SCHOOL OF ENGINEERING

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Consulting Associate Professor: Randy Komisar
Consulting Assistant Professor: William Behrman, Vadim Khayms

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

The School of Engineering offers undergraduate programs leading to the degree of Bachelor of Science (B.S.), programs leading to both B.S. and Master of Science (M.S.) degrees, other programs leading to a B.S. with a Bachelor of Arts (B.A.) in a field of the humanities or social sciences, dual-degree programs with certain other colleges, and graduate curricula leading to the degrees of M.S., Engineer, and Ph.D.

The school has nine academic departments: Aeronautics and Astronautics, Bioengineering, Chemical Engineering, Civil and Environmental Engineering, Computer Science, Electrical Engineering, Management Science and Engineering, Material Science and Engineering, and Mechanical Engineering. These departments and one interdisciplinary program, Scientific Computing and Computational Mathematics, are responsible for graduate curricula, research activities, and the departmental components of the undergraduate curricula. In research where faculty interest and competence embrace both engineering and the supporting sciences, there are numerous programs within the school as well as several interschool activities, including the Alliance for Innovative Manufacturing at Stanford, Center for Integrated Systems, Center for Materials Research, Center on Polymer Interfaces and Macromolecular Assemblies, Center for Space Science and Astrophysics, Joint Institute for Aeronautics, the NIH Biotechnology Graduate Training Grant in Chemical Engineering, and a program in Product Design. Petroleum Engineering is offered through the School of Earth Sciences.

Instruction in engineering is offered primarily during the Autumn, Winter, and Spring quarters of the regular academic year. During the Summer Quarter, a small number of undergraduate and graduate courses are offered.

UNDERGRADUATE PROGRAMS

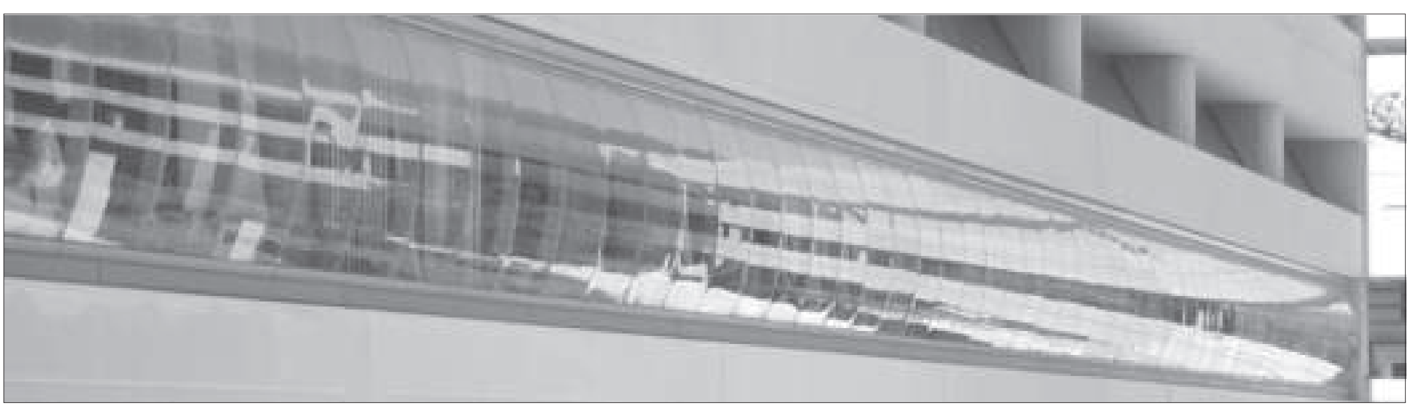
The principal goals of the undergraduate engineering curriculum are to provide opportunities for intellectual growth in the context of an engineering discipline, for the attainment of professional competence, and for the development of a sense of the social context of technology. The curriculum is flexible, with many decisions on individual courses left to the student and the adviser. For a student with well-defined educational goals, there is often a great deal of latitude.

In addition to the special requirements for engineering majors described below, all undergraduate engineering students are subject to the University general education, writing, and foreign language requirements outlined in the first pages of this bulletin. Depending on the program chosen, students have the equivalent of from one to three quarters of free electives to bring the total number of units to 180.

The School of Engineering's *Handbook for Undergraduate Engineering Programs* is available online at http://ughb.stanford.edu and provides detailed descriptions of all undergraduate programs in the school, as well as additional information about extracurricular programs and services. A hard copy version is also available from the Office of Student Affairs in Terman Engineering Center, room 201. Because it is published in the summer, and updates are made to the web site on a continuing basis, the handbook reflects the most up-to-date information for the academic year and is the definitive reference for all undergraduate engineering programs.

Accreditation—The Accreditation Board for Engineering and Technology (ABET) accredits college engineering programs nationwide using criteria and standards developed and accepted by U.S. engineering communities. At Stanford, the following undergraduate programs are accredited: Chemical Engineering, Civil Engineering, Environmental Engineering, Electrical Engineering, and Mechanical Engineering. In ABET-accredited programs, students must meet specific requirements for engineering science, engineering design, mathematics, and science course work. Students are urged to consult the School of Engineering undergraduate handbook and their adviser.

Accreditation is important in certain areas of the engineering profession; students wishing more information about accreditation should consult their department office or the office of the Senior Associate Dean for Student Affairs in Terman 201.



Policy on Satisfactory/No Credit Grading and Minimum Grade Point Average—All courses taken to satisfy major requirements (including the requirements for mathematics, science, engineering fundamentals, Technology in Society, and engineering depth) for all engineering students (including both department and School of Engineering majors) must be taken for a letter grade if the instructor offers that option.

For departmental majors, the minimum combined GPA (grade point average) for all courses taken in fulfillment of the Engineering Fundamentals requirement and the Engineering Depth requirement is 2.0. For School of Engineering majors, the minimum GPA on all engineering courses taken in fulfillment of the major requirements is 2.0.

ADMISSION

Students admitted to the University may declare a major in the School of Engineering if they elect to do so; no additional courses or examinations are required for admission to the school.

RECOMMENDED PREPARATION

FRESHMEN

Students who plan to enter Stanford as freshmen and intend to major in engineering should take the highest level of mathematics offered in high school. (See the "Mathematics" section of this bulletin for information on advanced placement in mathematics.) High school courses in physics and chemistry are strongly recommended, but not required. Additional elective course work in the humanities and social sciences is also recommended.

TRANSFER STUDENTS

Students who do the early part of their college work elsewhere and then transfer to Stanford to complete their engineering programs should follow an engineering or pre-engineering program at the first school, selecting insofar as possible courses applicable to the requirements of the School of Engineering, that is, courses comparable to those described below under "Undergraduate Programs." In addition, students should work toward completing the equivalent of Stanford's foreign language requirement and as many of the University's General Education Requirements (GERs) as possible before transferring. Some transfer students may require more than four years (in total) to obtain the B.S. degree. However, Stanford affords great flexibility in planning and scheduling individual programs, which makes it possible for transfer students, who have wide variations in preparation, to plan full programs for each quarter and to progress toward graduation without undue delay.

Transfer credit is given for courses taken elsewhere whenever the courses are equivalent or substantially similar to Stanford courses in scope and rigor. The policy of the School of Engineering is to study each transfer student's preparation and make a reasonable evaluation of the courses taken prior to transfer. Inquiries may be addressed to the Senior Associate Dean for Student Affairs and the Assistant Director for Undergraduate Studies in the School of Engineering at Stanford. For more information, see the transfer credit section of the *School of Engineering Undergraduate Handbook* web site at http://ughb.stanford.edu.

DEGREE PROGRAM OPTIONS

BACHELOR OF ARTS AND SCIENCE (B.A.S.)

This degree is available to students who complete both the requirements for a B.S. degree in engineering and the requirements for a major or program ordinarily leading to the B.A. degree. For more information, see the "Undergraduate Degrees" section of this bulletin.

DUAL AND COTERMINAL DEGREE PROGRAMS

A Stanford undergraduate may work simultaneously toward two bachelor's degrees or toward a bachelor's and a master's degree, that is, B.A. and M.S., B.A. and M.A., B.S. and M.S., or B.S. and M.A. The degrees may be granted simultaneously or at the conclusion of different quarters. Usually five years are needed for a combined program.

Dual B.A. and B.S. Degree Program—To qualify for both degrees, a student must (1) complete the stated University and department requirements for each degree, (2) complete 15 full-time quarters, or three full-time quarters after completing 180 units, and (3) complete a total of 225 units (180 units for the first bachelor's degree plus 45 units for the second bachelor's degree).

Coterminal Bachelor's and Master's Degree Program—A Stanford undergraduate may be admitted to graduate study for the purpose of working simultaneously toward a bachelor's degree and a master's degree, in the same or different disciplines. To qualify for both degrees, a student must (1) complete, in addition to the 180 units required for the bachelor's degree, the number of units required by the graduate department for the master's degree which in no event is fewer than the University minimum of 45 units, (2) complete the requirements for the bachelor's degree (department, school, and University) and apply for conferral of the degree at the appropriate time, and (3) complete the department and University requirements for the master's degree and apply for conferral of the degree at the appropriate time. A student may complete the bachelor's degree before completing the master's degree, or both degrees may be completed in the same quarter.

Admission to the coterminal program requires admission to graduate status by the pertinent department. Admission criteria vary from department to department.

Procedure for Applying for Admission to Coterminal Degree Programs—A Stanford undergraduate may apply to the pertinent graduate department using the University coterminal application form for admission to the coterminal master's degree program after completing 120 bachelor's degree units. Application deadlines vary by department, but in all cases the student must apply early enough to allow a departmental decision at least one quarter in advance of the anticipated date of conferral of the bachelor's degree.

Students should refer to the Registrar's Office or its web site for details about when courses may begin to count toward the master's degree requirements and when graduate tuition will be assessed; this may affect the decision about when to apply for admission to graduate status.

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

BACHELOR OF SCIENCE

Departments within the School of Engineering offer programs leading to the B.S. degree in the following fields: Chemical Engineering, Civil Engineering, Computer Science, Electrical Engineering, Environmental Engineering, Management Science and Engineering, Materials Science and Engineering, and Mechanical Engineering. The School of Engineering itself offers interdisciplinary programs leading to the B.S. degree in Engineering with specializations in Aeronautics and Astronautics, Computer Systems Engineering, and Product Design. In addition, students may elect a B.S. with an Individually Designed Major in Engineering.

Petroleum Engineering—Petroleum Engineering is offered by the School of Earth Sciences. Consult the "Petroleum Engineering" section of this bulletin for requirements.

School of Engineering majors who anticipate summer jobs or career positions associated with the oil industry may wish to consider enrolling in Engineering 120, Fundamentals of Petroleum Engineering.

Programs in Manufacturing—Programs in manufacturing are available at the undergraduate, M.S., and Ph.D. levels. The undergraduate programs of the departments of Civil and Environmental Engineering, Management Science and Engineering, and Mechanical Engineering provide general preparation for any student interested in manufacturing. More specific interests can be accommodated through Individually Designed Majors (IDMs).

SCHOOL OF ENGINEERING MAJORS

The School of Engineering offers the degree of Bachelor of Science in Engineering. School of Engineering programs must be approved by the Undergraduate Council of the school. There are two types of programs: majors that have been proposed by cognizant faculty groups and have been pre-approved by the council, and Individually Designed Majors. At present, there are five pre-approved majors: Aeronautics and Astronautics, Biomechanical, Biomedical Computation, Computer Systems Engineering, and Product Design.

AERONAUTICS AND ASTRONAUTICS (AA)

Mathematics (24 units):	
MATH 53, or CME 102 (formerly ENGR 155A)	5
MATH electives	(See Basic Requirement 1)
Science (18 units):	
PHYSICS 53. Mechanics	4
PHYSICS 55. Electricity and Magnetism	4
One further physics course	3
Science electives (see Basic Requirement 2)	9
Technology in Society (3-5 units):	
One course	(See Basic Requirement 4)
Engineering Fundamentals (three courses minimum, at least one of which must be unspecified by the department):	
ENGR 14. Statics	3
ENGR 30. Engineering Thermodynamics	3
ENGR 70A or 70X. Programming (recommended)	3-5
Engineering Depth (39 units):	
AA 100. Introduction to Aeronautics and Astronautics	3
AA 190. Directed Research in Aeronautics and Astronautics (WIM)	3
ENGR 15. Dynamics	3
CEE 101A. Mechanics of Materials	
or ME 80. Stress, Strain, and Strength	3-4
ME 161. Dynamic Systems	
or PHYSICS 110. Intermediate Mechanics	4
ME 70. Introductory Fluids Engineering	4
ME 131A. Heat Transfer	4
Depth Area I[1]	6
Depth Area II[1]	6
Engineering Electives[2]	3

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

1 Two of the following areas:
- Fluids (AA 200A, 210A, 214A, 280 or 283; ME 131B)
- Structures (AA 240A, 240B, 256)
- Dynamics and Controls (AA242A, 271A, 279; ENGR 105, 205)
- Systems Design (AA 241A, 241B, 236A, 236B)

2 Electives are to be approved by the adviser, and might be from the depth area lists, or courses such as AA 201A, 210B, 252; ENGR 206, 209A, 209B; or other upper-division Engineering courses.

BIOMECHANICAL (BME)

Mathematics (21 units minimum):	(See Basic Requirement 1)
Science (22 units minimum, should include 1 year of Chemistry or Physics (12 units) and 2 courses of HUMBIO core or Biocore (10 units), additional units from School of Engineering approved list):	
BIOSCI 44X. Biology Labs	4
BIOSCI/HUMBIO (Biocore/HUMBIO Core)	5
BIOSCI/HUMBIO (Biocore/HUMBIO Core)	5
Technology in Society (3-5 units):	
one course	(See Basic Requirement 4)
Additional courses as necessary (refer to ME Department)	
Engineering Topics (Engineering Science and Design):	
Engineering Fundamentals	
(three courses required, one from School of Engineering approved list)	
ENGR 14. Applied Mechanics: Statics	3
ENGR 25. Introduction to Biotechnology	3
Engineering Depth:	
ENGR 15. Dynamics	3
ENGR 30. Engineering Thermodynamics	3
ME 70. Introductory Fluids Engineering	4
ME 80. Stress, Strain, and Strength	3
ME 389. Bioengineering and Biodesign Forum	1
Options to complete the ME depth sequence	
(select 3 courses, minimum 9 units)	
ENGR 105. Feedback Control Design	3
ME 101.Visual Thinking	3
ME 103D. Engineering Drawing and Design	1
ME 112. Mechanical Systems Design	4
ME 113. Mechanical System Design	4
ME 131A. Heat Transfer	4
ME 131B. Fluid Mechanics: Compressible Flow and Turbomachinery	3
ME 140. Advanced Thermal Systems	4
ME 161. Dynamic Systems	4
ME 203. Manufacturing and Design	3-4
ME 210. Introduction to Mechatronics	4
ME 220. Introduction to Sensors	3-4
Options to complete the BME depth sequence	
(select 3 course, minimum 9 units):	
ME 281. Biomechanics of Movement	3-4
ME 284. Cardiovascular Bioengineering	3
ME 280. Skeleton Development & Evolution	3
ME 294. Medical Device Design	3

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

BIOMEDICAL COMPUTATION (BMC)

