree, including the completion of dissertations approved by their research advisers. Upon adviser approval, copies of the final draft of a dissertation must be distributed to each reading committee member. No sooner than three weeks after this distribution, students may schedule University oral examinations. The examination is a dissertation defense, based on the candidate's dissertation research, and is in the form of a public seminar followed by a private examination by the faculty on the student's oral examination committee. Satisfactory performance in the oral examination and acceptance of an approved dissertation by Graduate Degree Progress, Office of the University Registrar, leads to Ph.D. degree conferral.

PH.D. MINOR

A Ph.D. minor is a program outside a student's Ph.D. department. The University's general requirements for the Ph.D. minor are specified in the "Graduate Degrees" section of this bulletin. An application for a Ph.D. minor must be approved by both the major and minor departments.

A student desiring a Ph.D. minor in Chemical Engineering must have a minor program adviser who is a regular Chemical Engineering faculty member. At a minimum, this adviser must be a member of the student's reading committee for the doctoral dissertation, and the entire reading committee must meet at least once and at least one year prior to the scheduling of the student's oral examination. The department strongly prefers that regular reading committee meetings start in the second year of graduate study. In addition, the minor adviser must be a member of the student's University oral examination committee.

The Ph.D. minor program must include at least 20 units of graduate-level lecture courses (that is, courses numbered at the 200 level or above), but may not include in the 20-unit minimum any 1-2 unit courses in Chemical Engineering. The list of courses must form a coherent program and must be approved by the minor program adviser and the chair of the department. All courses for the minor must be taken for a letter grade, and a GPA of at least 3.0 earned for these courses.

RESEARCH ACTIVITIES

Research investigations are currently being carried out in the following fields: applied statistical mechanics, biocatalysis, bioengineering, colloid science, computational materials science, electronic materials, hydrodynamic stability, kinetics and catalysis, Newtonian and non-Newtonian fluid mechanics, polymer science, rheo-optics of polymeric systems, and surface and interface science. Additional information may be found at http://cheme.stanford.edu.

FELLOWSHIPS AND ASSISTANTSHIPS

Fellowships are awarded each year, primarily to Ph.D. students. Fellowships for incoming students are awarded in the spring prior to matriculation at the beginning of the following academic year. Current students are encouraged to apply for external, competitive fellowships and may obtain information about various awarding agencies from faculty advisers and student services.

Assistantships are paid positions for graduate students that, in addition to a salary, provide the benefit of a tuition allocation. Individual faculty appoint students to research assistantships; the department chair appoints doctoral students to teaching assistantships. Contact student services for further information.

FURTHER INFORMATION

More information about the department can be found at http://chemeng.stanford.edu. Current Stanford students interested in pursuing advanced work in Chemical Engineering are encouraged to contact student services; admission is by approval of an internal petition. All other students should go to http://gradadmissions.stanford.edu/ for additional guidelines regarding application requirements and processes.

GRADUATE COURSES IN BIOLOGICAL INTERDISCIPLINARY SCIENCES AND ENGINEERING

The Department of Chemical Engineering offers opportunities for students to pursue course work in interdisciplinary biosciences which include the chemical, physical, mathematical, and engineering sciences. These include CHEMENG 281 (formerly 288), 283 (formerly 289), 355, 450, and 454. In addition, students seeking a broad introduction to current topics in the interdisciplinary biosciences and engineering should consider CHEMENG 459, Frontiers in Interdisciplinary Biosciences, which covers emerging technologies and other subject matter at the intersection of engineering and biology ranging from molecular to complex systems; see http://biox.stanford.edu. Students are encouraged to review course offerings in all departments of the School of Engineering.

COURSES

WIM indicates that the course satisfies the Writing in the Major requirements. (AU) indicates that the course is subject to the University Activity Unit limitations for undergraduates (8 units maximum).

