SCHOOL OF ENGINEERING

CHEMICAL ENGINEERING

Emeriti: (Professors) Andreas Acrivos, Michel Boudart, George M. Homsy, Robert J. Madix
Chair: Chaitan Khosla
Professors: Stacey F. Bent, Curtis W. Frank, Gerald G. Fuller, Chaitan Khosla, Channing R. Robertson, Eric S. G. Shaqfeh, Alfred M. Spormann, James R. Swartz
Associate Professor: Zhenan Bao
Assistant Professors: Alexander R. Dunn, Thomas F. Jaramillo, Andrew J. Spakowitz, Clifford L. Wang
Courtesy Professors: Annelise E. Barron, Gordon E. Brown, Christopher E. D. Chidsey, Daniel Herschlag, Jeffrey R. Koseff, Franklin M. Orr, Jr., Robert M. Waymouth
Lecturers: Lisa Y. Hwang, Shari B. Libicki, Sara Loesch-Frank, John E. Moalli, Anthony Pavone
Consulting Professors: Douglas C. Cameron, Jae Chun Hyun, Kay Kanazawa, Wolfgang Knoll, Jaan Noolandi, Conrad Schadt, Do Yeung Yoon
Visiting Professors: Joon-Seop Kim, Subhash Risbud

Administrative Office: Stauffer III, Room 113
Student Services Office: Keck Science Building, Room 189
Mail Code: 94305-5025
Student Services Phone: (650) 723-1302
Web Site: http://cheme.stanford.edu

Courses offered by the Department of Chemical Engineering are listed under the subject code CHEMENG on the *Stanford Bulletin's* ExploreCourses web site.

Chemical engineers are responsible for the conception and design of processes involved in the production, transformation, and transport of materials and sources of energy. 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, materials, and energy. 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 and energy.

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

The Department of Chemical Engineering offers opportunities for both undergraduates and graduate students to pursue course work in interdisciplinary biosciences, which include the chemical, biological, physical, mathematical, and engineering sciences. Courses include CHEMENG 181/281, 183/283, 355, 450, 454, 456, 457, and 458. 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.

Further information about the department may be found at http://cheme.stanford.edu. Undergraduates considering majoring in Chemical Engineering are encouraged to talk with faculty and meet with staff in the departmental student services office. Students interested in pursuing advanced work in chemical engineering, including coterminal degrees, should contact the department as well. Admission to graduate programs for active Stanford students is by approval of an internal petition. All other students should go to http://gradadmissions.stanford.edu for general and departmental information about the requirements and processes for applying for admission to a graduate degree program.

UNDERGRADUATE PROGRAMS IN CHEMICAL ENGINEERING

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 IN CHEMICAL ENGINEERING

Chemical engineers design and implement the processes and technology needed to produce, to transform, and to transport energy and materials. This activity begins with experimentation in the laboratory and is followed by implementation of the technology to full scale production. The mission of the Chemical Engineering Program is to develop students' understanding of the core scientific, mathematical, and engineering principles that serve as the foundation underlying these technological processes. The program's core mission is reflected in its curriculum, which is built on the foundations of chemistry, physics, and biology. Course work includes the study of applied mathematics, material and energy balances, thermodynamics, fluid mechanics, energy and mass transfer, separations technologies, chemical reaction kinetics and reactor design, and process design. The program provides students with excellent preparation for careers in the corporate sector or in government, as well as for future graduate study.

The Chemical Engineering B.S. program requires basic courses in biology, chemistry, engineering, mathematics, and physics. The depth sequence of courses required for the major in chemical engineering provides training in applied chemical kinetics, biochemical engineering, electronic materials, engineering thermodynamics, plant design, polymers, process analysis and control, separation processes, and transport phenomena. 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 to fulfill the requirements for the major (courses in mathematics; science; technology and society; engineering fundamentals; and engineering depth) must be taken for a letter grade if this option is offered.