Mathematics (21 unit minimum):	(See Basic Requirement 1)
MATH 41. Calculus	5
MATH 42. Calculus	5
STATS 116. Theory of Probability[1]	5
CS 103. Discrete Structures (X, or A and B)	4-6
Science (17 units minimum):	(See Basic Requirement 2)
PHYSICS 53. Mechanics	4
CHEM 31. Chemical Principles	4
CHEM 33. Structure and Reactivity	4
BIOSCI 41. Evolution, Genetics, Biochem	5
BIOSCI 42. Cell Biology, Dev. Biology, and Neurobiology	5
BIOSCI 43. Physiology, Ecology, Behavioral	5
Engineering Fundamentals (two different courses required)	
CS 106. Programming Abstractions (X, or A and B)	5
For the second required course, see concentrations	
Technology in Society	
(one course required, 3-5 units):	(See Basic Requirement 4)
Engineering Depth (46 units minimum required):	
Programming:	
CS 107. Programming Paradigms	5
Core:	
BIOMEDIN 210. Intro Biomedical Informatics	3
Research:	
CS191W Research Project (WIM)[2]	6
or ME 191 Research Project[2]	
Engineering Depth Concentration:(choose one of the following concentrations)	
Cellular/Molecular Concentration:	
Mathematics: plus one of the following courses:	
MATH 51. Advanced Calculus	5
STATS 141. Biostatistics	5
Engineering Fundamentals:	
Elective[3]	3
Biology: (four courses)	
BIOSCI 126. Cell Bio: Molecular	4
BIOSCI 129. Cell Bio: Dynamics	4
BIOSCI 187. Biochemistry	5
BIOSCI 203. Advanced Genetics	4
Simulation Breadth (two courses)[4,5]	6
Informatics Breadth (two courses)[5,6]	6
General Breadth (one course)[5,7]	6
Informatics Concentration:	
Mathematics:	
STATS 141. Biostatistics	4
Engineering Fundamentals:	
Elective[3]	3
Informatics Core (two courses)	
CS 145. Databases	4
CS 161. Design and Analysis of Algorithms	4
CS 121/221. Artificial Intelligence	3
Informatics Electives (three courses)[8]	9
Cellular Breadth (two courses)[9]	6
Organs Breadth (two courses)[10]	6
Organs/Organisms Concentration:	
Mathematics: one of the following courses:	
MATH 51. Advanced Calculus	5
STATS 141. Biostatistics	5
Engineering Fundamentals:	
Elective[3]	3
Biology (three courses)	
BIOSCI 112. Human physiology	4
BIOSCI 187. Biochemistry	5
SBIO 211. Structure of Cells and Tissues	7
Simulation Breadth (two courses)[4,5]	6
Informatics Breadth (two course)[5,6]	6
General Breadth (one course)[5,11]	6
Simulation Concentration:	
Mathematics:	
MATH 51. Advanced Calculus I	5
MATH 53 or CME 102 (formerly ENGR 155A). Advanced Calculus II	5
MATH 52 or CME 104 (formerly ENGR 155B). Advanced Calculus III	5
Science:	
PHYSICS 51 or PHYSICS 55	3
Engineering Fundamentals:	
See requirement in Simulation Core	
Simulation Core: (two courses)[12]	6
Two courses from ENGR 14,15, ME 33 and ME 80	6
Simulation Breadth (two courses)[13]	6
Cellular Breadth (one course)[9]	6
Organs Breadth (one courses)[11]	3

1 MS&E 120 or EE 178 are acceptable substitutes for STATS 116.

2 CS 201 also fulfills the "Writing in the Major" requirement.
3 One course required, 3 to 5 units. See Fundamentals list in *School of Engineering Handbook*.
4 The simulation electives must be chosen from the following set: ENGR 14, ENGR 15, ENGR 30, ME 33, ME 80, ME 180, ME 181, ME 184A, CS 223A, CS 248, CS 277, CS 326A, SBIO 228, CHEM 171.
5 A total of 40 engineering units must be taken. The core classes only provide 27 engineering units, so the remaining units must be taken from within the electives.
6 The informatics electives must be chosen from the following set: CS 161, CS 145, CS 121, CS 147, CS 222, CS 228, CS 229, CS 262, BIOMEDIN 211, BIOMEDIN 214, BIOC 218, MS&E 252, STATS 206, STATS 315A, GENE 211.
7 The additional elective must be chosen from the lists in Cellular/Molecular concentration of simulation electives, informatics electives, or within the following set: BIOSCI 132, BIOSCI 133, SBIO 228, BIOSCI 214, CS 262, BIOMEDIN 214, BIOC 218, GENE 211, GENE 344.
8 The informatics electives must be chosen from the following set: CS 147, CS 222, CS 228, CS 229, CS 262, BIOMEDIN 211, BIOMEDIN 214, BIOC 218, MS&E 252, STATS 206, STATS 315A, GENE 211.
9 The cellular electives must be chosen from the following set: BIOSCI 126, BIOSCI 129, BIOC 200, BIOSCI 203, BIOSCI 132, BIOSCI 133, SBIO 228, BIOSCI 214, CS 262, BIOMEDIN 214, BIOC 218, GENE 211, GENE 344.
10 The organs electives must be chosen from the following set: BIOSCI 122, BIOC 200, SBIO 211, SURG 101, BIOSCI 158, BIOSCI 214, BIOSCI 230, BIOSCI 283, ME 180, ME 181, ME 184A, DBIO 210.
11 The additional elective must be chosen from the lists in Organs/Organisms concentration of simulation electives, informatics electives or within the following set: SURG 101, BIOSCI 158, BIOSCI 214, BIOSCI 283, ME 180, ME 181, ME 184A, DBIO 210.
12 Different subsets of these courses are required for different continuation courses in the track.
13 The simulation electives must be chosen from the following set: ME 180, ME 181, ME 184A CS 223A, CS 248, CS 277, CS 326A, SBIO 228, CHEM 171.

COMPUTER SYSTEMS ENGINEERING (CSE)

Mathematics (23 units):	
MATH 41, 42, 51. Calculus	15
MATH 52 or 53. Multivariable Math	5
STATS 116, Theory of Probability *or* MS&E 120 *or* CME 106 (formerly ENGR 155C)	3-5
Science (12 units):	
PHYSICS 51. Light and Heat	4
PHYSICS 53. Mechanics	4
PHYSICS 55. Electricity and Magnetism	4
Technology in Society (3-5 units):	
one course	(See Basic Requirement 4)
Engineering Fundamentals (13 units):	
ENGR 40. Electronics	5
ENGR 70X. Programming Methodology and Abstractions *or* CS 106A *and* B	5
Elective[1]	
Writing in the Major (one course):	
CS 191W, 194, 201, and 294W fulfill this requirement	
Computer Systems Engineering Core (32 units minimum):	
CS 103X.Discrete Structures *or* CS 103A and B	4 or 6
CS 107. Programming Paradigms	5
CS 108. Object-Oriented Systems Design	4
EE 108A. Digital Systems I	4
EE 108B. Digital Systems II	4
Senior Project (CS 191, 191W, 194, 294, or 294W)[2]	3
Plus two of the following:[3]	
EE 101A. Circuits I	4
EE 101B. Circuits II	4
EE 102A. Signals and Systems I	4
EE 102B. Signals and Systems II	4
Computer Systems Engineering Depth (19-25 units; choose one of the following specializations):	
Digital Systems Specialization	
CS 140. Operating Systems *or* CS 143. Compilers	4
EE 109. Digital Systems Design Lab	4
EE 271. VLSI Systems	3
Plus three to four of the following:[4]	
CS 140 or 143 (if not counted above)	4
CS 244A. Intro to Networking	4
EE 273. Digital Systems Engineering	3
EE 275. Logic Design	3
EE 281. Embedded Sys Design Lab	3
EE 282. Computer Architecture	3
Robotics and Mechatronics Specialization	
CS 205. Math for Robotics, Vision, Graphics	3
CS 223A. Intro to Robotics	3
EE 118. Intro to Mechatronics	4
ENGR 105. Feedback Control Design	3
Plus two to three of the following:[4]	
AA 278. Optimal Control Hybrid Sys	3
CS 223B. Intro to Computer Vision	3
CS 225A. Experimental Robotics	3
CS 225B. Robot Programming Lab	4
CS 277. Experimental Haptics	3
ENGR 205. Intro to Control Design	3
ENGR 206. Control Sys Design/Sim	4
ENGR 210B. Adv Topics in Comp for Control	3
Networking Specialization	
CS 140. Operating Systems	4
CS 244A. Intro to Networking	4
Plus four to five of the following:[4]	
CS 193I. Internet Technologies	3
CS 241. Internet Technologies and Systems	3
CS 244B. Distributed Systems	3
EE 179. Intro to Communications	3
EE 276. Wireless Personal Communications	3

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.
1 One course required, 3 to 5 units. See list in the *Handbook for Undergraduate Engineering Programs* at http://ughb.stanford.edu.
2 Independent study projects (CS 191 or 191W) require faculty sponsorship and must be approved in advance by the adviser, faculty sponsor, and the CSE program adviser (M. Johnson). A signed approval form, along with a brief description of the proposed project, should be filed at least two quarters before graduation. Further details can be found in the *Handbook for Undergraduate Engineering Programs* at http://ughb.stanford.edu.
3 Students pursuing the Robotics and Mechatronics or Networking specializations must take EE 102A and B.
4 Students opting to take CS103X instead of CS103A and B must complete the higher number of course.

PRODUCT DESIGN

Mathematics (20 units minimum):	
Recommended: one course in Statistics	
Science (22 units minimum):	
15 units must be from School of Engineering approved list[1]	
Recommended: one year of PHYSICS	
Behavioral Science1 (7 units minimum)	
PSYCH 1. Introduction to Psychology (required)	5
PSYCH elective[2] (courses numbered 20-95)	3-5
Mathematics and Science (maximum combined total of 45 units):	
Technology in Society (one course):	
ME 120. History of Philosophy of Design (required)	3-4
Engineering Fundamentals (3 courses minimum):	
ENGR 40, 70 required, plus remainder of course work from ENGR 10, 15, 20, 25 30, 50, 60; MS&E 100, 133	
Engineering Depth (45 units):	
ARTHIST 60. Basic Design	3
ARTHIST 160. Intermediate Design	3
Art Studio courses (two; ARTSTUDI 70 recommended)	6
ENGR 14	3
ENGR 102M[3]	1
ME 80. Stress, Strain, and Strength	4
ME 101. Visual Thinking	3
ME 103D. Engineering Drawing	1
ME 110A. Design Sketching	1
ME 112. Mechanical Systems	4
ME 115. Human Values in Design	3
ME 116. Product Design: Formgiving	4
ME 203. Manufacturing and Design[3]	4
ME 216A. Advanced Product Design	4
ME 216B. Advanced Product Design[2]	4

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.
1 School of Engineering approved science list available at http://ughb.stanford.edu.
2 One quarter abroad may substitute for this course.
3 Must be taken concurrently to fulfill the writing in the major requirement.

INDIVIDUALLY DESIGNED MAJORS (IDMS)

IDMs are intended for undergraduates interested in pursuing engineering programs that, by virtue of their focus and intellectual content, cannot be accommodated by existing departmental majors or the pre-approved School of Engineering majors. IDM curricula are designed by students with the assistance of two faculty advisers of their choice and are submitted to the Undergraduate Council's Subcommittee on Individually Designed Majors. The degree conferred is "Bachelor of Science with an Individually Designed Major in Engineering: (approved title)."

Students must submit written proposals to the IDM Subcommittee detailing their course of study. Programs must meet the following requirements: mathematics (21 unit minimum, see Basic Requirement 1 below), science (17 units minimum, see Basic Requirement 2 below), Technology in Society (one approved course, see Basic Requirement 4 below), engineering (40 units minimum), and sufficient relevant additional course work to bring the total number of units to at least 90 and at most 107. (Students may take additional courses pertinent to their IDM major, but the IDM proposal itself may not exceed 107 units.) The student's curriculum must include at least three Engineering Fundamentals courses (ENGR 10, 14, 15, 20, 25, 30, 40, 50, 60, 62, 70A, and 70X). Students are responsible for completing the prerequisites for all courses included in their majors.

Each proposal should begin with a statement describing the proposed major. In the statement, the student should make clear the motivation for and goal of the major, and indicate how it relates to her or his projected career plans. The statement should also specify how the various courses to be taken relate to and move the student toward realizing the major's goal. A proposed title for the major should be included. The title approved by the IDM Subcommittee is listed on the student's official University transcript.

The proposal statement should be followed by a completed Program Sheet listing all the courses comprising the student's IDM curriculum, organized by the five categories printed on the sheet (mathematics, science, Technology in Society, additional courses, and engineering depth). Normally, the courses selected should comprise a well-coordinated sequence or sequences that provide mastery of important principles and techniques in a well-defined field. In some circumstances, especially if the proposal indicates that the goal of the major is to prepare the student for graduate work outside of engineering, a more general engineering program may be appropriate. A four-year study plan, showing courses to be taken each quarter should also be included in the student's IDM proposal.

The proposal must be signed by two faculty members whose signatures certify that they endorse the major as described in the proposal and that they agree to serve as the student's permanent advisers. One of the faculty members, who must be from the School of Engineering, acts as the student's primary adviser. The proposal must be accompanied by a statement from that person giving her or his appraisal of the academic value and viability of the proposed major.

Students proposing IDMs must have at least four quarters of undergraduate work remaining at Stanford after the quarter in which their proposals are first submitted. Any changes in a previously approved major must be endorsed by the advisers and re-approved by the IDM subcommittee. A request by a student to make changes in her or his approved curriculum must be made sufficiently far in advance so that, should the request be denied, adequate time remains to complete the original, approved curriculum. Proposals are reviewed and acted upon once a quarter. Forms may be obtained from the *Handbook for Undergraduate Engineering Programs*' web site at http://ughb.stanford.edu. Completed proposals should be submitted to Bertha Love in the Office of Student Affairs, Terman 201.

DEPARTMENTAL MAJORS

Curricula for majors offered by the departments of Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering, Management Science and Engineering, Materials Science and Engineering, and Mechanical Engineering have the following components: 40-47 units of mathematics and science (see Basic Requirements 1 and 2 at the end of this section); engineering fundamentals (three course minimum, at least one of which must be unspecified by the department, see Basic Requirement 3); Technology in Society (TIS) (one course minimum, see Basic Requirement 4); engineering depth (courses such that the total of units for Engineering Fundamentals and Engineering Depth is between 60 and 75). Curricular requirements for departmental majors were being revised at the time of publication. Consult the 2003-04 *Handbook for Undergraduate Engineering Programs* online at http://ughb.stanford.edu for the most up-to-date listing of curricular requirements.

Experimentation—Departmental major programs, other than Computer Science and Management Science and Engineering, must include 8 units of experimentation. Lab courses taken in the sciences, as well as experimental work taken in courses within the School of Engineering, can be used in fulfillment of this requirement. By careful planning, the experimentation requirement should not necessitate additional course work beyond that required to meet the other components of an engineering major. A list of courses and their experimentation content (in units) can be found online at http://ughb.stanford.edu in the 2004-05 *Handbook for Undergraduate Engineering Programs.*

CHEMICAL ENGINEERING (CHE)

Course No. and Subject	*Units*
Mathematics:	
MATH 41, 42	10
CME 100. Vector Calculus for Engineers (formerly ENGR 154)	5
or MATH 51. Calculus	5
CME 102 (formerly ENGR 155A). Ordinary Differential Equations for Engineers	5
or MATH 52. Calculus	
and MATH 53. Ordinary Differential Equations	10
CME 104 (formerly ENGR 155B). Linear Algebra and Partial Differential Equations	5
or CME 106 (formerly ENGR 155C). Introduction to Probability and Statistics for Engineers	4
Science:	
CHEM 31X. Chemical Principles	4
or CHEM 31A. Chemical Principles I	
and CHEM 31B. Chemical Principles II	8
CHEM 33. Structure and Reactivity	4
CHEM 35. Organic Monofunctional Compounds	4
CHEM 36. Chemical Separations	3
PHYSICS 53. Mechanics	4
PHYSICS 55. Electricity and Magnetism	3
Technology in Society (one course required):	
(See Basic Requirement 4)	3-5
Engineering Fundamentals (three courses minimum, at least one of which must be unspecified by the department):	
ENGR 20. Introduction to Chemical Engineering	3
ENGR 25. Biotechnology	3
One Engineering fundamentals elective	3-5
Chemical Engineering Depth:	
BIOSCI 41. Genetics and Biochemistry	5
CHEMENG 10. The Chemical Engineering Profession	1
CHEMENG 100. Chemical Process Modeling, Dynamics, & Control	3
CHEMENG 110. Equilibrium Thermodynamics	3
CHEMENG 120A. Fluid Mechanics	4
CHEMENG 120B. Energy and Mass Transport	4
CHEMENG 130. Separation Process	3
CHEMENG 170. Kinetics and Reactor Design	3
CHEMENG 180. Chemical Engineering Plant Design	3
CHEMENG 185A. Chemical Engineering Laboratory (WIM)	4
CHEM 130. Qualitative Organic Analysis	4
CHEM 131. Organic Polyfunctional Compounds	3
CHEM 171. Physical Chemistry: Chemical Thermodynamics	3
CHEM 173. Physical Chemistry: Quantum Chemistry	3
CHEM 175. Physical Chemistry	3
Two of:	
CHEMENG 140. Microelectronics Processing Technology	3
CHEMENG 150. Biochemical Engineering	3
CHEMENG 160. Polymer Science and Engineering	3

Unit count is higher if program includes one or more of the following: MATH 20 series, MATH 50 series (in lieu of the ENGR math courses), or CHEM 31A,B (in lieu of CHEM 31X) The above requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook*. Handbooks are available at http://ughb.stanford.edu or from the department or school.