PRIMARILY FOR UNDERGRADUATES

CHEMENG 10. The Chemical Engineering Profession—Open to all undergraduates. Professionals present career paths and post-graduation opportunities open to Chemical Engineering graduates. Possible topics: preparing for graduate school (M.S. and Ph.D. in law, business, medicine, and other engineering fields); and opportunities in areas such as energy technologies, electronics production, soft and hard materials, and biotechnology.

1 unit, Aut (Swartz, J; Wang, C; Jaramillo, T)

SCHOOL OF ENGINEERING

CHEMENG 20. Introduction to Chemical Engineering—(Same as ENGR 20.) 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, production of chemicals, materials processing, and purification. Prerequisite: CHEM 31. GER:DB-EngrAppSci

3 units, Spr (Robertson, C)

CHEMENG 25. Biotechnology—(Same as ENGR 25.) Interplay among biology, technology, and society. Topics include biological fundamentals, genetic engineering, protein production, pharmaceuticals, antibodies, plant biotechnology, vaccines, transgenic animals, and stem cells. The role of intellectual property, business, government regulations, and ethics in biotechnology. GER:DB-EngrAppSci

3 units, Spr (Wang, C)

CHEMENG 60Q. Environmental Regulation and Policy—Stanford Introductory Seminar. Preference to sophomores. How environmental policy is formulated in the U.S. How and what type of scientific research is incorporated into decisions. How to determine acceptable risk, the public's right to know of chemical hazards, waste disposal and clean manufacturing, brownfield redevelopment, and new source review regulations. The proper use of science and engineering including media presentation and misrepresentation, public scientific and technical literacy, and emotional reactions. Alternative models to formulation of environmental policy. Political and economic forces, and stakeholder discussions. GER:DB-EngrAppSci

3 units, Aut (Robertson, C; Libicki, S)

CHEMENG 70Q. Masters of Disaster—Stanford Introductory Seminar. 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. GER:DB-EngrAppSci

3 units, Aut (Robertson, C; Moalli, J)

CHEMENG 80Q. Art, Chemistry, and Madness: The Science of Art Materials—Stanford Introductory Seminar. 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 topics include stretching canvas, applying gesso grounds, grinding pigments, preparing egg tempera paint, bamboo and quill pens, gilding and illumination, and papermaking. GER:DB-EngrAppSci

3 units, Spr (Frank, C; Loesch-Frank, S)

CHEMENG 100. Chemical Process Modeling, Dynamics, and Control—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.

3 units, Aut (Hwang, L)

CHEMENG 110. Equilibrium Thermodynamics—Thermodynamic properties, equations of state, properties of non-ideal systems including mixtures, and phase and chemical equilibria. Prerequisite: CHEM 171 or equivalent.

3 units, Win (Bao, Z)

CHEMENG 120A. Fluid Mechanics—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; 100 and CME 102 or equivalent.

4 units, Win (Fuller, G)

CHEMENG 120B. Energy and Mass Transport—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 120A or consent of instructor.

4 units, Spr (Spakowitz, A)

CHEMENG 130. Separation Processes—Analysis and design of equilibrium and non-equilibrium separation processes. Possible examples: distillation, liquid-liquid extraction, flash distillation, electrophoresis, centrifugation, membrane separations, chromatography, and reaction-assisted separation processes.

3 units, Spr (Jaramillo, T)

CHEMENG 140. Microelectronics Processing Technology—(Same as 240.) The chemistry and transport of microelectronics device fabrication. Introduction to solid state materials and electronic devices. Chemical processes including crystal growth, chemical vapor deposition, etching, oxidation, doping, diffusion, metallization, and plasma processing with emphasis on chemical, kinetic, and transport considerations. Recommended: CHEM 33, 171, and PHYSICS 55.

3 units, Spr (Bao, Z)

CHEMENG 150. Biochemical Engineering—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.