There are several sample 4-year sequences of courses leading to a B.S. in Chemical Engineering. While each sequence starts at a different level, based on the student's 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 faculty advisers, especially if transferring from another major, e.g. biology, chemistry, physics, or another engineering major. With advance planning, students can usually arrange to attend one of the overseas campuses.

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

HONORS PROGRAM

The Department of Chemical Engineering offers a program leading to the degree of Bachelor of Science in Chemical Engineering with Honors. Qualified undergraduate majors conduct independent study and research at an advanced level with faculty mentors, graduate students, and fellow undergraduates. This three-quarter sequential program involves research study in an area proposed to and approved by a Department of Chemical Engineering faculty adviser; concurrent participation each quarter in the CHEMENG 191H seminar; 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. Work should begin at least four quarters prior to graduation.

Admission to the honors program is by application. Declared Chemical Engineering majors with a cumulative grade point average (GPA) of 3.5 or higher are encouraged to apply. Students should submit their applications by Winter Quarter of their junior year; applications must be submitted no later than the end of the first week of Autumn Quarter of the senior year. An application includes a research proposal, approved by both a research thesis adviser and a faculty reader. The faculty adviser or, alternatively, a faculty sponsor, must be a member of the Department of Chemical Engineering. Students should start their 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 honors research proposal. See departmental student services staff in Keck 189 for more information about the application process, a proposal template, and other assistance.

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

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 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. Enroll in CHEMENG 191H, Undergraduate Honors Seminar, concurrently with each quarter of CHEMENG 190H.
4. Participate with a poster and oral presentation of thesis work at the Chemical Engineering Honors Poster Session held during Spring Quarter or, at the faculty's discretion, at a comparable public event.
5. Submit final drafts of a thesis simultaneously to the adviser and reader and, if appropriate, to the Chemical Engineering faculty sponsor, no later than April 16th, or the end of the second week of the first month of the quarter in which the degree is to be conferred.
6. Complete all work and thesis revisions and obtain indicated faculty approvals on the Certificate of Final Reading of Thesis forms by the end of the first week of May, or the second month of the graduation quarter.
7. Submit five (5) final copies of the honors thesis, as approved by the appropriate faculty. Include in each, an original, completed faculty signature sheet immediately following the title page. The deadline is May 10, 2010, or the Monday at the beginning of the second week of the second month of the graduation quarter.
8. Submit one copy of the honors thesis in electronic format to student services by May 10, 2010, or at the same time as the final copies of the thesis.

GRADUATE PROGRAMS IN CHEMICAL ENGINEERING

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

Current research and teaching activities cover a number of advanced topics in chemical engineering, including applied statistical mechanics, biocatalysis, biochemical engineering, bioengineering, biophysics, computational materials science, colloid science, dynamics of complex fluids, energy conversion, functional genomics, hydrodynamic stability, kinetics and catalysis, microrheology, molecular assemblies, nanoscience and technology, Newtonian and non-Newtonian fluid mechanics, polymer physics, protein biotechnology, protein biotechnology, renewable fuels, semiconductor processing, soft materials science, solar utilization, surface and interface science, and transport mechanics.

Fellowships and Assistantships—Qualified applicants are encouraged to apply for predoctoral competitive fellowships, for example, those from the National Science Foundation. Applicants to the Ph.D. program should consult with their financial aid officers for information and applications. Matriculated Ph.D. students are primarily supported by fellowship awards and assistantship appointments. Assistantships are paid positions for graduate students that, in addition to a salary, provide the benefit of a tuition allocation. Individual faculty members appoint students to research assistantships; the department chair appoints doctoral students to teaching assistantships. Contact departmental student services for additional information. All students are encouraged to apply for external, competitive fellowships and may obtain information about various awarding agencies from faculty advisers and student services. In the absence of other awards, incoming Ph.D. students normally are awarded departmental fellowships.