CIVIL ENGINEERING (CEE)

Mathematics and Science:
(45 units minimum)[1] (See Basic Requirements 1 and 2)
Technology in Society (one course): (See Basic Requirement 4)
Engineering Fundamentals (three courses minimum, at least one of which must be unspecified by department):

ENGR 14. Applied Mechanics: Statics	3
ENGR 60. Engineering Economy	3
Elective Fundamental (see Basic Requirement 3)	3-5
Engineering Depth:	
CEE 70. Environmental Science and Technology	3
CEE 100. Managing Civil Engineering Projects (WIM)	4
CEE 101A. Mechanics of Materials	4
CEE 101B. Mechanics of Fluids	4
CEE 101C. Geotechnical Engineering	4
Specialty courses in either Environmental and Water Studies[2] *or* Structures and Construction[3]	33-40
Other School of Engineering Electives	0-7

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

1 Mathematics must include CME 102 (formerly ENGR 155A) and a Statistics class. Science must include PHYSICS 53, CHEM 31, and GES 1. For students in the Environmental and Water Studies track, CHEM 33 also is required.
2 Environmental and Water Studies: ENGR 30; CEE 101D, 160, 161A, 166A, 166B, 171, 172, 177, 179A; and either CEE 169 or 179B. Remaining specialty units from: CEE 63, 64, 164, 169, 173A, 173B, 176A, 176B, 178, 179B, 199.
3 Structures and Construction: ENGR 50; CEE 102, 156, 156A, 180, 181, 181A, 182, 182A, and 183. Remaining specialty units from: ENGR 15, CME 104 (formerly ENGR 155B); CEE 101D, 111, 122A/B, 140, 147, 148, 154, 155, 160, 161A, 171, 176A, 176B, 195, 196, 199, 203, and one of 130, 131, 134, or 138.

COMPUTER SCIENCE (CS)

Mathematics (23 units minimum):	
CS 103X. Discrete Structures (Accelerated) *or* CS 103A and 103B	4-6
MATH 41, 42. Calculus[1]	10
STATS 116. Theory of Probability *or* MS&E 120 *or* CME 106 (formerly ENGR 155C)	3-5
Plus two electives[2]	
Science (11 unit):	
PHYSICS 53. Mechanics	4
PHYSICS 55. Electricity and Magnetism	4
Science Elective[3]	3
Technology in Society (one course, 3-5 units)	(See Basic Requirement 4)
Engineering Fundamentals (13 units):	
CS 106X. Programming Methodology and Abstractions (Accelerated) *or* CS 106A and 106B	5
ENGR 40. Electronics	5
Elective[4]	
Writing in the Major (one course):	
CS 191W, 194, 201 and 294W fulfill this requirement	
Computer Science Depth (43 units minimum):	
Programming (two courses):	
CS 107. Programming Paradigms	5
CS 108. Object-Oriented Systems Design	4
Theory (two courses):	
CS 154. Introduction to Automata and Complexity Theory	4
CS 161. Design and Analysis of Algorithms	4
Systems (three courses):	
EE 108B. Digital Systems II	4
Two systems electives[5]	7-8
Applications (two courses):	
CS 121 or 221. Introduction to Artificial Intelligence	3-4
One applications elective[6]	3-4
Project (one course):	
CS 191, 191W, 194, 294 or 294W[7]	3
Restricted Electives (two or three courses)[8]	6-12

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

1 MATH 19, 20, and 21 may be taken instead of MATH 41 and 42 as long as at least 25 math units are taken.
2 The Mathematics electives list consists of: MATH 51, 103 *or* 113, 108, 109, 110, CS 157 *or* PHIL 160A, CS 205; CME 100 (formerly ENGR 154), 104, 106 (formerly ENGR 155A, 155B). Completion of MATH 52 and 53 satisfies the MATH 103/113 requirement. MATH 51 and MATH 103, or MATH 51 and CME 100, or MATH 103 and CME 100, may not be used in combination to satisfy the math electives requirement. MATH 51 and MATH 113 may be used in combination to satisfy the math electives requirement.
3 The science elective may be any course of 3 or more units from the School of Engineering lists plus PSYCH 30 or 40; AP Chemistry also meets this requirement. Either of the PHYSICS sequences 61/63 or 21/23 may be substituted for 53/55 as long as at least 11 science units are taken.
4 One course required, 3 to 5 units. See list in the *Handbook for Undergraduate Engineering Programs* at http://ughb.stanford.edu.
5 The two systems courses must be chosen from the following set: CS 140, 143, 155, 242, and 244A. The systems electives must include a course with a large software project, currently satisfied by either CS 140 or 143.
6 The applications elective must be chosen from the following set: CS 145, 147, 148, 223A, 223B, or 248.
7 Independent study projects (CS 191 or 191W) require faculty sponsorship and must be approved by the adviser, faculty sponsor, and the CS program adviser (M. Johnson). A signed approval form, along with a brief description of the proposed project, should be filed at least two quarters before graduation. Further details can be found in the *Handbook for Undergraduate Engineering Programs*.
8 Students who take CS 103A,B must complete two electives; students who opt for 103X must complete three. The list of approved electives is reviewed annually by the Undergraduate Program Committee. The current list consists of CS 110, 137, 140, 143, 145, 147, 148 or 248, 155, 157, 205, 206, 222, 223A, 223B, 224M, 224N, 224S, 225A, 225B, 226, 227, 228, 229, 240, 241, 242, 243, 244A, 245, 246, 247A, 247B, 249, 255, 256, 257, 258, 261, 270, 271, 272, 273, 274, 277, 295; and EE 282.

ELECTRICAL ENGINEERING (EE)

Mathematics:	
MATH 41, 42	10
MATH 51 and 52, or CME 100 and 104 (formerly ENGR 154 and 155B)	10
MATH 53 or CME 102 (formerly ENGR 155A)	5
EE 178, STATS 116, MATH 151, or CME 106 (formerly ENGR 155C)	3-5
Science:	
PHYSICS (51, 53, 55) or (61, 63, 65)	12
Math or Science electives:	3-4
Technology in Society (one course):	3-5
Technical Writing: ENGR 102E (WIM corequisite for EE 108A)	1
EE 100. The Electrical Engineering Profession	1
Engineering Fundamentals (three courses minimum, at least one of which must be unspecified by department):	
CS 106X or CS 106B	5
ENGR 40	5
One additional course not in EE or CS	3-5
Engineering Depth:	
Circuits: EE 101A,B	8
Signals and Systems: EE 102A,B	8
Digital Systems: EE 108A (Laboratory, WIM), 108B	8
Analog Laboratory: 122	3
Physics in Electrical Engineering: EE 41 or EE 141	4-5
Specialty courses[1]	9-12
One course in Design[2]	
Electrical Engineering electives	9-15

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

1 Three courses from one of the specialty areas shown below (consultation with an adviser in the selection of these courses is especially important):
Computer Hardware: EE 109, 184 (CS 107), (271 or 275), 273, 282
Computer Software: EE 184 (CS 107), 189A (CS 108), 189B (CS 194) (284 or CS 244A)
Controls: EE 105 (ENGR 105), 205 (ENGR 205), 206 (ENGR 206), 209A (ENGR 209A), 209B (ENGR 209B)
Circuits: EE 116, 133, 212, 214, 216
Fields and Waves: EE 134, 142, 144, 241, 247
Communications and Signal Processing: EE 133, 168, 179, 261 (264 or 265), 278, 279
2 The design course may, but need not, be part of the specialty sequence. The following courses satisfy this requirement: EE 109, 189B (CS 194), 133, 144, 168, 256; ENGR 206.

ENVIRONMENTAL ENGINEERING (in CEE)

Mathematics and Science:
45 unit minimum[1] (See Basic Requirement 1 and 2)
Technology in Society[2] (one course): (See Basic Requirement 4)
Engineering Fundamentals (three courses minimum, at least one of which must be unspecified by department): (See Basic Requirement 3)

ENGR 30. Engineering Thermodynamics	3
ENGR 60. Engineering Economy	3
Elective Fundamental	3-5
Engineering Depth:	
CEE 64. Air Pollution: From Urban Smog to Global Change	3
CEE 70. Environmental Science and Technology	3
CEE 100. Managing Civil Engineering Projects (WIM)	4
CEE 101B. Mechanics of Fluids	4
CEE 101D. MathLab Applications in CEE	2
CEE 160. Mechanics of Fluids Laboratory	2
CEE 161A. Rivers, Streams, and Canals	3
CEE 166A. Watersheds and Wetlands	3
CEE 166B. Floods and Droughts, Dams, and Aqueducts	3
CEE 171. Environmental Planning Methods	3
CEE 172. Air Quality Management	3
CEE 177. Aquatic Chemistry and Biology	4
CEE 179A. Aquatic Chemistry Laboratory	2
Capstone design experience (either CEE 169 or 179B)	5
CEE Breadth Electives[3]	10
Other School of Engineering Electives	2-9

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

1 Math must include CME 102 (formerly ENGR 155A) and a Statistics course. Science must include PHYSICS 53; CHEM 31, 33; and GES 1.
2 Should choose a class that specifically includes an ethics component, such as STS 101, 110, 115, 170, or 215.
3 Breadth electives currently include CEE 63, 101C, 164, 169, 173A, 173B, 176A, 176B, 178, 179B, and 199.

MANAGEMENT SCIENCE AND ENGINEERING (MS&E)

Mathematics (32 units minimum):[1]	(See Basic Requirement 1)
MATH 41. Calculus	5
MATH 42. Calculus	5
MATH 51. Calculus	5
MATH 53. Ordinary Differential Equations with Linear Algebra	5
MS&E 120. Probabilistic Analysis	5
MS&E 121. Introduction to Stochastic Modeling	4
STATS 110 or 200. Statistical Methods/Inference	3-5
Science (11 units minimum[1]):	(See Basic Requirement 2)
One of the following three sequences:	
CHEM 31 and 33	8
PHYSICS 21, 22, 23, and 24	8
PHYSICS 53 and 55	8
Technology in Society (one course[2]): (See Basic Requirement 4)	3-5
Engineering Fundamentals (three courses minimum, at least one of which must be unspecified by department):	(See Basic Requirement 3)
CS 106A. or X Programming Methodology[3]	5
ENGR 25 or 40. Biotechnology or Introduction to Electronics	3-5
One other engineering fundamental from School of Engineering approved list[4]	3-5
Engineering Depth (core):	22-29
CS 106B (unless 106X used as fundamental)	0-5
ENGR 60. Engineering Economy[4]	3
ENGR 62. Introduction to Optimization[4]	4
MS&E 108. Senior Project	5
MS&E 130, 131, or134. Information	3-4
MS&E 142 or 160. Investment Science or Production	3-4
MS&E 180. Organizations: Theory and Management	4
Engineering Depth (Concentration: choose one of the following five concentrations):[7]	20-30
Financial and Decision Engineering Concentration:	27-29
ECON 50. Economic Analysis I	5
ECON 51. Economic Analysis II	5
MS&E 140. Industrial Accounting	4
MS&E 152. Introduction to Decision Analysis (WIM)	4
MS&E 245G or 247G or 247S. Finance	3-4
Two of the following five courses:	
ENGR 145 High Tech Entrepreneurship[8]	4
MS&E 107. Interactive Management Science	3
MS&E 160. Production and Operating Systems[6]	4
MS&E 223. Stimulation	3
MS&E 250A. Engineering Risk Analysis	3
Operations Research Concentration:	24-27
MATH 113. Linear Algebra and Matrix Theory[8]	3
MATH 115. Functions of a Real Variable[8]	3
MS&E 112. Network and Integer Optimization	3
MS&E 142 or 160. Investment Science or Production[6]	3-4
MS&E 152. Introduction to Decision Analysis (WIM)	3-4
MS&E 241. Economic Analysis	3-4
MS&E 251. Stochastic Decision Models	3
STATS 202. Data Analysis[8]	3
Organization, Technology, and Entrepreneurship Concentration	20-24
At least five of the following 15 courses (including at least two of the following marked with an asterisk*):	
CS 147. Intro to Human-Computer Interaction	3-4
ENGR 131. Ethical Issues in Engineering[8]	4
ENGR 145. High Tech. Entrepreneurship[8]*	4
ME 101. Visual Thinking	3
ME 115. Human Values in Design	3
MS&E 134. Organizations and Info Systems[5]	4
MS&E 140. Industrial Accounting	3-4
MS&E 175. Innovation, Creativity, and Change*	4
MS&E 181. Issues in Technology and Work[8]*	4
MS&E 266. Mgmt. of New Prod Devellopment	3-4
MS&E 267. Innovations in Manufacturing	3-4
MS&E 281. Mgmt. and Org. of R&D	3
MS&E 284. Technology and Work	3
MS&E 430. Contextual and Org. Issues in HCL	3-4
PSYCH 70. Introduction to Social Psychology[8]	4
Production and Operations Management Concentration	27-29
ECON 50. Economic Analysis I	5
ECON 51. Economic Analysis II	5
MS&E 140. Industrial Accounting	3-4
MS&E 152. Introduction to Decision Analysis (WIM)	4
MS&E 164. Manufacturing Systems Design	3
Two of the following eight courses:	
MS&E 142 or 245G. Investment Science/Finance	3-4
MS&E 169. Quality Engineering	4
MS&E 262. Supply Chain Management	3
MS&E 263. Internet-Enabled Supply Chains	3
MS&E 265. Reengineering the Mfg. Function	4
MS&E 266. Mgmt. of New Product Development	3-4
MS&E 267. Innovations in Manufacturing	3-4
MS&E 268. Manufacturing Strategy	3
Technology and Policy Concentration:	24-30
ECON 50. Economic Analysis I	5
ECON 51. Economic Analysis II	5
ECON 150/PUBLPOL 104. Economics and Public Policy	5
One of the following three courses:	
MS&E 197. Ethics and Public Policy (WIM)[3]	5
POLISCI 122. Introduction to American Law	3-5
PUBLPOL 101. Politics and Public Policy	5
One of the following six T&P application area courses:	
CEE 171. Environmental Planning Methods	3
COMM 137. Telecommunication Policy and the Internet	4-5
ECON 155. Environmental Economics and Policy	5
MS&E 193. Role of Technology and Nation Security (WIM)[8]	3
MS&E 195. International Security in a Changing World	5
MS&E 196. Transportation Systems and Urban Development	3
One of the following six advanced Technology and Policy courses:	
CEE 265B. Environmental Policy Design & Implementation	3
ECON 158. Antitrust and Regulation	5
MS&E 237. Progress in Worldwide Telecommunications (Summer only)	3
MS&E 290. Public Policy Analysis	3
MS&E 298. Technology Policy and Management in Newly Developed Countries[3]	3-4
PUBLPOL 194. Technology Policy	5

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

1 Math and Science must total a minimum of 45 units. Electives must come from the School of Engineering approved list, or PHYSICS 21, 22, 23, 24, 25, 26, PSYCH 40, or PSYCH 70. AP credit for Biology, Chemistry, Mathematics, Physics, and Statistics may be used.
2 Technology in Society course must be one of the following MS&E approved courses: STS 101/ENGR 130, STS 110/MS&E 197 (WIM), STS 115/ENGR 131, STS 135/MS&E 181, STS 162, STS 170/MS&E 182, STS 171/MS&E 193 (WIM), STS 215, STS 279/ MS&E 298.
3 AP credit for CS may be used.
4 Students may not count ENGR 60 or 62 for engineering fundamentals as those courses count toward engineering depth (core) and cannot be double counted.
5 Students may not count 134 for both core and the Organization, Technology, and Entrepreneurship concentration.
6 Students may not count 142 or 160 for both core and concentration. Students doing the Financial and Decision Engineering concentration must take 142, students doing the Operations Research concentration must take both 142 and 160, and students doing the Production and Operations Management concentration must take 160.
7 Engineering fundamentals, engineering depth (core), and engineering depth (concentration) must total a minimum of 60 units.
8 Courses used to satisfy the Math, Science, Technology in Society, or Engineering Fundamental requirement may not also be used to satisfy an engineering depth requirement.