3 units, Aut (Swartz, J)

CHEMENG 160. Polymer Science and Engineering—(Same as 260.) 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. Recommended: CHEM 33 and 171, or equivalent.

3 units, Win (Hwang, L)

CHEMENG 170. Kinetics and Reactor Design—Chemical kinetics, elementary reactions, mechanisms, rate-limiting steps, and quasi-steady state approximations. Ideal isothermal and non-isothermal reactors; design principles. Steady state and unsteady state operation of reactors; conversion and limitations of thermodynamic equilibrium. Enzymes and heterogeneous catalysis and catalytic reaction mechanisms. Prerequisites: 110, 120A, 120B.

3 units, Aut (Bent, S)

CHEMENG 174. Environmental Microbiology I—(Same as 274, CEE 274A) 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, 35, and BIOSCI 41, CHEMENG 181 (formerly 188), or equivalents.

3 units, Aut (Spormann, A), Sum (Sepulveda-Torres, L)

CHEMENG 180. Chemical Engineering Plant Design—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.

3 units, Spr (Pavone, A)

CHEMENG 181. Biochemistry I—(Same as 281, BIOSCI 188/288, CHEM 181. CHEM and CHEMENG offerings formerly listed as 188/288.) Chemistry of major families of biomolecules including proteins, nucleic acids, carbohydrates, lipids, and cofactors. Structural and mechanistic analysis of properties of proteins including molecular recognition, catalysis, signal transduction, membrane transport, and harvesting of energy from light. Molecular evolution. Pre- or corequisites: CHEM 131; and CHEM 135 or 171. GER: DB-NatSci

3 units, Aut (Staff)

CHEMENG 183. Biochemistry II—(Same as 283, BIOSCI 189/289, CHEM 183. CHEM and CHEMENG offerings formerly listed as 189/289.) Metabolism. Glycolysis, gluconeogenesis, citric acid cycle, oxidative phosphorylation, pentose phosphate pathway, glycogen metabolism, fatty acid metabolism, protein degradation and amino acid catabolism, protein translation and amino acid biosynthesis, nucleotide biosynthesis, DNA replication, recombination and repair, lipid and steroid biosynthesis. Medical consequences of impaired metabolism. Therapeutic intervention of metabolism. Prerequisite: BIOSCI 188/288 or CHEM 181 or CHEMENG 181/281 (formerly 188/288). GER: DB-NatSci

3 units, Win (Khosla, C)

CHEMENG 185A. Chemical Engineering Laboratory A—Experimental aspects of chemical engineering science emphasizing development of communication skills. Experiments illustrating lecture subjects conducted by student groups. Prerequisites: 120A,B. Corequisite: 170. WIM

4 units, Aut (Frank, C; Hwang, L)

CHEMENG 185B. Chemical Engineering Laboratory B—Methods and techniques of biochemical engineering. Emphasis is on team organization, communication skills, experimental design, and project execution. Presentations, experiments, and demonstrations of biotechnology designed for high school students. Prerequisite: BIOSCI 41, CHEMENG 181 (formerly 188), or equivalent.

4 units, Win (Wang, C; Hwang, L)

CHEMENG 190. Undergraduate Research in Chemical Engineering—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.

1-6 units, Aut, Win, Spr, Sum (Staff)

CHEMENG 190H. Undergraduate Honors Research in Chemical Engineering—For department approved Chemical Engineering B.S. with honors majors who have obtained faculty approval for a research proposal. Research for at least 3 quarters, concluding thesis, and oral presentation of work. May be repeated for credit.

2-5 units, Aut, Win, Spr, Sum (Staff)

PRIMARILY FOR GRADUATE STUDENTS

CHEMENG 240. Microelectronics Processing Technology—(Same as 140; see 140.)

3 units, Spr (Bao, Z)

CHEMENG 260. Polymer Science and Engineering—(Same as 160; see 160.)

3 units, Win (Hwang, L)

CHEMENG 274. Environmental Microbiology I—(Same as 174, CEE 274A; see 174.)