COGNATE COURSES FOR ADVANCED DEGREES IN CHEMICAL ENGINEERING

In addition to core CHEMENG graduate courses in the 300 series and elective CHEMENG graduate courses in the 200 and 400 series, students pursuing advanced degrees in chemical engineering often consider including elective courses offered by other departments. The following list is a partial list of the more frequently chosen courses and is subdivided into five focus areas.

Broadly Applicable—

APPPHYS 207. Laboratory Electronics (3 units)
CHEM 221. Advanced Organic Chemistry (3 units)
CHEM 271. Advanced Physical Chemistry (Quantum Mechanics) (3 units)
CHEM 273. Advanced Physical Chemistry (Angular Momentum, etc.) (3 units)
EE 261. The Fourier Transform and its Applications (3 units)
EE 268. Introduction to Modern Optics (3 units)
MS&E 234. Organizations and Information Systems (4 units)
STATS 200. Statistical Inference (3 units)

Biochemistry and Bioengineering focus, e.g. with CHEMENG 281, 283, 454, 456—

BIO 203. Advanced Genetics (human)
BIO 217. Neuronal Biophysics (4 units)
BIOC 133. Genetics of Prokaryotes (3 units; needs approval of chair)
BIOE 331. Protein Engineering (3 units)
BIOPHYS/SBIO 228. Computational Structural Biology (3 units)
BIOPHYS/SBIO 241. Biologic Macromolecules (3-5 units)
CBIO 241. Molecular, Cellular, and Genetics Basis of Cancer (3 units)
CEE 274. Environmental Microbiology I & II (3 units each)
MCP 256. How Cells Work: Energetics, Compartments, and Coupling in Cell Biology (4 units)
MPHA 210. Signal Transduction Pathways and Networks (4 units)
MPHA 240. Drug Discovery (4 units)
MPHA 260. Quantitative Chemical Biology (4 units)
SBIO 228. Computational Structural Biology (3 units)
SBIO 241. Biological Macromolecules (3-5 units)

Fluid Mechanics, Applied Mathematics, and Numerical Analysis focus, e.g. with CHEMENG 462—

AA 218. Introduction to Symmetry Analysis (3 units)

CME 200. Linear Algebra with Application to Engineering Computations (3 units)
CME 204. Partial Differential Equations in Engineering (3 units)
CME 206. Introduction to Numerical Methods for Engineering (3 units)
CME 212. Introduction to Large-Scale Computing in Engineering (3 units)
CME 332. Computational Methods for Scientific Reasoning and Discovery (3 units)
CME 340. Computational Methods in Data Mining (3 units)
ME 338A. Continuum Mechanics (3 units)
ME 351A. Fluid Mechanics (3 units)
ME 457. Fluid Flow in Microdevices (3 units)
ME 469A. Computational Methods in Fluid Mechanics (3 units)

Materials Science focus, e.g. with CHEMENG 260, 442, 460, 461, 464, 466—
MATSCI 210. Organic and Biomaterials (3 units)
MATSCI 251. Microstructure and Mechanical Properties (3 units)
MATSCI 316. Nanoscale Science, Engineering, and Technology (3 units)
MATSCI 343. Organic Semiconductors for Electronics and Photonics (3 units)
MATSCI 380. Molecular Biomaterials (3 units)

Microelectronics focus, e.g. with CHEMENG 240—
AA 218. Introduction to Symmetry Analysis (3 units)
CME 200. Linear Algebra with Application to Engineering Computation (3 units)
CME 204. Partial Differential Equations in Engineering (3 units)
CME 206. Introduction to Numerical Methods for Engineering (3 units)
CME 212. Introduction to Large-Scale Computing in Engineering (3 units)
CME 332. Computational Methods for Scientific Reasoning and Discovery (3 units)
CME 340. Computational Methods in Data Mining
ME 338A. Continuum Mechanics (3 units)
ME 351. Fluid Mechanics (3 units)
ME 457. Fluid Flow in Microdevices (3 units)
ME 469A. Computational Methods in Fluid Mechanics (3 units)

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). Interested students should discuss their educational goals with their faculty advisers before applying and should talk with departmental student services about the departmental requirements and deadlines for applications.