MATERIALS SCIENCE AND ENGINEERING (MATSCI)

Mathematics (20 units minimum):	(See Basic Requirement 1)
Science (20 units minimum):	(See Basic Requirement 2)
Technology in Society (one course):	(See Basic Requirement 4)
Engineering Fundamentals (three courses minimum, at least one of which must be unspecified by department):	(See Basic Requirement 3)
Engineering Depth:	
MATSCI 151. Microstructure and Mechanical Properties	4
MATSCI 152. Electronic Materials Engineering	3
MATSCI 161. Materials Science Lab I	4
MATSCI 162. Materials Science Lab II (WIM)	4
MATSCI 163. Materials Science Lab III	4
Materials Science Fundamentals[1]	24
Science and Engineering Options[2]	9

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

1 MATSCI Fundamentals; 24 units from MATSCI 190, 191, 192, 193, 194, 195, 196, 197, 198, 199
2 MATSCI Options; 9 units from one of the following six areas:
Chemistry (CHEM 151, 153, 171, 173, 175)
Chemical Engineering (CHEMENG 110, 130, 140, 150, 170; ENGR 20; ME 70)
Electrical Engineering (EE 101A, 101B, 102A, 102B, 141, 142; ENGR 40)
Mechanical Engineering (ENGR 14, 15; ME 70, 80, 131A, 131B, 161, 203)
Physics (PHYSICS 110,, 120, 121, 124,130, 131, 134 170, 171, 172)
Self-Defined Option (petition for a self-defined cohesive program, minimum of 9 units)

MECHANICAL ENGINEERING (ME)

Mathematics (24 units minimum):	(See Basic Requirement 1)
Science (18 units minimum[1]):	(See Basic Requirement 2)
Technology in Society (one course):	(See Basic Requirement 4)
Engineering Fundamentals (three courses minimum, at least one of which must be unspecified by the department):	(See Basic Requirement 3)
Engineering Depth:	
ENGR 14. Applied Mechanics: Statics and Deformables	3
ENGR 15. Dynamics	3
ENGR 102M. Technical Writing (WIM corequisite for ME 203)	1
ME 70. Introductory Fluids Engineering	4
ME 80. Stress, Strain, and Strength	3
ME 101. Visual Thinking	3
ME 103D. Engineering Drawing	1
ME 112. Mechanical Systems Design	4
ME 113. Engineering Design	3
ME 131A. Heat Transfer	4
ME 131B. Fluid Mechanics	3
ME 140. Advanced Thermal Systems	4
ME 161. Mechanical Vibrations	4
ME 203. Manufacturing and Design (WIM)	4
Options to complete the ME Depth sequence (pick three items below):	
ENGR 105A. Control Systems	3
ME 150. Internal Combustion Engines	3
ME 210. Introduction to Mechatronics	4
ME 220. Introduction to Sensors	3
ME 227. Vehicle Dynamics and Control	3
ME 280. Skeletal Development and Evolution	3
ME 281. Biomechanics of Movement	3

These requirements are subject to change. The final requirements are published with example programs in the *School of Engineering Undergraduate Handbook* during the summer.

1 Math and science must total 45 units. Math: 24 units required and must include a course in differential equations (e.g., ME 155A). Science: 18 units minimum and must include chemistry and physics, with at least one year's study in one of them.

BASIC REQUIREMENTS

Basic Requirement 1 (Mathematics)—Engineering students need a solid foundation in the calculus of continuous functions including differential equations, an introduction to discrete mathematics, and an understanding of statistics and probability theory. The minimum preparation should normally include calculus to the level of MATH 53. Knowledge of ordinary differential equations and matrices is important in many areas of engineering, and students are encouraged to select additional courses in these topics. To meet ABET accreditation criteria, a student's program must include the study of differential equations.

Courses that satisfy the mathematics requirement are listed online at http://ughb.stanford.edu in the *Handbook for Undergraduate Engineering Programs*.

Basic Requirement 2 (Science)—A strong background in the basic concepts and principles of natural science in such fields as biology, chemistry, geology, and physics is essential for engineering. Most students include the study of physics and chemistry in their programs.

Courses that satisfy the science requirement are listed online at http://ughb.stanford.edu and in the *Handbook for Undergraduate Engineering Programs*.

Basic Requirement 3 (Engineering Fundamentals)—The Engineering Fundamentals requirement is satisfied by a nucleus of technically rigorous introductory courses chosen from the various engineering disciplines. It is intended to serve several purposes. First, it provides students with a breadth of knowledge concerning the major fields of endeavor within engineering. Second, it allows the incoming engineering student an opportunity to explore a number of courses before embarking on a specific academic major. Third, the individual classes each offer a reasonably deep insight into a contemporary technological subject for the interested non-engineer.

The requirement is met by taking three courses from the following list, at least one of which must be unspecified by the department):

ENGR 10. Introduction to Engineering Analysis
ENGR 14. Applied Mechanics: Statics and Deformables
ENGR 15. Dynamics
ENGR 20. Introduction to Chemical Engineering
ENGR 25. Biotechnology
ENGR 30. Engineering Thermodynamics
ENGR 40. Introductory Electronics[1]
ENGR 50. Introductory Science of Materials[1]
ENGR 60. Engineering Economics
ENGR 62. Introduction to Optimization
ENGR 70A or 70X. Introduction to Software Engineering

1 ENGR 40 and 50 may be taken on video at some of Stanford's Overseas Centers.

Basic Requirement 4 (Technology in Society)—It is important for the student to obtain a broad understanding of engineering as a social activity. To foster this aspect of intellectual and professional development, all engineering majors must take one course devoted to exploring issues arising from the interplay of engineering, technology, and society. Courses that fulfill this requirement are listed online at http://ughb.stanford.edu and in the *Handbook for Undergraduate Engineering Programs*.

MINORS

An undergraduate minor in Engineering may be pursued by interested students in many of the school's departments; consult with a department's undergraduate program representative, or the Office of Student Affairs, Terman Engineering Center, room 201. General requirements and policies for a minor in the School of Engineering are: (1) a set of courses totaling not less than 18 and not more than 36 units, with a minimum of six courses of at least 3 units each; (2) the set of courses should be sufficiently coherent as to present a body of knowledge within a discipline or subdiscipline; (3) prerequisite mathematics, statistics, or science courses, such as those normally used to satisfy the school's requirements for a department major, may not be used to satisfy the requirements of the minor; conversely, engineering courses that serve as prerequisites for subsequent courses must be included in the unit total of the minor program; (4) departmentally based minor programs are structured at the discretion of the sponsoring department, subject only to requirements 1, 2, and 3 above. Interdisciplinary minor programs may be submitted to the Undergraduate Council for approval and sponsorship. A general Engineering minor is not offered.

AERONAUTICS AND ASTRONAUTICS (AA)

The Aero/Astro minor introduces undergraduates to the key elements of modern aerospace systems. Within the minor, students may focus on aircraft, spacecraft, or disciplines relevant to both. The course requirements for the minor are described in detail below. Courses cannot be double-counted within a major and a minor, or within multiple minors; if necessary, the Aero/Astro adviser can help select substitute courses to fulfill the AA minor core.

The following core courses fulfill the minor requirements:

Course No. and Subject	*Units*
AA 100. Introduction to Aeronautics and Astronautics	3
ENGR 14. Statics[1]	3
ENGR 15. Dynamics[1]	3
ENGR 30. Thermodynamics[1]	3
ME 70. Introductory Fluids	4
ME 131A. Heat Transfer	4

1 ENGR 14, 15, or 30 are waived as minor requirements if already taken as part of the major.

The following courses are upper-division electives.

Two courses from one of the elective areas below	6
One course from a second area	3
Aerospace Systems Synthesis/Design:	
AA 236A,B. Spacecraft Design	6
AA 241A,B. Aircraft Design	6
Dynamics and Controls:	
AA 242A. Classical Dynamics	3
AA 271. Dynamics and Control of Spacecraft/Aircraft	3
AA 279. Space Mechanics	3
ENGR 105. Feedback Control Design	3
ENGR 205. Introduction to Control Design Techniques	3
Fluids:	
AA 200A. Applied Aerodynamics	3
AA 210A. Fund of Compressible Flow	3
AA 214A. Numerical Methods in Fluid Mechanics	3
or AA 283. Aircraft Propulsion	3
Structures:	
AA 240A. Analysis of Structures	3
AA 240B. Analysis of Structure II	3
AA 256. Mechanics of Composites	3

CHEMICAL ENGINEERING

The following courses fulfill the minor requirements:

CHEMENG 100. Chemical Process Modeling, Dynamics, and Control	3
CHEMENG 110. Equilibrium Thermodynamics	3
CHEMENG 120A. Fluid Mechanics	4
CHEMENG 120B. Energy and Mass Transport	4
CHEMENG 140. Microelectronics Processing Technology *or* CHEMENG 150. Biochemical Engineering *or* CHEMENG 160. Polymer Science and Engineering	3
CHEMENG 170. Kinetics and Reactor Design	3
CHEMENG 180. Chemical Engineering Plant Design	3
CHEMENG 185A. Chemical Engineering Lab	3
CHEM 171. Physical Chemistry	3
ENGR 20. Introduction to Chemical Engineering	3

CIVIL ENGINEERING (CEE)

The Civil Engineering minor is intended to give students an in-depth introduction to one or more areas of civil engineering. Departmental expertise and undergraduate course offerings are available in the areas of Construction Engineering, and Management, Structural Engineering, and Architectural Engineering. The minimum prerequisite for a Civil Engineering minor is MATH 42 (or 21); however, many courses of interest require PHYSICS 53 and/or MATH 51 as prerequisites. Students should recognize that a minor in Civil Engineering is *not* an ABET-accredited degree program.

Since civil engineering is a very broad field and undergraduates with widely varying backgrounds may be interested in obtaining a civil engineering minor, no single set of course requirements is appropriate for all students. Instead, interested students are encouraged to propose their own set of courses within the guidelines listed below; this list must be officially approved by the Civil and Environmental Engineering (CEE) undergraduate minor adviser. Additional information on preparing a minor program, including example programs focusing on each of the areas of expertise listed above is available in the CEE office (Terman M-2). While each example program focuses on a different area of expertise within the department, other combinations of courses are also possible.

General guidelines are:

1. A Civil Engineering minor must contain at least 24 units of course work not taken for the major, and must consist of at least six classes of at least 3 units each.
2. The list of courses must represent a coherent body of knowledge in a focused area, and should include classes that build upon one another.
3. Professor Street (524-524R; 723-4969; street@stanford.edu) is the CEE undergraduate minor adviser, and provides guidance and advice. Students must consult with Professor Street in developing their minor program, and obtain approval of the finalized study list from him.

COMPUTER SCIENCE (CS)

The following courses fulfill the minor requirements. Prerequisites include the standard mathematics sequence through MATH 51.

Introductory Programming:	
CS 106A,B. Programming Method/Abstractions	10
or CS 106X. Programming Method/Abstractions (Accelerated)	5
(AP Credit may be used to fulfill this requirement)	
Core:	
CS 103A/B. Discrete Math/Structures	6
or CS 103X. Discrete Structures	4
CS 107. Programming Paradigms	5
CS 108. Object-Oriented Systems Design	4
Electives: select two courses from different areas	
Artificial Intelligence:	
CS 121. Introduction to Artificial Intelligence	3
CS 221. AI: Principles and Techniques	4
Human-Computer Interaction:	
CS 147. Introduction to Human-Computer Interaction Design	3-4
Numerical Computing:	
CS 137. Introduction to Scientific Computing	4
Systems:	
CS 140. Operating Systems	4
CS 143. Compilers	4
CS 145. Databases	4
CS 148. Graphics	3
Theory:	
CS 154. Automata and Complexity Theory	4
CS 157. Logic and Automated Reasoning	4
CS 161. Design and Analysis of Algorithms	4

Note: for students with no programming background and who begin with CS 106A, the minor consists of seven or eight courses.

ELECTRICAL ENGINEERING (EE)

Courses fulfilling the minor are from any of the following three tracks:

Option I:	
ENGR 40. Introductory Electronics	5
EE 101A.Circuits I	4
EE 101B Circuits II	4
Four graded EE courses of level 100 or higher	
Option II:	
ENGR 40. Introductory Electronics	5
EE 102A. Signal Processing and Linear Systems I	4
EE 102B. Signal Processing and Linear Systems II	4
Four graded EE courses of level 100 or higher	
Option III:	
ENGR 40. Introductory Electronics	5
EE 108A. Digital Systems I	4
EE EE 108B Digital Systems II	4
Four graded EE courses of level 100 or higher	

ENVIRONMENTAL ENGINEERING

The Environmental Engineering minor is intended to give students a broad introduction to one or more areas of Environmental Engineering. Departmental expertise and undergraduate course offerings are available in the areas of Environmental Engineering and Science, Environmental Fluid Mechanics and Hydrology, and Energy Engineering. The minimum prerequisite for an Environmental Engineering minor is MATH 42 (or 21): however, many courses of interest require PHYSICS 53 and/or MATH 51 as prerequisites. Students should recognize that a minor in Environmental Engineering is not an ABET-accredited degree program.

Since undergraduates having widely varying backgrounds may be interested in obtaining an environmental engineering minor, no single set of course requirements is appropriate for all students. Instead, interested students are encouraged to propose their own set of courses within the guidelines listed below; this list must be officially approved by the Civil and Environmental Engineering (CEE) undergraduate minor adviser. Additional information on preparing a minor program, including example programs focusing on each of the areas of expertise listed above, is available in the CEE office (Terman M-42). While each example program focuses on a different area of expertise within the department, other combinations of courses are also possible.

General guidelines are:

1. An Environmental Engineering minor must contain at least 24 units of course work not taken for the major, and must consist of at least six classes of at least 3 units each.
2. The list of courses must represent a coherent body of knowledge in a focused area, and should include classes that build upon one another.
3. Professor Street (524-524R; 723-4969; street@stanford.edu) is the CEE undergraduate minor adviser, and provides guidance and advice. Students must consult with Professor Street in developing their minor program, and obtain approval of the finalized study list from him.

MANAGEMENT SCIENCE AND ENGINEERING (MS&E)

The following courses fulfill the minor requirements:

Background requirements:	
MATH 51. Calculus	
Minor requirements:	
ENGR 60. Engineering Economy (prerequisite: MATH 41)	3
ENGR 62. Introduction to Optimization	4
MS&E 120. Probabilistic Analysis (prerequisite: MATH 51)	5
MS&E 121. Introduction to Stochastic Modeling	4
MS&E 130, 131, or 134. Information	3-4
MS&E 180. Organizations: Theory and Management	4
MS&E 142 or 160. Investment Science or Production	3-4
Elective (any 100- or 200-level MS&E course)	3-4

MATERIALS SCIENCE AND ENGINEERING (MATSCI)

A minor in Materials Science and Engineering allows interested students to explore the role of materials in modern technology and to gain an understanding of the fundamental processes that govern materials behavior.

The following courses fulfill the minor requirements:

Fundamentals:	
ENGR 50. Introductory Science of Materials	4
MATSCI 151. Microstructure and Mechanical Properties	4
MATSCI 152. Electronic Materials Engineering	3
Electives (four courses from the MSE Core, 16 units):	
MATSCI 190. Organic Materials	4
MATSCI 191. Mathematical and Computational Methods in Materials Science	4
MATSCI 192. Solid State Thermodynamics	4
MATSCI 193. Atomic Arrangements in Solids	4
MATSCI 194. Phase Equilibria	4
MATSCI 195. Waves and Diffraction in Solids	4
MATSCI 196. Imperfections in Crystalline Solids	4
MATSCI 197. Rate Processes in Materials	4
MATSCI 198. Mechanical Properties of Materials	4
MATSCI 199. Electrical and Optical Properties of Solids	4

MECHANICAL ENGINEERING (ME)

The following courses fulfill the minor requirements:

General Minor—This minor aims to expose students to the breadth of ME in terms of topics and of analytic and design activities. The minor consists of seven courses totaling 26 to 28 units. Prerequisites are MATH 41, 42; PHYSICS 53.

ENGR 14. Applied Mechanics: Statics	3
ENGR 15. Dynamics	4
ENGR 30. Engineering of Thermodynamics	3
ME 70. Introductory Fluids Engineering	4
ME 101. Visual Thinking	3

Plus two of the following:

ME 80. Stress, Strain, and Strength	4
ME 131A. Heat Transfer	4
ME 161. Dynamic Systems	4
ME 203. Manufacturing and Design	4

Thermosciences—This minor consists of seven courses totaling 26 units. Prerequisites are MATH 41, 42, 43; PHYSICS 53.

ENGR 14. Applied Mechanics: Statics	3
ENGR 30. Engineering Thermodynamics	3
ME 70. Introductory Fluids Engineering	4
ME 131A. Heat Transfer	4
ME 131B. Fluid Mechanics	3
ME 140. Advanced Thermal Systems	3

Mechanical Design—This minor aims to expose students to design activities supported by analysis. This proposed minor consists of seven courses totaling 24-26 units. Prerequisites are MATH 41, 42; PHYSICS 53.

ENGR 14. Applied Mechanics: Statics	3
ENGR 15. Dynamics	3
ME 80. Stress, Strain, and Strength	4
ME 112. Mechanical Systems	4

Plus two of the following:

ME 99. Mechanical Dissection	3
ME 101. Visual Thinking	3
ME 203. Manufacturing and Design	4

Plus one of the following:

ME 113. Engineering Design	3
ME 220. Introduction to Sensors	3
ME 210. Introduction to Mechatronics	4

GRADUATE PROGRAMS

ADMISSION

Application for admission with graduate standing in the school should be made to the department's graduate admissions committee. While most graduate students have undergraduate preparation in an engineering curriculum, it is feasible to enter from other programs, including chemistry, geology, mathematics, or physics.