3 units, Aut (Spormann, A), Sum (Sepulveda-Torres, L)

CHEMENG 281. Biochemistry I—(Same as 181, BIOSCI 188/288, CHEM 181; see 181.)

3 units, Aut (Staff)

CHEMENG 283. Biochemistry II—(Same as 183, BIOSCI 189/289, CHEM 183; see 183.)

3 units, Win (Khosla, C)

CHEMENG 300. Applied Mathematics in the Chemical and Biological Sciences—(Same as CME 330.) 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.

3 units, Aut (Shaqfeh, E)

CHEMENG 310. Microscale Transport in Chemical Engineering—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.

3 units, Win (Fuller, G)

CHEMENG 340. Molecular Thermodynamics—Statistical mechanics; ensembles, partition functions, and distribution functions. Applications to imperfect gases, liquid theory, and defects and heat capacity of solids; statistical mechanics of phase equilibria, and phase diagrams; and the Ising model, intermolecular forces and molecular simulation.

3 units, Aut (Spakowitz, A)

CHEMENG 345. Fundamentals and Applications of Spectroscopy—Development of theoretical approaches to spectroscopy, including spectroscopic transitions, transition probabilities, and selection rules. Application to photon and electron spectroscopies of the gas and solid phases. Topics: rotational spectroscopy; infrared and Raman vibrational spectroscopies; fluorescence spectroscopy; Auger, x-ray and ultraviolet photoelectron spectroscopies. Prerequisite: CHEM 271 or course in quantum mechanics.

3 units, Win (Jaramillo, T)

CHEMENG 355. Advanced Biochemical Engineering—(Same as BIOE 355.) 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.

3 units, Spr (Swartz, J)

CHEMENG 442. Structure and Reactivity of Solid Surfaces—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.

3 units, Spr (Bent, S), not given next year

CHEMENG 444. Quantum Simulations of Molecules and Materials—Quantum atomistic simulations to predict atomic structure, properties, reaction mechanisms, and kinetics. Review of quantum mechanics. Quantum chemical theory and electronic structure methods including Hartree Fock, configuration interaction, many body perturbation theory, and density functional theory. Property calculations: energy, forces, structure, and electronic and vibrational spectra. Student designed simulation projects involve applications to semiconductor processing, surface science, biochemistry, catalysis, polymers, environmental chemistry, and combustion. Prerequisite: quantum mechanics.

3 units, Aut (Musgrave, C)

CHEMENG 450. Advances in Biotechnology—Guest academic and industrial speakers. Latest developments in fields such as bioenergy, green process technology, production of industrial chemicals from renewable resources, protein pharmaceutical production, industrial enzyme production, stem cell applications, medical diagnostics, and medical imaging. Biotechnology ethics, business and patenting issues, and entrepreneurship in biotechnology. Prerequisite: BIOSCI 41 or CHEMENG 181 or equivalent.

3 units, Spr (Hwang, L: Swartz, J)

CHEMENG 454. Synthetic Biology and Metabolic Engineering—(Same as BIOE 454.) 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.

3 units, alternate years, not given this year (Swartz, J)

CHEMENG 456. Metabolic Biochemistry of Microorganisms—(Same as CEE 274B.) Microbial metabolism, biochemical and metabolic principles, unity and diversity of metabolic pathways, evolution of enzymes and metabolic pathways, microbial degradation of natural and anthropogenic organic compounds, predicting biodegradation, and metabolic origin of life.

3 units, Win (Spormann, A), alternate years, not given next year

CHEMENG 457. Microbial Ecology and Evolution—(Same as CEE 274C.) Structure/function relationship of microbial communities; metabolic and ecological basis of interactions in microbial communities; microbial ecology and population biology in natural and human host systems; and evolution of microbial life. Prerequisite: CEE 274A, CHEMENG 281 (formerly 288), or equivalent.