Further University-wide information is in the "Undergraduate Degrees" section of this bulletin. For the University's coterminal degree program rules and application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

MASTER OF SCIENCE IN CHEMICAL ENGINEERING

A range of M.S. programs comprising appropriate course work is available to accommodate students wishing to obtain further academic preparation after receiving a B.S. degree and before pursuing a professional chemical engineering career. This degree is a terminal M.S. degree. It 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 completed units of academic work is required, including (1) four Chemical Engineering lecture courses selected from the 300 series—not including 320 in 09-10; (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, 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 is an up-to-six-unit combination of research units and 1, 2, or 3 units of 459 or other similar 1- or 2-unit graduate seminar courses, with faculty developed curricula, 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 eighth week, a M.S. 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. Each M.S. candidate must obtain approvals for the final M.S. program no later than the eighth week of the quarter preceding the quarter of 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 as early as feasible and in advance of the anticipated quarter(s) of research. Once arrangements are mutually agreed upon, including the number of units, students 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 IN CHEMICAL ENGINEERING

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 a prerequisite for 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, 310, 340, 345, 355, (2) 320 may not be substituted in 09-10 for one of the five just listed, and (3) 3 units of 699. The remaining lecture courses, to total at least 45 completed 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 curriculum committee chair and the department chair. In fulfilling the required 45-unit requirement for lecture course units, an aggregate of 6 units maximum of the required 45-unit minimum of course work may include such courses as 459 and 699, but not 500 level seminar courses or research units. Students seeking the Engineer degree may petition to add a M.S. program and 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).

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 assist in the keeping of accurate degree progress records by informing student services when meetings have occurred.

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 student's 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 research work completed for that degree, for the purpose of qualifying for the Ph.D. degree. If the request is granted, the student's thesis must be approved by the reading committee and available in its final form for inspection by the entire faculty at least two weeks prior to the scheduled date of said examination.

DOCTOR OF PHILOSOPHY IN CHEMICAL ENGINEERING

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 a 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, 310, 340, 345, and 355, plus two courses in the 440, 450, or 460 series. These are to be taken at Stanford, and any petition to substitute another graduate-level course for any of these core courses must be approved by the department chair. The remaining lecture courses may be chosen from graduate-level science and engineering lecture courses in any department and, by petition to the department chair, from upper-division undergraduate lecture courses in the sciences and engineering. Three units of 699 must be completed and may be included in the required 45 units of lecture courses. Additionally, 1, 2, or 3 units of seminar courses with faculty developed curricula, e.g. 459, may be substituted for up to 3 units of the unspecified lecture courses, 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 or his designee. 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 may petition for a M.S. degree program to be added to their university record. When the petition is approved, students may apply in Axess for M.S. degree conferral once the requirements for that degree have been fulfilled (see the "Master of Science in Chemical Engineering" section in this bulletin). The M.S. degree must be awarded within the University's candidacy period 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 normally 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 the "Master of Science in Chemical Engineering" section of this bulletin). 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 parts of the qualifying examination must promptly submit to departmental student services 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 meeting with the full committee 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 full reading committee. It is the student's responsibility to schedule committee meetings and to assist in the maintenance of degree progress records by reporting 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 Ph.D. program, 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 their oral examinations. This 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 members 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 IN CHEMICAL ENGINEERING

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 meetings of the full reading committee start in the second year of graduate study or when the student is admitted to Ph.D. candidacy. In addition, the chemical engineering faculty member who is 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 (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.