Fellowships and Assistantships—Departments and divisions of the School of Engineering award graduate fellowships, research assistantships, and teaching assistantships each year. For further information and application instructions, see the department sections in this bulletin or http://gradadmissions.stanford.edu.

Registration—New graduate students should follow procedures for registration as listed in the University's quarterly *Time Schedule*. Adviser assignments can be obtained from department offices.

THE HONORS COOPERATIVE PROGRAM

A number of industrial firms, government laboratories, and other organizations participate in the Honors Cooperative Program (HCP), a program that permits qualified engineers, scientists, and technology professionals to register for Stanford courses and obtain a graduate degree on a part-time basis.

The courses are offered by the School of Engineering on campus or through the Stanford Center for Professional Development (SCPD). SCPD offers more than 200 courses a year delivered in a variety of formats, including microwave broadcast, Internet, videotape, as well as on campus. For industry students not part of the HCP, courses are also available on a Non-Degree Option, Audit Option, certificate, or short course basis and may be customized to meet a company's needs. For a full description of educational services provided by SCPD, see http://scpd.stanford.edu; call (650) 725-3000; fax (650) 725-2868; write Durand Building, Room 300, Stanford, CA 94305-4036; or email scpd-registration@stanford.edu.

MANUFACTURING

Programs in manufacturing are available at the undergraduate, master's, and Ph.D. level. Master's programs are offered by the departments of Civil and Environmental Engineering, Management Science and Engineering (MS&E), and Mechanical Engineering. The Construction Engineering and Management program, offered by the Department of Civil and Environmental Engineering, is also a manufacturing program for students interested in facility and public works manufacturing. All of these programs take advantage of modern computer technology.

Doctoral programs related to manufacturing are available in a number of departments and involve research projects ranging from machine tool design to the integration of databases into production software.

For detailed information about the master's and Ph.D. programs, see the sections of this bulletin pertaining to management science, mechanical, and civil and environmental engineering. For more information on manufacturing research and education in Engineering, see http://www.stanford.edu/group/AIM and the web sites of departments.

CURRICULA

For further details about the following programs, see the department sections in this bulletin.

Related aspects of particular areas of graduate study are commonly covered in the offerings of several departments and divisions. Graduate students are encouraged, with the approval of their department advisers, to select courses in departments other than their own to achieve a broader appreciation of their field of study. For example, most departments in the school offer courses concerned with properties of materials, and a student interested in an aspect of materials engineering can often gain appreciable benefit from the related courses given by departments other than her or his own.

Departments and divisions of the school offer graduate curricula as follows.

AERONAUTICS AND ASTRONAUTICS

The current research and teaching activities cover a number of advanced fields, with special emphasis on:

Active Noise Control
Aerodynamic Noise
Aeroelasticity
Aircraft Design, Performance, and Control
Applied Aerodynamics
Biomedical Mechanics

Computational Aero-Acoustics
Computational Fluid Dynamics
Computational Mechanics and Dynamical Systems
Control of Robots, including Space and Deep-Underwater Robots
Conventional and Composite Structures/Materials
Direct and Large Eddy Simulation of Turbulence
Distributed Control of Networks
High-Lift Aerodynamics
Hybrid Propulsion
Hypersonic and Supersonic Flow
Inertial Instruments
Multidisciplinary Design Optimization
Navigation Systems (especially GPS)
Networked and Hybrid Control
Optimal Control, Estimation, System Identification
Physical Gas Dynamics
Spacecraft Design and Satellite Engineering
Turbulent Flow and Combustion

CHEMICAL ENGINEERING

Applied Statistical Mechanics
Biocatalysis
Biochemical Engineering and Biophysics
Bioengineering
Computational Materials Science
Colloid Science
Dynamics of Complex Fluids
Functional Genomics
Hydrodynamic Stability
Kinetics and Catalysis
Microrheology
Molecular Assemblies
Newtonian and Non-Newtonian Fluid Mechanics
Polymer Physics
Protein Biotechnology
Semiconductor Processing
Surface and Interface Science
Transport Mechanics

CIVIL AND ENVIRONMENTAL ENGINEERING

Construction Engineering and Management
Design/Construction Integration
Environmental and Water Studies
- Environmental Engineering and Science
- Environmental Fluid Mechanics and Hydrology

Structural Engineering and Geomechanics
- Geomechanics
- Structural Engineering

COMPUTER SCIENCE

Analysis of Algorithms
Artificial Intelligence
Automated Deduction
Autonomous Agents
Biomedical Computation
Compilers
Complexity Theory
Computational Biology
Computational Geometry
Computational Physics
Computer Architecture
Computer Graphics
Computer Logic
Computer Security
Computer Vision
Database Systems
Design Automation
Digital Libraries
Distributed and Parallel Computation
Formal Verification
Haptic Display of Virtual Environments
Human-Computer Interaction
Image Processing
Knowledge-Based and Expert Systems
Knowledge Representation and Logic
Machine Learning
Mathematical Theory of Computation
Multi-Agent Systems
Natural Language Processing
Networks, Internet Infrastructure, and Distributed Systems
Operating Systems
Programming Systems/Languages
Reasoning Under Uncertainty
Robotics
Scientific Computing and Numerical Analysis
Ubiquitous and Pervasive Computing

ELECTRICAL ENGINEERING

Computer Hardware
Computer Software Systems
Control and Systems Engineering
Communication Systems
Electronic Circuits
Electronic Devices, Sensors, and Technology
Fields, Waves, and Radioscience
Lasers, Optoelectronics, and Quantum Electronics
Network Systems
Image Systems
Signal Processing
Solid State Materials and Devices
VLSI Design

ENGINEERING

Interdepartmental Programs
Interdisciplinary Programs

MANAGEMENT SCIENCE AND ENGINEERING

Decision and Risk Analysis
Dynamic Systems
Economics
Entrepreneurship
Finance
Information
Marketing
Optimization
Organization Behavior
Organizational Science
Policy
Production
Stochastic Systems
Strategy

MATERIALS SCIENCE AND ENGINEERING

Biomaterials
Ceramics and Composites
Computational Materials Science
Design/Manufacturing
Electrical and Optical Behavior of Solids
Electron Microscopy
Fracture and Fatigue
Imperfections in Crystals
Kinetics
Magnetic Behavior of Solids
Magnetic Storage Materials
Organic Materials
Phase Transformations

Physical Metallurgy
Solid State Chemistry
Structural Analysis
Thermodynamics
Thin Films
X-Ray Diffraction

MECHANICAL ENGINEERING

Biomechanics
Combustion Science
Computational Mechanics
Controls
Design of Mechanical Systems
Dynamics
Environmental Science
Experimental Stress and Analysis
Fatigue and Fracture Mechanics
Finite Element Analysis
Fluid Mechanics
Heat Transfer
High Temperature Gas Dynamics
Kinematics
Manufacturing
Mechatronics
Product Design
Robotics
Sensors
Solids
Thermodynamics
Turbulence

SCIENTIFIC COMPUTING AND COMPUTATIONAL MATHEMATICS

See the "Scientific Computing and Computational Mathematics" section of this bulletin.

SPACE SCIENCE

See the "Center for Space Science and Astrophysics" section of this bulletin.

MASTER OF SCIENCE

The M.S. degree is conferred on graduate students in engineering according to the University regulations stated in the "Graduate Degrees" section of this bulletin, and is described in the various department listings. A minimum of 45 units is usually required in M.S. programs in the School of Engineering. However, the presentation of a thesis is not a school requirement.

MASTER OF SCIENCE IN ENGINEERING

The M.S. in Engineering is available to students who wish to follow an interdisciplinary program of study that does not conform to a normal graduate program in a department.

There are three school requirements for the M.S. degree in Engineering: (1) the student's program must be a coherent one with a well-defined objective and must be approved by a department within the school; (2) the student's program must include at least 21 unit of courses within the School of Engineering with numbers 200 or above in which the student receives letter grades; and (3) the program must include a total of at least 45 units. Each student's program is administered by the particular department in which it is lodged and must meet the standard of quality of that department. Transfer into this program is possible from any program within the school by application to the appropriate department.

ENGINEER

The degree of Engineer is awarded at the completion of a comprehensive two-year program of graduate study. It is intended for students who desire more graduate training than can be obtained in an M.S. program. The program of study must satisfy the student's department and usually includes 90 units beyond the B.S. degree, of which at least 60 must be devoted to advanced or graduate study in the major subject or closely related subjects. The presentation of a thesis is required. The University regulations for the Engineer degree are stated in the "Graduate Degrees" section of this bulletin, and further information is found in the individual departmental sections of this bulletin.

DOCTOR OF PHILOSOPHY

Programs leading to the Ph.D. degree are offered in each of the departments of the school. Special Ph.D. programs which may be interdepartmental in nature can be arranged. University regulations for the Ph.D. are given in the "Graduate Degrees" section of this bulletin. Further information is found in departmental listings.

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 (8 units maximum).

The following Engineering courses deal with subject areas within engineering that are, in their essential nature, broader than the confines of any particular branch of engineering. These courses are taught by professors from several departments of the School of Engineering, under the supervision of those listed below.

Of the courses described in this section, many are of general interest to both engineering and non-engineering students. In addition, certain departmental courses are of general interest and without prerequisites.

Students interested in the interactions between technology and society should also consult the "Science, Technology, and Society" section of this bulletin.

PRIMARILY FOR UNDERGRADUATES

ENGR 10. Introduction to Engineering Analysis—Integrated approach to the fundamental scientific principles that are the cornerstones of engineering analysis: conservation of mass, atomic species, charge, momentum, angular momentum, energy, production of entropy expressed in the form of balance equations on carefully defined systems, and incorporating simple physical models. Emphasis is on setting up analysis problems arising in engineering. Topics: simple analytical solutions, numerical solutions of linear algebraic equations, and laboratory experiences. Provides the foundation and tools for subsequent engineering courses. GER:2b

4 units, Spr (Cappelli)

ENGR 14. Applied Mechanics: Statics—Introduction to the mechanics of particles, rigid bodies, trusses, frames, and machines in static equilibrium, with emphasis on the use of free-body diagrams and the principle of virtual work. Frictional effects and internal forces in structural members. Prerequisite: PHYSICS 41 or consent of instructor. GER:2b

3 units, Aut (Sheppard), Spr (Kiremidjian)

ENGR 15. Dynamics—The application of Newton's Laws to solve static and dynamic problems, particle and rigid body dynamics, freebody diagrams, and writing equations of motion. 2-D and 3-D cases including gyroscopes, spacecraft, and rotating machinery. Solution of equations of motion and dynamic response of simple mechanical systems. Problem sessions. Prerequisites: MATH 23 or 43, PHYSICS 41. GER:2b

3 units, Aut (Niemeyer), Spr (Waldron)

ENGR 20. Introduction to Chemical Engineering—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 31A and B, or 31X. GER:2b

3 units, Spr (Robertson)

ENGR 25. Biotechnology—The interplay between molecular and cellular biology and engineering principles in the design, development, manufacture, and formulation of new drugs and agrochemicals. Emphasis is on understanding the scope of engineering in modern biotechnology. Topics include biological fundamentals, genomics and bioinformatics, protein engineering, fermentation and downstream recovery of biomolecules, antibody technologies, plant biotechnology, vaccines, transgenic animals, and stem cell technologies. The role of intellectual property and venture capital in biotechnology. Recommended: prior exposure to chemistry and biology. GER:2b

3 units, Spr (Kao)

ENGR 30. Engineering Thermodynamics—Introduction to the concepts of energy and entropy from elementary considerations of the microscopic nature of matter. Use of basic thermodynamic concepts in the solution of engineering problems. Methods and problems in the socially responsible economic generation and utilization of energy in central power stations, solar systems, gas turbine engines, refrigeration devices, and automobile engines. Prerequisites: MATH 19, 20, 21, or 41, 42, and PHYSICS 41 or equivalent. GER:2b

3 units, Aut (Mungal), Win (Pitsch)

ENGR 31. Introduction to Solid State Chemistry with Application to Materials Technology—Preparation for engineering disciplines emphasizing modern technological applications of solid state chemistry. Topics include: crystallography; chemical kinetics and equilibria; thermodynamics of phase changes and reaction; quantum mechanics of chemical bonding, molecular orbital theory, and electronic band structure of crystals; and the materials science of basic electronic and photonic devices. Prerequisite: high school or college chemistry background in stoichiometry, periodicity, Lewis and VSEPR structures, dissolution/precipitation and acid/base reactions, gas laws, and phase behavior. GER:2a

4 units, Aut (McIntyre)

ENGR 40. Introductory Electronics—Overview of electronic engineering. Electrical quantities and their measurement including operation of the oscilloscope. The basic function of electronic components including ideal diodes and transistors. Digital logic circuits and their functions including the elementary microprocessor. Analog circuits including the operational amplifier and tuned circuits. Lab assignments. Enrollment limited to 200. Prerequisite: PHYSICS 23. Corequisite: PHYSICS 45. GER:2b

5 units, Aut, Spr (Khuri-Yakub)

ENGR 50. Introductory Science of Materials—Survey of materials, fabrication, and primary applications. Atomic structure and engineering, microelectronics, and memory devices. Mechanical and electronic behavior, semiconductors, alloys, ceramics, composites, and plastics. May be taken on video at some of Stanford's Overseas Centers; see "Overseas Studies." GER:2b

4 units, Win (Melosh), Spr (Sinclair)

ENGR 60. Engineering Economy—May be taken by freshmen, but recommended for sophomore or higher students. Fundamentals of economic analysis. Interest rates, present value, and internal rate of return. Applications to personal and corporate financial decisions. Mortgage evaluation, insurance decision, hedging/risk reduction, project selection, capital budgeting, and investment valuation. Decisions under uncertainty and utility theory. Prerequisite: MATH 41 or equivalent. Recommended: previous knowledge of elementary probability. GER:2b

3 units, Win (Chiu), Spr (Weber), Sum (Bhimjee)

ENGR 62. Introduction to Optimization—Formulation and analysis of linear optimization problems. Solution using Excel solver. Polyhedral geometry and duality theory. Applications to contingent claims analysis, production scheduling, pattern recognition, two-player zero-sum games, and network flows. Prerequisite: MATH 51. GER:2b

4 units, Aut (Veinott), Spr (Van Roy)

ENGR 70A. Programming Methodology—(Enroll in CS 106A.)

3-5 units, Aut, Spr (Parlante), Win (Roberts)

ENGR 70X. Programming Methodology and Abstractions (Accelerated)—(Enroll in CS 106X.)

3-5 units, Aut (Sahami), Win (Cain)

ENGR 100. Teaching Public Speaking—The theory and practice of teaching public speaking and presentation development. Developing an instructional plan, audiovisual equipment for instruction, tutoring techniques, and teaching delivery, organization, audience analysis, visual aids, and unique speaking situations. Weekly practice speaking. Students serve as apprentice speech tutors. Those completing course may become paid speech instructors in the Technical Communications Program. Prerequisite: consent of instructor.

5 units, Aut, Win (Lougee, Staff)

ENGR 102E. Technical/Professional Writing for Electrical Engineers—Required of Electrical Engineering majors. The process of writing technical/professional documents. Lectures, writing assignments, individual conferences. Corequisite for WIM: EE 108A.

1 unit, Aut, Win (Lougee, Staff)

ENGR 102M. Technical/Professional Writing for Mechanical Engineers—Required of Mechanical Engineering majors. The process of writing technical/professional documents. Lecture, writing assignments, individual conferences. (Corequisite for WIM: ME 203, or consent of instructor) WIM

1 unit, Aut, Win, Spr (Lougee)

ENGR 103. Public Speaking—Priority to Engineering students. Introduction to speaking activities, from impromptu talks to carefully rehearsed formal professional presentations. How to organize and write speeches, analyze audiences, create and use visual aids, combat nervousness, and deliver informative and persuasive speeches effectively. Weekly class practice, rehearsals in one-on-one tutorials, videotaped feedback. Limited enrollment.