3 units, alternate years, not given this year (Spormann, A)

CHEMENG 459. Frontiers in Interdisciplinary Biosciences—(Same as BIOC 459, BIOE 459, BIOSCI 459, CHEM 459, PSYCH 459. Cross-listed in departments in the schools of H&S, Engineering, and Medicine; 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://www.stanford.edu/group/biox/courses/459.html. Recommended: basic mathematics, biology, chemistry, and physics.

1 unit, Aut, Win, Spr (Robertson, C)

CHEMENG 460. Polymer Surfaces and Interfaces—Principles of interfacial thermodynamics and polymer physics applied to polymer surfaces and interfaces. Treatments of intermolecular forces; conformational statistics of macromolecular structure; models for polymer dynamics; tethering of polymers at different interfaces; techniques for chemical modification of surfaces; methods for physical characterization of polymer surfaces and interfaces. Applications in adhesion and biocompatibility. Prerequisite: exposure to principles of polymer science or consent of instructor.

3 units, alternate years, not given this year

CHEMENG 461. Polymeric Materials in Medical Devices—Integrated approach to polymer synthesis, characterization, and processing for polymer properties of technological benefit in biomedical devices. Classes of materials include ultra high molecular weight polyethylene, silicone elastomers, block copolymer segmented polyurethanes, highly orientated nylon fibers, hydrogels, and biodegradable polymers. Applications include prosthetic orthopedic devices, ophthalmic devices, sutures, and drug delivery systems.

3 units, Win (Frank, C)

CHEMENG 464. Polymer Chemistry—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.

3 units, Aut (Bao, Z), not given next year

CHEMENG 466. Polymer Physics—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.

3 units, alternate years, not given this year

CHEMENG 468. Advanced Transport Topics in Complex Fluids and Biological Systems—Topics include: the theory of Brownian motion; slender body theory in Stokes flows; advection-dispersion theory and generalized Taylor dispersion; the molecular basis for complex fluid rheology; hindered diffusion and flow in porous media; heat and mass transfer in laminar boundary layers with reactions, adsorption, and desorption; drop deformation and breakup; and the hydrodynamic stability of laminar multiphase flows. Prerequisite: 310 or equivalent, or consent of instructor.

3 units, not given this year

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

1 unit, Aut, Win, Spr, Sum (Swartz, J)

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

1 unit, Aut, Win, Spr, Sum (Bent, S)

CHEMENG 502. Special Topics in Computational Materials Science—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

1 unit, Aut, Win, Spr, Sum (Musgrave, C)

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

1 unit, Aut, Win, Spr, Sum (Khosla, C)

CHEMENG 504. Special Topics in Bioengineering—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.

1 unit, Aut, Win, Spr, Sum (Robertson, C)

CHEMENG 505. Special Topics in Microrheology—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Fuller, G)

CHEMENG 507. Special Topics in Polymer Physics and Molecular Assemblies—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Frank, C)

CHEMENG 510. Special Topics in Transport Mechanics—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Shaqfeh, E)

CHEMENG 513. Special Topics in Functional Organic Materials for Electronic and Optical Devices—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Bao, Z)

CHEMENG 514. Special Topics in Biopolymer Physics—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Spakowitz, A)

CHEMENG 515. Special Topics in Molecular and Systems Biology—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Wang, C)

CHEMENG 516. Special Topics in Energy and Catalysis—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Jaramillo, T)

CHEMENG 517. Special Topics in Microbial Physiology and Metabolism—Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Spormann, A)

CHEMENG 600. Graduate Research in Chemical Engineering—Laboratory and theoretical work leading to partial fulfillment of requirements for an advanced degree.
1-12 units, Aut, Win, Spr, Sum (Staff)

CHEMENG 699. Colloquium—Weekly lectures by experts from academia and industry in the field of chemical engineering.
1 unit, Aut, Win, Spr (Spakowitz, A)

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