CHEMICAL ENGINEERING (CHEMENG)

UNDERGRADUATE COURSES IN CHEMICAL ENGINEERING

CHEMENG 10. The Chemical Engineering Profession
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.
1 unit, Aut (Jaramillo, T)

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, energy, production of chemicals, materials processing, and purification. Prerequisite: CHEM 31. GER:DB-EngrAppSci
3 units, Spr (Hwang, L)

CHEMENG 25. Biotechnology
(Same as ENGR 25) Biology and chemistry fundamentals, genetic engineering, cell culture, protein production, pharmaceuticals, genomics, viruses, gene therapy, evolution, immunology, antibodies, vaccines, transgenic animals, cloning, stem cells, intellectual property, governmental regulations, and ethics. Prerequisites: CHEM 31 and MATH 41 or equivalent courage. GER:DB-EngrAppSci
3 units, Spr (Wang, C)

CHEMENG 35N. Renewable Energy for a Sustainable World
(F,Sem) Stanford Introductory Seminar. Preference to freshmen. An overall world energy assessment, projections, and technologies. How to assess good and bad potential impacts of leading renewable energy candidates: benefit versus impact ratio using quantitative cradle-to-grave approach. Technologies suitable for near-term application in developing economic systems. Governmental policies, governmental versus private sector investments, raw materials supply issues, and impact of cultural influences on technology choices and speed of implementation. GER:DB-EngrAppSci
3 units, Aut (Swartz, J)

CHEMENG 60Q. Environmental Regulation and Policy
(S,Sem) 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
(S,Sem) 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
(S,Sem) 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 laboratory includes 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 (Fuller, G)

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. Micro and Nanoscale Fabrication Engineering
(Same as CHEMENG 240) (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
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 (Hwang, L)

CHEMENG 160. Polymer Science and Engineering
(Same as CHEMENG 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 CHEMENG 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 (Krieger, C)

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 BIO 188, BIO 288, CHEMENG 281, CHEM 181) (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. Prerequisites: CHEM 135 or 171. GER: DB-NatSci
3 units, Win (Zare, R; Cegelski, L)

CHEMENG 183. Biochemistry II
(Same as BIO 189, BIO 289, CHEMENG 283, CHEM 183) 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. Prerequisite: BIO 188/288 or CHEM 181 or CHEMENG 181/281 (formerly 188/288). GER: DB-NatSci
3 units, Spr (Dunn, A)

CHEMENG 185A. Chemical Engineering Laboratory A
Experimental aspects of chemical engineering science. Emphasizes laboratory work and development of communication skills. Lab work in student groups. Student presentations. Prerequisites: 120A,B. Corequisite: 170.
4 units, Aut (Frank, C; Hwang, L)

CHEMENG 185B. Chemical Engineering Laboratory B
Methods and techniques in molecular biology and biochemical engineering. Emphasis is on team organization, communiction skills, experimental design, and project execution. Creation of presentations, experiments, and demonstrations for high school students. Additional laboratory times to be arranged. Prerequisite: BIO 41, CHEMENG 181, or equivalent.
4 units, Win (Wang, C)

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 (Staff), Win (Staff), Spr (Staff), 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.
1-5 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CHEMENG 191H. Undergraduate Honors Seminar
For Chemical Engineering majors approved for honors research. May be repeated for credit. Corequisite: 190H.
1 unit, Aut (Hwang, L), Win (Hwang, L), Spr (Hwang, L), Sum (Hwang, L)

GRADUATE COURSES IN CHEMICAL ENGINEERING

CHEMENG 240. Micro and Nanoscale Fabrication Engineering
(Same as CHEMENG 140) (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
3 units, Spr (Bao, Z)

CHEMENG 260. Polymer Science and Engineering
(Same as CHEMENG 160) 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 274. Environmental Microbiology I
(Same as CHEMENG 174, 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 (Krieger, C)

CHEMENG 281. Biochemistry I
(Same as BIO 188, BIO 288, CHEMENG 181, CHEM 181) (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. Prerequisites: CHEM 135 or 171.
3 units, Win (Zare, R; Cegelski, L)

CHEMENG 283. Biochemistry II
(Same as BIO 189, BIO 289, CHEMENG 183, CHEM 183) 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. Prerequisite: BIO 188/288 or CHEM 181 or CHEMENG 181/281 (formerly 188/288).
3 units, Spr (Dunn, A)