3 units, Aut, Win, Spr (Lougee)

ENGR 105. Feedback Control Design—Design of linear feedback control systems for command-following error, stability, and dynamic response specifications. Root-locus and frequency response design techniques. Examples from various fields. Some use of computer aided design with MATLAB. Prerequisite: EE 102, ME 161, or equivalent. GER:2b

3 units, Win (Rock)

ENGR 120. Fundamentals of Petroleum Engineering—(Same as PETENG 120.) Engineering topics in petroleum recovery; origin, discovery, and development of oil and gas. Chemical, physical, and thermodynamic properties of oil and natural gas. Material balance equations and reserve estimates using volumetric calculations. Gas laws. Single phase and multiphase flow through porous media. Field trip. GER:2b

3 units, Aut (Juanes)

ENGR 130. Science, Technology, and Contemporary Society—(Same as STS 101/201.) Key social, cultural, and values issues raised by contemporary scientific and technological developments; distinctive features of science and engineering as sociotechnical activities; major influences of scientific and technological developments on 20th-century society, including transformations and problems of work, leisure, human values, the fine arts, and international relations; ethical conflicts in scientific and engineering practice; and the social shaping and management of contemporary science and technology. GER:3b

4-5 units, Aut (McGinn)

ENGR 131. Ethical Issues in Engineering—(Same as STS 115.) Moral rights and responsibilities of engineers in relation to society, employers, colleagues, and clients; cost-benefit-risk analysis, safety, and informed consent; the ethics of whistle blowing; ethical conflicts of engineers as expert witnesses, consultants, and managers; ethical issues in engineering design, manufacturing, and operations; ethical issues arising from engineering work in foreign countries; and ethical implications of the social and environmental contexts of contemporary engineering. Case studies, guest practitioners, and field research. Limited enrollment. GER:3a

4 units, Spr (McGinn)

ENGR 140A. Management of Technology Ventures—First of three-part sequence for students selected to the Mayfield Fellows Program. Management and leadership within high technology startups, focusing on entrepreneurial skills related to product and market strategy, venture financing and cash flow management, team recruiting and organizational development, and the challenges of managing growth and handling adversity in emerging ventures. Other engineering faculty, founders, and venture capitalists participate as appropriate. Recommended: accounting or finance course (MS&E 140, ECON 90, or ENGR 60).
3-4 units, Spr (Byers)

ENGR 140B. Management of Technology Ventures—Open to Mayfield Fellows only; taken during the summer internship at a technology startup. Students meet to exchange experiences and continue the formal learning process. Activities journal. Credit given following quarter.
1 unit, Aut (Byers)

ENGR 140C. Management of Technology Ventures—Open to Mayfield Fellows only. Capstone to the 140 sequence. Students, faculty, employers, and venture capitalists share and compare recent internship experiences and analytical frameworks. Students develop living case studies and integrative project reports.
3 units, Aut (Byers)

ENGR 145. Introduction to High Technology Entrepreneurship—For juniors, seniors, and coterminal students of all majors who want to form or grow a technology company some day, and those with a general interest in the field. Overview of the entrepreneurial process, enterprise, and individual. Weekly assignments, case studies, lectures, workshops, and projects. GER:3b
4 units, Win (Byers, Komisar)

ENGR 150. Social Entrepreneurship Startup—(Graduate students register for 250.) The art of innovation and social entrepreneurship through a real project for the social sector. From understanding the problem based upon research, interviews, and fieldwork, the team develops, tests, and iteratively improves a technology-based social innovation and a business plan to deploy it. Feedback and coaching from domain experts, product designers, and successful social entrepreneurs. Goal is to deploy solution. Information on current and upcoming projects at http://ses.stanford.edu.
1-6 units, Aut, Win, Spr (Behrman)

ENGR 154. Vector Calculus for Engineers—(Enroll in CME 100).
5 units, Aut (Khayms)

ENGR 155A. Ordinary Differential Equations for Engineers—(Enroll in CME 102.)
5 units, Win (Darve), Spr (Taylor)

ENGR 155B. Introduction to Partial Differential Equations for Engineers—(Enroll in CME 104.)
5 units, Spr (Khayms)

ENGR 155C. Introduction to Probability and Statistics for Engineers—(Enroll in CME 106.)
4 units, Win (Khayms)

ENGR 159Q. Research in Japanese Companies—Stanford Introductory Seminar (Same as MATSCI 159Q.) Preference to sophomores. The structure of a Japanese company from the point of view of Japanese society. Visiting researchers from Japanese companies give presentations on their research enterprise, with question and answer periods. Exploration of the Japanese research ethic. The home campus equivalent of a Kyoto SCTI course. GER:3b
3 units, Spr (Sinclair)

ENGR 199. Special Studies in Engineering—Special studies, lab work, or reading. Research experience opportunities may exist in ongoing research projects. Students make arrangements with individual faculty and enroll in the corresponding section number. Prerequisite: consent of instructor.
1-15 units, Aut, Win, Spr (Staff)

PRIMARILY FOR GRADUATE STUDENTS

ENGR 200. Research Universities: Stanford, a Case Study—For prospective and current new faculty, but open to all interested members of the University community. How modern research universities work. Topics include the history of Stanford and Silicon Valley; university governance; budgets, finance, and indirect costs; appointments and promotions; how to get research funding; research policies; ethical issues in the publication process; current trends in multidisciplinary scholarship; and Stanford and society.
1 unit, Spr (Kruger, Jones)

ENGR 202S. Writing: Special Projects—Structured writing instruction for students working on non-course related materials including theses, dissertations, and journal articles. Weekly individual conferences.
1-5 units, Aut, Win, Spr (Lougee, Staff)

ENGR 202W. Technical and Professional Writing—The process of writing technical and professional documents. Analyzing audiences; defining purpose; generating and selecting appropriate report materials; structuring, designing, and drafting clear and convincing reports; and clear, concise, emphatic, and mechanically and grammatically clean editing. Weekly writing assignments and individual conferences.
3 units, Aut, Win, Spr (Lougee)

ENGR 205. Introduction to Control Design Techniques—Review of root-locus and frequency response techniques for control system analysis and synthesis. State-space techniques for modeling, full-state feedback regulator design, pole placement, and observer design. Combined observer and regulator design. Lab experiments on computers connected to mechanical systems. Prerequisites:105, MATH 103, 113. Recommended: knowledge of Matlab.
3 units, Aut (Tomlin)

ENGR 206. Control System Design—Design and construction of a control system and working plant. Topics include: linearity, actuator saturation, sensor placement, controller and model order; linearization by differential actuation and sensing; analog op-amp circuit implementation. Emphasis is on qualitative aspects of analysis and synthesis, generation of candidate design, and engineering tradeoffs in system selection. Large team-based project. Prerequisite: ENGR 105.
4 units, Spr (Niemeyer)

ENGR 207A. Modern Control Design I—Design and analysis of controllers for discrete-time systems. Frequency domain techniques using z-transforms, and time-domain techniques using state-space linear dynamical systems. Introduction to ideas of linear estimation, linear state-feedback control, and optimal control. Simple laboratory experiments on mechanical systems. Prerequisites: 205 or EE 263, and familiarity with basic linear algebra.
3 units, Win (Lall)

ENGR 207B. Modern Control Design II—Design of optimal controllers and optimal estimators for linear dynamical systems. D eterministic linear estimation via least-squares methods, and stochastic minimum variance estimators. The effects of noise on linear systems using frequency-domain and state-space methods. Recursive filtering and smoothing, and the Kalman filter. Prerequisites: 207A and basic probability.
3 units, Spr (Lall)

ENGR 209A. Analysis and Control of Nonlinear Systems—First of series. Introduction to nonlinear phenomena: multiple equilibria, limit cycles, bifurcations, complex dynamical behavior. Planar dynamical systems, analysis using phase plane techniques. Describing functions. Lyapunov stability theory. SISO feedback linearization, sliding mode control. Design examples. Prerequisites: 205, MATH 113, EE 263.
3 units, Win (Tomlin)

ENGR 209B. Advanced Nonlinear Control—Second of series. Introduction to differential geometry. Input/output analysis and stability: small gain theorems, passivity theorems, Lure problem. Popov and circle criteria. Geometric nonlinear control. MIMO feedback linearization; backstepping. Design examples. Prerequisite: 209A.
3 units (Tomlin) alternate years, given 2005-06

ENGR 210A. Robust Control Analysis and Synthesis—Analysis and design of feedback controllers for systems subject to significant modeling uncertainty and unknown disturbances. Formulation and solution of control design problems using convex optimization. Parameterization of all stabilizing controllers, and computation of stability and performance margins. Prerequisites: 207B or EE 363, or equivalent..
3 units (Lall) not given 2004-05

ENGR 210B. Advanced Topics in Computation for Control—Recent developments in computational methods. Focus is on the use of convex programming to find both exact and approximate solutions to optimization problems: formulation of physical and logical problems as optimization problems involving polynomial equations and inequalities, use of duality and algebraic methods to find feasible points and certificates of infeasibility, and solution of polynomial optimization problems using semidefinite programming. Applications include feedback control methods for multi-vehicle systems and communications networks. Prerequisites: EE 364 or equivalent course on convex optimization; and 207B or EE 363 or equivalent course on control. GER:2b
3 units, Aut (Lall)

ENGR 220A,B,C. Partial Differential Equations of Applied Mathematics—(Enroll in MATH 220A,B,C.)
3 units, Aut (Liu), Win (Levy), Spr (Papanicolaou)

ENGR 235A,B. Space Systems Engineering—40-50 students, mostly from engineering and science, but also from business and political science, form a team to prepare a preliminary design study of a space system. Recently, international engineers have joined the team to define an initiative to put humans on Mars by 2010. Continued studies with Japan, Russia, and Europe define space vehicles for the missions. About 20 invited speakers from government and industry give the necessary background information. At the end of the second quarter, the class gives an oral briefing to government and industry representatives and publishes a final report on the system. Prerequisite: senior or graduate standing in Engineering or Physics, or consent of instructor.
3 units, **A.** *Win,* **B.** *Spr (Lusignan)*

ENGR 250. Social Entrepreneurship Startup—(Undergraduates register for ENGR 150; see 150).
1-6 units, Aut, Win, Spr (Behrman)

ENGR 251. Work Seminar—Students participate in the Creating Research Examples Across the Teaching Enterprise (CREATE) writing program. Goal is for students to produce, through a peer reviewed process, 1,000 word statements describing their research in ways that are understandable and compelling to undergraduates and other novices in the field. Unit credit when the final approved statements appear on the CREATE web site.
1 unit, Aut, Win, Spr (Reis)

ENGR 290. Graduate Environment of Support—Discussion by guest faculty, advanced graduate students, specialists from industry and government, and the dean's office. Topics and information are related to adapting graduate study to the environment in terms of psychosocial, financial, and career issues. How these relate to diversity, affirmative action and minority services, resources, policies, and procedures. Readings and observation participation sessions.
1 unit, Aut (Osgood, Lozano)

ENGR 297A,B,C. Ethics of Development in a Global Environment—Wednesday evening seminars on world affairs, mostly on issues affecting poor nations. Autumn Quarter treats war and peace: the background of current wars and peace negotiations, the UN peace keeping efforts, war and religion, arms trade. Winter Quarter treats international resources and commerce: the debt crisis, environmental protection, resource depletion, Japan in the world economy, aid and monetary institutions. Spring Quarter treats poverty and prejudice: development models, comparative national health, AIDS, control of wealth, India, China, Africa, S. America today. Expert speakers from Stanford and other institutions who deal directly with world policy makers through research and advisory activities. One unit credit for attendance of the speaker series; 3 units additional credit for workshops treating issues in more depth. Sequential registration not required.
1-4 units, Aut, Win, Spr (Lusignan)

ENGR 298. Seminar in Fluid Mechanics—Interdepartmental seminar on problems in all branches of fluid mechanics, with talks by visitors, faculty, and students. Graduate students may register for 1 unit, without letter grade; a letter grade is given for talks. (AU)
1 unit, Aut (Lele), Win (Pitsch), Spr (Fringer)

ENGR 299. Special Studies in Engineering—Special studies, lab work, or reading under the direction of a faculty member. Often research experience opportunities exist in ongoing research projects. Students make arrangements with individual faculty and enroll in the corresponding section. Prerequisite: consent of instructor.
1-15 units, Aut, Win, Spr (Osgood)

ENGR 310A. Tools for Team-Based Design—(Same as ME 310A.) For graduate students; open to limited SITN/global enrollment. Project-based, exposing students to the tools and methodologies for forming and managing an effective engineering design team in a business environment, including product development teams that may be spread around the world. Topics: personality profiles for creating teams with balanced diversity; computational tools for project coordination and management; real time electronic documentation as a critical design process variable; and methods for refining project requirements to ensure that the team addresses the right problem with the right solution. Computer-aided tools for supporting geographically distributed teams. Final project analyzes industry-sponsored design projects for consideration in 310B,C. Investigation includes benchmarking and meetings with industrial clients. Deliverable is a detailed document with project specifications and optimal design team for subsequent quarters. Limited enrollment.
3-4 units, Aut (Cutkosky, Leifer)

ENGR 310B,C. Design Project Experience with Corporate Partners—(Same as ME 310B,C.) Two quarter project for graduate students with design experience who want involvement in an entrepreneurial design team with real world industrial partners. Products developed are part of the student's portfolio. Each team functions as a small startup company with a technical advisory board of the instructional staff and a coach. Computer-aided tools for project management, communication, and documentation; budget provided for direct expenses including technical assistants and conducting tests. Corporate liaisons via site visits, video conferencing, email, fax, and phone. Hardware demonstrations, peer reviews, scheduled documentation releases, and a team environment provide the mechanisms and culture for design information sharing. Enrollment by consent of instructor; depends on a pre-enrollment survey in December and recommendations by project definition teams in 310A. For some projects, 217 and 218 may be prerequisites or corequisites; see http://me310.stanford.edu for admission guidelines.
3-4 units, Win, Spr (Cutkosky, Leifer)

ENGR 310X. Tools for Team-Based Design Global Teaming Lab—(Same as ME 310X.) Participation in a global design team with students in Sweden or Japan. Limited enrollment. Prerequisite: consent of instructor. Corequisite: ENGR 310A,B,C.
1 unit, Win, Spr (Cutkosky, Leifer)

ENGR 311A. Women's Perspective: Choose Your Own Adventure—Master's and Ph.D. seminar series driven by student interests. Possible topics: time management, career choices, health and family, diversity, professional development, and personal values. Graduate students share experiences and examine scientific research in these areas. Guests speakers from academia and industry, student presentations with an emphasis on group discussion. (AU)
1 unit, Win, Spr (Sheppard)

ENGR 311B. Engineering: Women's Perspective—Continuation of 311A.
1 unit, Spr (Sheppard)

OVERSEAS STUDIES

These course are approved for the School of Engineering and offered on video overseas at the location indicated. Students should discuss with their major department adviser which courses would best meet individual needs. Descriptions are in the "Overseas Studies" section of this bulletin.

BERLIN

ENGR 40B. Introductory Electronics
5 units, Aut, Win, Spr (Khuri-Yakub)

ENGR 50B. Introductory Science of Materials
4 units, Aut, Win, Spr (Bravman)

FLORENCE

ENGR 50F. Introductory Science of Materials
4 units, Aut, Win, Spr (Bravman)

KYOTO

ENGR 40K. Introductory Electronics
5 units, Spr (Khuri-Yakub)

ENGR 50K. Introductory Science of Materials
4 units, Spr (Bravman)

PARIS

ENGR 40P. Introductory Electronics
5 units, Aut, Spr (Khuri-Yakub)

ENGR 50P. Introductory Science of Materials
4 units, Aut, Win, Spr (Bravman)

AERONAUTICS AND ASTRONAUTICS

Emeriti: (Professors) Holt Ashley,* Donald Baganoff, Peter Bradshaw, Arthur E. Bryson, Robert H. Cannon, I-Dee Chang, Chi-Chang Chao, Daniel B. DeBra,* Erastus H. Lee, Jean Mayers, Bradford W. Parkinson,* J. David Powell,* Stephen W. Tsai,* Milton D. Van Dyke, Walter G. Vincenti
Chair: Brian J. Cantwell
Professors: Brian J. Cantwell, Fu-Kuo Chang, Per Enge, Antony Jameson, Ilan Kroo, Sanjiva Lele, Robert W. MacCormack, Stephen Rock, George S. Springer, Charles R. Steele
Assistant Professors: Juan Alonso, Sanjay Lall, Claire Tomlin, Matthew West
Professor (Research): Richard Christensen
Courtesy Professors: Ronald K. Hanson, Lambertus Hesselink
Consulting Professors: David Altman, Cynthia H. Null, Bernard Ross, Robert Twiggs
Consulting Associate Professor: Jonathan P. How
Lecturer: Thomas H. Pulliam

* Recalled to active duty.

Phone: (650) 723-3317
Web Site: http://aa.stanford.edu

Courses given in Aeronautics and Astronautics have the subject code AA. For a complete list of subject codes, see Appendix.

The Department of Aeronautics and Astronautics prepares students for professional positions in industry, government, and academia by offering a comprehensive program of graduate teaching and research. In this broad program, students have the opportunity to learn and integrate multiple engineering disciplines. The program emphasizes structural, aerodynamic, guidance and control, and propulsion problems of aircraft and spacecraft. Courses in the teaching program lead to the degrees of Master of Science, Engineer, and Doctor of Philosophy. Undergraduates and doctoral students in other departments may also elect a minor in Aeronautics and Astronautics.

Requirements for all degrees include courses on basic topics in Aeronautics and Astronautics, as well as in Mathematics, and related fields in Engineering and the Sciences.

The current research and teaching activities cover a number of advanced fields, with special emphasis on:

Active Noise Control
Aerodynamic Noise
Aeroelasticity and Flow Simulation
Aircraft Design, Performance, and Control
Applied Aerodynamics
Biomedical Mechanics
Computational Aero-Acoustics
Computational Fluid Dynamics
Computational Mechanics and Dynamical Systems
Control of Robots, including Space and Deep-Underwater Robots
Conventional and Composite Materials and Structures
Direct and Large-Eddy Simulation of Turbulence
High-Lift Aerodynamics
Hybrid Propulsion
Hypersonic and Supersonic Flow
Inertial Instruments
Multidisciplinary Design Optimization
Navigation Systems (especially GPS)
Networked and Hybrid Control
Optimal Control, Estimation, System Identification
Physical Gas Dynamics
Spacecraft Design and Satellite Engineering
Turbulent Flow and Combustion

INSTRUCTION AND RESEARCH FACILITIES

The work of the department is centered in the William F. Durand Building for Space Engineering and Science. This 120,000 square foot building houses advanced research and teaching facilities and concentrates in one complex the Department of Aeronautics and Astronautics as well as some of the activities of the Mechanical Engineering Department.

The Durand Building also houses faculty and staff offices and several conference rooms. Attached to the building is a modern classroom building equipped for televising lectures; it contains a lecture auditorium.

Through the department's close relations with nearby NASA-Ames Research Center, students and faculty have access to one of the best and most extensive collections of experimental aeronautical research facilities in the world, as well as the latest generation of supercomputers.

GENERAL INFORMATION

Further information about the facilities and programs of the department is available at http://aa.stanford.edu/, or from the department's student services office.

The department has a student branch of the American Institute of Aeronautics and Astronautics, which sponsors films covering aerospace topics and monthly socials. It also conducts visits to nearby research, government, and industrial facilities, and sponsors a Young Astronauts Program in the local schools.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

Although primarily a graduate-level department, Aeronautics and Astronautics offers both an undergraduate minor and an interdisciplinary program in Aeronautics and Astronautics (AA) leading to the B.S. degree in Engineering. For detailed information, see the "School of Engineering" section of this bulletin and the *Undergraduate Handbook*, available from the Office of the Dean of Engineering or at http://ughb.stanford.edu.

Undergraduates interested in aerospace are encouraged to combine either a minor or a coterminal M.S. in Aeronautics and Astronautics with a major in a related discipline (such as Mechanical or Electrical Engineering). Students considering these options are encouraged to contact the department's student services office.

COTERMINAL DEGREES PROGRAM

This special program allows Stanford undergraduates an opportunity to work simultaneously toward a B.S. in another field and an M.S. in Aeronautics and Astronautics. General requirements for this program and admissions procedures are described in the "School of Engineering" section of this bulletin. Admission is granted or denied through the departmental faculty Admissions and Awards Committee. A coterminal student must meet the course and scholarship requirements detailed for the M.S. below.

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

GRADUATE PROGRAMS

Admission—To be eligible to apply for admission to the department, a student must have a bachelor's degree in engineering, physical science, mathematics, or an acceptable equivalent. Students who have not yet received a master's degree in a closely allied discipline will be admitted to the master's program; eligibility for the Ph.D. program is considered after the master's year (see "Doctor of Philosophy" below). Applications for admission including financial aid (fellowships or assistantships) must be received and completed by December 7 for the next Autumn Quarter; applications for admission without financial aid are accepted until January 18.

Information about admission to the Honors Cooperative Program is included in the "School of Engineering" section of this bulletin. The department may consider HCP applications for Winter, Spring, or Summer quarters as well as for Autumn Quarter; prospective applicants should contact the department's student services office.

Further information and application forms for all graduate degree programs may be obtained from Graduate Admissions, the Registrar's Office, http://gradadmissions.stanford.edu/.

Waivers and Transfer Credits—Students may receive departmental waivers of required courses for the M.S. degree in Aeronautics and Astronautics by virtue of substantially equivalent and satisfactorily performed course work at other institutions. A waiver petition (signed by the course instructor and adviser) should be submitted to the student services office indicating (1) the Stanford University course number and title, and (2) the institution, number(s), and title(s) of the course(s) wherein substantially equivalent material was treated. If a waiver is granted, the student must take an additional technical elective, chosen in consultation with their adviser, from graduate courses in Aeronautics and Astronautics. The total 45-unit requirement for the master's degree is not reduced by course waivers.

A similar procedure should be followed for transfer credits. The number of transfer credits allowed for each degree (Engineer and Ph.D.) is delineated in the "Graduate Degrees" section of this bulletin; transfer credit is not accepted for the M.S. degree. Transfer credit is allowed only for courses taken as a graduate student, after receiving a bachelor's degree, in which equivalence to Stanford courses is established and for which a grade of 'B' or better has been awarded. Transfer credits, if approved, reduce the total number of Stanford units required for a degree.

Fellowships and Assistantships—Fellowships and course or research assistantships are available to qualified graduate students. Fellowships sponsored by Gift Funds, Stanford University, and Industrial Affiliates of Stanford University in Aeronautics and Astronautics provide grants to several first-year students for the nine-month academic year to cover tuition and living expenses. Stanford Graduate Fellowships, sponsored by the University, provide grants for three full years of study and research; each year, the department is invited to nominate several outstanding doctoral or predoctoral students for these prestigious awards. Students who have excelled in their master's-level course work at Stanford are eligible for course assistantships in the department; those who have demonstrated research capability are eligible for research assistantships from individual faculty members. (Students may also hold assistantships in other departments if the work is related to their academic progress; the criteria for selecting course or research assistants are determined by each hiring department.) A standard, 20 hours/week course or research assistantship provides a semi-monthly salary and an 8-10 unit tuition grant per quarter. Research assistants may be given the opportunity of additional summer employment. They may use their work as the basis for a dissertation or Engineer's thesis.

MASTER OF SCIENCE

The University's basic requirements for the master's degree are outlined in the "Graduate Degrees" section of this bulletin. Students with an aeronautical engineering background should be able to qualify for the master's degree in three quarters of work at Stanford. Students with a bachelor's degree in Physical Science, Mathematics, or other areas of Engineering may find it necessary to take certain prerequisite courses, which would lengthen the time required to obtain the master's degree. The following are departmental requirements.

Grade Point Averages—A minimum grade point average (GPA) of 2.75 is required to fulfill the department's M.S. degree requirements and a 3.4 is the minimum required for eligibility to attempt the Ph.D. qualifying examination. It is incumbent upon both M.S. and potential Ph.D. candidates to request letter grades in all courses except those that do not offer a letter grade option and those that fall into the categories of colloquia and seminars (for example, AA 297 and ENGR 298). Insufficient grade points on which to base the GPA may delay expected degree conferral or result in refusal of permission to take the qualifying examinations. Candidates with GPAs of 3.0 through 3.4 may request the permission of the candidacy committee to attempt the qualifying examinations.

AERONAUTICS AND ASTRONAUTICS

The master's program (45 units) in Aeronautics and Astronautics (AA) is designed to provide a solid grounding in the basic disciplines. All candidates for this degree are expected to meet the basic course requirements in experimentation in aeronautics and astronautics, fluid mechanics, guidance and control, propulsion, and structural mechanics (category A below), in addition to work in applied mathematics (category B) and technical electives (category C).

A. *Basic Courses*—Candidates select eight courses as follows:

1. One course in each basic area of Aeronautics and Astronautics::
   a) Experimentation: 241X, 236A or 290; or ENGR 205, 206, or 207A
   b) Fluids: one of 200A, 200B, 210A
   c) Guidance and Control: ENGR 105
   d) Propulsion: 283
   e) Structures: 240A
2. Three courses, one each from three of the areas below:
   a) Fluids: 200A or 200B (if 210A was taken or waived in item 1); or 210A (if 200A or 200B was taken or waived in item 1)
   b) Structures: 240B or 256
   c) Guidance and Control: 242A or 271A or 279
   d) Aero/Astro elective: AA course numbered 200 and above, excluding seminars and independent research.

Candidates who believe they have satisfied a basic courses requirement in previous study may request a waiver of one or more courses (see "Waivers and Transfer Credits" above).

B. *Mathematics Courses*—During graduate study, each candidate is expected to develop a competence in the applied mathematics pertinent to his or her major field. This requirement can be met by matriculating in a minimum of 6 units in either (1) applied mathematics (for example, complex variables, linear algebra, partial differential equations, probability), or (2) technical electives that strongly emphasize applied mathematics. A list of courses approved for the mathematics requirement is available in the departmental student services office. (Calculus, ordinary differential equations, and vector analysis are fundamental mathematics prerequisites, and do not satisfy the master's mathematics requirement.) Students planning to continue to the Ph.D. should note that 25 percent of the major-field Ph.D. qualifying examination is devoted to pertinent mathematics.

C. *Technical Electives*—Candidates, in consultation with their advisers, select at least four courses (totaling at least 12 units) in their major field from among the graduate-level courses offered by the departments of the School of Engineering and related science departments. This requirement increases by one course, taken in either the major or peripheral fields, for each basic course that is waived. Normally, one course (3 units) in this category may be directed research. Courses taken in satisfaction of the other master's requirements (categories A, B, and D) may not also be counted as technical electives.

D. *Other Electives*—It is recommended that all candidates enroll in at least one humanities or social science course. Language classes qualify in this category, but practicing courses in, for example, art, music, and physical education do not qualify.

When planning their programs, candidates should check course descriptions carefully to ensure that all prerequisites have been satisfied. A course that is taken to satisfy a prerequisite for courses in category A (basic courses) or B (mathematics) cannot be counted as a technical elective, but can count toward the M.S. degree in category D (other electives).

ENGINEERING

Students whose career objectives require a more interdepartmental or narrowly focused program than is possible in the M.S. program in Aeronautics and Astronautics (AA) may pursue a program for an M.S. degree in Engineering (45 units). This program is described in the School of Engineering "Graduate Programs of Study" section of this bulletin.

Sponsorship by the Department of Aeronautics and Astronautics in this more general program requires that the student file a proposal before completing 18 units of the proposed graduate program. The proposal must be accompanied by a statement explaining the objectives of the program and how the program is coherent, contains depth, and fulfills a well-defined career objective. The proposed program must include at least 12 units of graduate-level work in the department and meet rigorous standards of technical breadth and depth comparable to the regular AA Master of Science program. The grade and unit requirements are the same as for the M.S. degree in Aeronautics and Astronautics.

ENGINEER

The degree of Engineer represents an additional year (or more) of study beyond the M.S. degree and includes a research thesis. The program is designed for students who wish to do professional engineering work upon graduation and who want to engage in more specialized study than is afforded by the master's degree alone. It is expected that fulltime students will be able to complete the degree within two years of study after the master's degree.

The University's basic requirements for the degree of Engineer are outlined in the "Graduate Degrees" section of this bulletin. The following are department requirements.

The candidate's prior study program should have fulfilled the department's requirements for the master's degree or a substantial equivalent. Beyond the master's degree, a total of 45 units of work is required, including a thesis and a minimum of 30 units of courses chosen as follows:

1. 24 units of approved technical electives, of which 9 are in mathematics or applied mathematics. (A list of courses approved for the mathematics requirement is available in the departmental student services office.) The remaining 15 units are chosen in consultation with the adviser, and represent a coherent field of study related to the thesis topic. Suggested fields include: (a) acoustics, (b) aerospace structures, (c) aerospace systems synthesis and design, (d) analytical and experimental methods in solid and fluid mechanics, (e) computational fluid dynamics, and (f) guidance and control.
2. 6 units of free electives.
3. The remaining 15 units may be thesis, research, technical courses, or free electives.

Candidates for the degree of Engineer are expected to have a minimum grade point average (GPA) of 3.0 for work in courses beyond those required for the master's degree. All courses except seminars and directed research should be taken for a grade.

DOCTOR OF PHILOSOPHY

The University's basic requirements for the Ph.D. degree are outlined in the "Graduate Degrees" section of this bulletin. Department requirements are stated below.

Qualifications for candidacy for the doctoral degree are contingent on:

1. Having fulfilled department requirements for the master's degree or its substantial equivalent.
2. Maintaining a high scholastic record for graduate course work at Stanford.
3. Completing 3 units of a directed research problem (AA 290 or an approved alternative).
4. In the first year of doctoral study, passing an oral Ph.D. qualifying examination given by the department during Autumn and Spring Quarters.

Detailed information about the deadlines, nature, and scope of the Ph.D. qualifying examination can be obtained from the department. Research on the doctoral dissertation may not be formally started before passing this examination.

Beyond the master's degree, a total of 90 additional units of work is required, including a minimum of 36 units of approved formal course work (excluding research, directed study, and seminars). The courses should consist primarily of graduate courses in engineering and related sciences, and should form a strong and coherent doctoral program. At least 12 units must be from graduate-level courses in mathematics or applied mathematics (a list of approved courses is available from the department student services office). University requirements for continuous registration apply to doctoral students for the duration of the degree.

Dissertation Reading Committee—Each Ph.D. candidate is required to establish a reading committee for the doctoral dissertation within six months after passing the department's Ph.D. Qualifying exams. Thereafter, the student should consult frequently with all members of the committee about the direction and progress of the dissertation research.

A dissertation reading committee consists of the principal dissertation adviser and at least two other readers. Reading committees in Aeronautics and Astronautics often include faculty from another department. It is expected that at least two members of the AA faculty be on each reading committee. If the principal research adviser is not within the AA department, then the student's AA academic adviser should be one of those members. The initial committee, and any subsequent changes, must be officially approved by the department Chair.

University Oral and Dissertation—The Ph.D. candidate is required to take the University oral examination after the dissertation is substantially completed (with the dissertation draft in writing), but before final approval. The examination consists of a public presentation of dissertation research, followed by substantive private questioning on the dissertation and related fields by the University oral committee (four selected faculty members, plus a chair from another department). Once the oral has been passed, the student finalizes the dissertation for reading committee review and final approval. Forms for the University oral scheduling and a one-page dissertation abstract should be submitted to the department student services office at least three weeks prior to the date of the oral for departmental review and approval.

PH.D. MINOR

A student who wishes to obtain a Ph.D. minor in Aeronautics and Astronautics should consult the department office for designation of a minor adviser. A minor in Aeronautics and Astronautics may be obtained by completing 20 units of graduate-level courses in the Department of Aeronautics and Astronautics, following a program (and performance) approved by the department's candidacy chair.

The student's Ph.D. reading committee and University oral committee must each include at least one faculty member from Aeronautics and Astronautics.

COURSES

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

AA 100. Introduction to Aeronautics and Astronautics—The principles of fluid flow, flight, and propulsion; the creation of lift and drag, aerodynamic performance including take-off, climb, range, and landing performance, structural concepts, propulsion systems, trajectories, and orbits. Remarks on the history of aeronautics and astronautics. Prerequisites: MATH 41, 42; elementary physics. GER:2b

3 units, Aut (Alonso)

AA 105. Feedback Control Design—(Enroll in ENGR 105.)

3 units, Win (Rock)

AA 113N. Structures: Why Things Don't (and Sometimes Do) Fall Down—Stanford Introductory Seminar. Preference to freshmen. Structures keep things up and keep things in. How structures created by nature or built by human beings perform these tasks. Topics: nature's structures from microorganisms to large vertebrae; buildings from ancient dwellings to modern skyscrapers; spacecraft and airplanes; boats from ancient times to America's Cup sailboats, and how they win or break; sports equipment from Odysseus's bow to modern skis; and biomedical devices including bone replacements and cardiovascular stents. How composite materials are used to make a structure light and strong. GER:2b

3 units, Win (Springer)

AA 115N. The Global Positioning System: Where on Earth are We, and What Time is It?—Stanford Introductory Seminar. Preference to freshmen. Why people want to know where they are: answers include cross-Pacific trips of Polynesians, missile guidance, and distraught callers. How people determine where they are: navigation technology from dead-reckoning, sextants, and satellite navigation (GPS). Hands-on experience. How GPS works; when it does not work; possibilities for improving performance. GER:2b

3 units, Aut (Enge)

AA 190. Directed Research and Writing in Aero/Astro—For undergraduates. Experimental or theoretical work under faculty direction, and emphasizing development of research and communication skills. Written report(s) and letter grade required; if this is not appropriate, enroll in 199. Consult faculty in area of interest for appropriate topics, involving one of the graduate research groups or other special projects. Prerequisite: consent of student services manager and instructor. WIM

3-5 units, Aut, Win, Spr, Sum (Staff)

AA 199. Independent Study in Aero/Astro—Directed reading, lab, or theoretical work for undergraduates. Consult faculty in area of interest for topics involving one of the graduate research groups or other special projects. Prerequisite: consent of instructor.