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.
3 units, not given this year

CHEMENG 310. Microhydrodynamics
(Same as ME 451D) 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, Aut (Shaqfeh, E)

CHEMENG 320. Chemical Kinetics and Reaction Engineering
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.
3 units, Aut (Dunn, A)

CHEMENG 340. Molecular Thermodynamics
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.
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 business and regulatory requirements. Prerequisite: CHEMENG 181 (formerly 188) or BIOSCI 41, or equivalent.
3 units, Win (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, Win (Bent, S)

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.
3 units, Spr (Swartz, J)

CHEMENG 451. Chemical Principles in Drug Discovery and Development
Application of physical and organic chemistry to the discovery and subsequent product development of small molecule and macromolecular drugs. Course discusses key physical, chemical, and biological properties of drug candidates and how to measure them, how to engineer them. Discussion of principles of drug formulation and delivery. Graduate-level background in physical and organic chemistry recommended.
3 units, Aut (Khosla, C)

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, Spr (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, not given this year

CHEMENG 458. Recent Advances in Genetic, Cellular, and Biomolecular Systems
Current topics, experimental methods, technologies, quantitative analysis, and mathematical models.
3 units, not given this year

CHEMENG 459. Frontiers in Interdisciplinary Biosciences
(Same as BIO 459, BIOC 459, BIOE 459, CHEM 459, PSYCH 459) 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.
1 unit, Aut (Robertson, C), Win (Robertson, C), Spr (Robertson,)

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
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, not given this year

CHEMENG 462. Complex Fluids and Non-Newtonian Flows
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.
3 units, not given this year

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)

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, not given this year

CHEMENG 467. Physics of Biomacromolecules
Advanced topics in the equilibrium and dynamic behavior of biomacromolecules. Theoretical approaches addressed include path integral approaches to polymer Green function theory, polymer field theory, application of Smoluchowski and fractional Fokker Planck equations to biopolymer transport, and Brownian dynamics and Monte Carlo simulations. These methods will be applied to topics such as DNA/protein semiflexibility, DNA supercoiling, lyotropic polymer ordering, anomalous diffusion in crowded environments, motor-protein transport, and protein dynamics. Prerequisites: CHEMENG 340 and 466 or consent of the instructor.
3 units, Win (Spakowitz, A)

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 (Swartz, J), Win (Swartz, J), Spr (Swartz, J), 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 (Bent, S), Win (Bent, S), Spr (Bent, S), Sum (Bent, S)

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 (Khosla, C), Win (Khosla, C), Spr (Khosla, C), 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 (Robertson, C), Win (Robertson, C), Spr (Robertson, C), 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 (Fuller, G), Win (Fuller, G), Spr (Fuller, G), 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 (Frank, C), Win (Frank, C), Spr (Frank, C), 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 (Shaqfeh, E), Win (Shaqfeh, E), Spr (Shaqfeh, E), 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 (Bao, Z), Win (Bao, Z), Spr (Bao, Z), 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 (Spakowitz, A), Win (Spakowitz, A), Spr (Spakowitz, A), 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 (Wang, C), Win (Wang, C), Spr (Wang, C), 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 (Jaramillo, T), Win (Jaramillo, T), Spr (Jaramillo, T), 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 (Spormann, A), Win (Spormann, A), Spr (Spormann, A), Sum (Spormann, A)

CHEMENG 518. Special Topics in Advanced Biophysics and Protein Design
Recent developments and current research. May be repeated for credit. Prerequisite: graduate standing and consent of instructor.
1 unit, Aut (Dunn, A), Win (Dunn, A), Spr (Dunn, A), Sum (Dunn, 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 (Staff), Win (Staff), Spr (Staff), Sum (Staff)

CHEMENG 699. Colloquium
Weekly lectures by experts from academia and industry in the field of chemical engineering.
1 unit, Aut (Wang, C), Win (Fuller, G), Spr (Bao, Z)