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

AA 200A. Applied Aerodynamics—Review of the fundamental equations of fluid dynamics and the physical assumptions on which they are based; overview of appropriate methods for solving these equations including nonlinear CFD, conformal mapping, linear panel and vortex methods; estimation of pressure distributions and resultant airloads on 2-D airfoils, finite wings, slender bodies, and lifting systems; compressibility effects; boundary layer analysis and prediction of drag, separation, and displacement effects. Application to airfoil and wing design. Prerequisite: undergraduate aeronautics course. Recommended: 210A.

3 units, Win (MacCormack)

AA 200B. Applied Aerodynamics II—Analytical and numerical techniques for the aerodynamic analysis of aircraft, focusing on finite wing theory, far-field and Trefftz-plane analysis, two-dimensional laminar and turbulent boundary layers in airfoil analysis, similarity rules, aerodynamic stability derivatives. Bi-weekly assignments require MATLAB or a suitable programming language. Prerequisite: 200A or equivalent. Recommended: 210A.

2-3 units, Win (Alonso)

AA 201A. Fundamentals of Acoustics—Acoustic equations for a stationary homogeneous fluid; wave equation; plane, spherical, and cylindrical waves; harmonic (monochromatic) waves; simple sound radiators; reflection and transmission of sound at interfaces between different media; multipole analysis of sound radiation; Kirchoff integral representation; scattering and diffraction of sound; propagation through ducts (dispersion, attenuation, group velocity); sound in enclosed regions (reverberation, absorption, and dispersion); radiation from moving sources; propagation in the atmosphere and underwater. Prerequisite: first-year graduate standing in engineering, mathematics, sciences; or consent of instructor.

3 units, Spr (Lele)

AA 201B. Topics in Aeroacoustics—Acoustic equations for moving medium, simple sources, Kirchhoff formula, and multipole representation; radiation from moving sources; acoustic analogy approach to sound generation in compact flows; theories of Lighthill, Powell, and Mohring; acoustic radiation from moving surfaces; theories of Curl, Williams, and Hawkings; application of acoustic theories to the noise from propulsive jets, airframe noise and rotor noise; computational methods for acoustics. Prerequisite: 201A or consent of instructor.

3 units (Lele) not given 2004-05

AA 206. Bio-Aerodynamics—The fundamental ideas behind the aerodynamics of biological systems. Flapping flight, low Reynolds number aerodynamics, wing design, flocks, swarms, and dynamic soaring. Readings from current and historical literature dealing with theoretical and observational studies. Applications in aircraft design, and simulation-based problem sets. Prerequisites: course in aerodynamics such as 100, 200A, or 241A.

3 units (Kroo) not given 2004-05

AA 208. Aerodynamics of Aircraft Dynamic Response and Stability—Companion to 200A for those interested in control and guidance. Typical vehicles and technical tradeoffs affecting their design. Equations of motion, stressing applications to dynamic performance, stability, and forced response. Forms and sources for the required aerodynamic data. Response to small disturbances and stability derivatives. Static stability and trim. Review of aerodynamic fundamentals, leading to airload predictions for wings, bodies, and complete aircraft. Paneling and other methods for derivative estimation. Natural motions of the aircraft, and the influence on them of various configuration parameters. Vehicle behavior in maneuvers of small and large amplitudes. Pre- or corequisites: 200A, 210A, or equivalents.

3 units (Kroo) not given 2004-05

AA 210A. Fundamentals of Compressible Flow—Introduction to compressible flow. Topics: development of the three-dimensional, nonsteady, field equations for describing the motion of a viscous, compressible fluid; differential and integral forms of the equations; constitutive equations for a compressible fluid; the entropy equation; compressible boundary layers; area-averaged equations for one-dimensional steady flow; shock waves; channel flow with heat addition and friction; flow in nozzles and inlets; oblique shock waves; Prandtl-Meyer expansion; unsteady one-dimensional flow; the shock tube; small disturbance theory; acoustics in one-dimension; steady flow in two-dimensions; potential flow; linearized potential flow; lift and drag of thin airfoils. Prerequisites: undergraduate background in fluid mechanics and thermodynamics.

3 units, Aut (Cantwell)

AA 210B. Fundamentals of Compressible Flow—Continuation of 210A with emphasis on more general flow geometry. Use of exact solutions to explore the hypersonic limit. Identification of similarity parameters. Solution methods for the linearized potential equation with applications to wings and bodies in steady flow; their relation to physical acoustics and wave motion in nonsteady flow. Nonlinear solutions for nonsteady constant area flow and introduction to Riemann invariants. Elements of the theory of characteristics; nozzle design; extension to nonisentropic flow. Real gas effects in compressible flow. Flows in various gas dynamic testing facilities. Prerequisite: 210A.

3 units, Spr (Alonso)

AA 214A. Numerical Methods in Fluid Mechanics—The basic principles underlying the Navier-Stokes equations. Relations between time-accurate and relaxation methods. Implicit and explicit methods combined with flux splitting and space factorization. Considerations of accuracy, stability of numerical methods, and programming complexity. Prerequisites: knowledge of linear algebra and CME 200, 204 (formerly ME 300A,B), or equivalent approved by instructor.
3 units, Aut (Pulliam)

AA 214B. Numerical Computation of Compressible Flow—Numerical methods for solving hyperbolic sets of partial differential equations. Explicit, implicit, flux-split, finite difference, and finite volume procedures for approximating the governing equations and boundary conditions. Numerical solution by direct approximate factorization and iterative Gauss-Seidel line relaxation. Application to the Euler equations in two and three dimensions. Computational problems are assigned. Prerequisite: 214A.
3 units, Win (MacCormack)

AA 214C. Numerical Computation of Viscous Flow—Numerical methods for solving parabolic sets of partial differential equations. Numerical approximation of the equations describing compressible viscous flow with adiabatic, isothermal, slip, and no-slip wall boundary conditions. Applications to the Navier-Stokes equations in two and three dimensions at high Reynolds number. Computational problems are assigned. Prerequisite: 214B.
3 units, Spr (MacCormack)

AA 215A,B. Advanced Computational Fluid Dynamics—High resolution schemes for capturing shock waves and contact discontinuities; upwinding and artificial diffusion; LED and TVD concepts; alternative flow splittings; numerical shock structure. Discretization of Euler and Navier Stokes equations on unstructured meshes; the relationship between finite volume and finite element methods. Time discretization; explicit and implicit schemes; acceleration of steady state calculations; residual averaging; math grid preconditioning. Automatic design; inverse problems and aerodynamic shape optimization via adjoint methods. Pre- or corequisite: 214B or equivalent.
3 units, **A:** *Win,* **B:** *Spr (Jameson)*

AA 217A. Linear Algebra with Application to Engineering Computations—(Enroll in CME 200.)
3 units, Aut (Gerritsen)

AA 217B. Partial Differential Equations in Engineering—(Enroll in CME 204.)
3 units, Win (Lele)

AA 217C. Introduction to Numerical Methods for Engineering—(Enroll in CME 206.)
3 units, Spr (Farhat)

AA 218. Introduction to Symmetry Analysis—Methods of symmetry analysis and their use in the reduction and simplification of physical problems. Topics: dimensional analysis, phase-space analysis of autonomous systems of ordinary differential equations, use of Lie groups to reduce the order of nonlinear ODEs and to generate integrating factors, use of Lie groups to reduce the dimension of partial differential equations and to generate similarity variables, exact solutions of nonlinear PDEs generated from groups. Mathematica-based software developed by the instructor is used for finding invariant groups of ODEs and PDEs. Prerequisite: ME 300A or equivalent.
3 units, Spr (Cantwell)

AA 219A. Computational Methods in Fluid Mechanics—(Enroll in ME 469A.)
3 units, Win (Farhat)

AA 220. Parallel Methods in Numerical Analysis—(Enroll in CS 238, CME 342.)
3 units, Spr (Alonso)

AA 222. Introduction to Multidisciplinary Design Optimization—Design of aerospace systems within a formal optimization environment. Mathematical formulation of the multidisciplinary design problem (parameterization of design space, choice of objective functions, constraint definition); survey of algorithms for unconstrained and constrained optimization and optimality conditions; description of sensitivity analysis techniques. Hierarchical techniques for decomposition of the multidisciplinary design problem; use of approximation theory.Applications to design problems in aircraft and launch vehicle design. Prerequisites: multivariable calculus; familiarity with a high-level programming language: FORTRAN, C, C++, or MATLAB.
3 units (Alonso) not given 2004-05

AA 235A,B. Space Systems Engineering—(Enroll in ENGR 235A,B.)
3 units, **A:** *Win,* **B:** *Spr (Lusignan)*

AA 236A. Spacecraft Design—The design of unmanned spacecraft and spacecraft subsystems, concentrating on identification of design drivers and current design methods. Topics: spacecraft configuration design, mechanical design, structure and thermal subsystem design, attitude control, electric power, command and telemetry, and design integration and operations.
5 units, Aut (Twiggs)

AA 236B,C,D. Spacecraft Design Laboratory—Continuation of 236A. Prerequisite: 236A or consent of instructor.
3 units, **B:** *Win,* **C:** *Spr,* **D:** *Sum (Twiggs)*

AA 238. Human-Centered Design for Aerospace Engineers—The what, when, who, and how of human-centered design. Is it art, or magic? Is it science, or engineering? How to integrate human-centered processes into engineering design processes. Analysis of recent human-centered aeronautical and space systems to evaluate their successes and limitations.
3 units, Aut (Null)

AA 240A. Analysis of Structures—Elements of two-dimensional elasticity theory. Boundary value problems; energy methods; analyses of solid and thin walled section beams, trusses, frames, rings, monocoque and semimonocoque structures. Prerequisite: ENGR 14 or equivalent.
3 units, Aut (Chang)

AA 240B. Analysis of Structures—Thin plate analysis. Structural stability. Material behavior: plasticity and fracture. Introduction of finite element analysis; truss, frame, and plate structures. Prerequisite: 240A or consent of instructor.
3 units, Win (F. Chang)

AA 241A,B. Introduction to Aircraft Design, Synthesis, and Analysis—New aircraft systems emphasizing commercial aircraft. Economic and technological factors that create new aircraft markets. Determining market demands and system mission performance requirements; optimizing configuration to comply with requirements; the interaction of disciplines including aerodynamics, structures, propulsion, guidance, payload, ground support, and parametric studies. Applied aerodynamic and design concepts for use in configuration analysis. Application to a student-selected aeronautical system; applied structural fundamentals emphasizing fatigue and fail-safe considerations; design load determination; weight estimation; propulsion system performance; engine types; environmental problems; performance estimation. Direct/indirect operating costs prediction and interpretation. Aircraft functional systems; avionics; aircraft reliability and maintainability. Prerequisite: 100 or equivalent.
3 units, **A:** *Win,* **B:** *Spr (Kroo)*

AA 241X. Design, Construction, and Testing of Autonomous Aircraft—Students are grouped according to their expertise to carry out the multidisciplinary design of a solar-powered autonomous aircraft that must meet a clearly stated set of design requirements. Emphasis is on design and construction of the airframe, integration with existing guidance, navigation, and control systems, and development and operation of the resulting design. Weekly design reviews and bi-weekly reports.

Prerequisites: expertise in any of the following disciplines by having satisfied the specified courses or equivalent work elsewhere: conceptual design (241A,B); applied aerodynamics (200A,B); structures (240A); composite manufacturing experience; guidance and control (208/271, ENGR 205).
3 units, Aut (Kroo)

AA 242A. Classical Dynamics—(Same as ME 331A.) Accelerating and rotating reference frames. Kinematics of rigid body motion; Euler angles, direction cosines. D'Alembert's principle, equations of motion. Inertia properties of rigid bodies. Dynamics of coupled rigid bodies. Lagrange's equations and their use. Dynamic behavior, stability, and small departures from equilibrium. Prerequiste: ENGR 15 or equivalent.
3 units, Aut (Rock)

AA 242B. Advanced Dynamics—(Same as ME 331B.) Formulation of equations of motion with Newton/Euler equations; angular momentum principle; D'Alembert principle; power, work, and energy; Kane's method; and Lagrange's equations. Numerical solutions of nonlinear algebraic and dfferential equations govering the behavior of multiple degree of freedom systems. Computer simulation of multi-body dynamic systems. Computer simulation of multi-body dynamic systems. Computed torque control.
3 units, Win (Mitiguy)

AA 244A. Free and Forced Motion of Structures—Vibrations and forced response of linear systems with a finite number of degrees of freedom. Vibrations and forced response of continuous structures, developed in a framework of analytical dynamics; rods, beams, membranes, and other elastic systems. Approximate methods for analyzing non-uniform and built-up structures. Finite-element methods in a dynamic context. Introduction to random responses and to nonlinear systems, as time permits. Prerequisites: 240A, ENGR 15 or equivalent.
3 units (Staff) not given 2004-05

AA 245. Structural Dynamics and Aeroelasticity—Finite-element methods and vibration of continuous, two-dimensional structures. Introduction to aeroelasticity from a unified viewpoint applicable to flight vehicles, rotating machinery, and other elastic systems. Aeroelastic operators and unsteady aerodynamics in two dimensions. Forced response, static and dynamic eigenvalues of a simplified system. Aeroelastic analysis of representative one- and two-dimensional systems. Computational problems covering aeroelastic analysis of simple systems. Prerequisite: familiarity with MATLAB or a programming language.
3 units (Alonso) not given 2004-05

AA 246. Computational Impact and Contact Modeling—Rigid body contact including multi-body impact, persistent contact, complementarity formulations, and solution techniques. Impact of elastic bodies using finite elements including penalty and mixed constraint formulations, solution techniques, and time-stepping methods. Shocks and vibration induced by impact. Friction and plasticity models for impact and persistent contact. Prerequisites: 242A, 242B or equivalent, familiarity with MATLAB.
3 units, Win (West)

AA 252. Techniques of Failure Analysis—Introduction to the field of failure analysis, including fire and explosion analysis, large scale catastrophe projects, traffic accident reconstruction, aircraft accident investigation, human factors, biomechanics and accidents, design defect cases, materials failures and metallurgical procedures, and structural failures. Product liability, failure modes and effects analysis, failure prevention, engineering ethics, and the engineer as expert witness.
2 units, Spr (Ross)

AA 253. Aerospace Product and Systems Development—Modern approaches to aerospace design development for life cycle value. Concepts of air and space systems development in a systems context. Stakeholder value issues and requirements through manufacturing and delivery. Processes and practices for functional analysis, concept and architecture development, trades, domain criteria, interfaces, and verification and validation. Reliability, risk, and safety. Value stream analysis, integrated product and process development, key characteristics, and hardware/software integration aimed at information systems. Tools involve quality function deployment, design structure matrices, and decision mechanisms.
3 units, Spr (Weiss)

AA 254. Information Systems in Aerospace Vehiches—Sensors, processors, activators, and operators, and the media and protocols that integrate them for performance and safety.
2 units, Win (Staff)

AA 256. Mechanics of Composites—Fiber reinforced composites. Stress, strain, and strength of composite laminates and honeycomb structures. Failure modes and failure criteria. Environmental effects. Manufacturing processes. Design of composite structures. Individual design project required of each student, resulting in a usable computer software. Prerequisite: ENGR 14 or equivalent.
3 units, Win (Springer)

AA 257. Design of Composite Structures—Hands-on design, analysis, and manufacturing in composites. Composite beams, columns, and plates; application of finite element methods to composite structures; failure analysis and damage tolerance design of composite structures; and impact damage, compression after impact, and bolted and bonded composites joints. Class divided into working teams (design, analysis, manufacturing, and tests) to design and build a composite structure to be tested to failure at the end; the structure may enter the national SAMPE composite bridge design contest. Prerequisite: 256 or consent of instructor.
3 units, Spr (F. Chang)

AA 259A. Advanced Design and Engineering of Space Systems I—(Enroll in ME 359A.) The application of advanced theory and concepts to the development of spacecraft and missile subsystems; taught by experts in their fields. Practical aspects of design and integration. Mission analysis, systems design and verification, radiation and space environments, orbital mechanics, space propulsion, electrical power and avionics subsystems, payload communications, and attitude control. Subsystem-oriented design problems focused around a mission to be completed in groups. Tours of Lockheed Martin facilities. Limited enrollment. Prerequisites: undergraduate degree in related engineering field or consent of instructor.
4 units, Win (Khayms)

AA 259B. Advanced Design and Engineering of Space Systems II—(Enroll in ME 359B.)
4 units, Spr (Yiu)

AA 261A. Turbulence—(Enroll in ME 361.)
3 units, Spr (Pitsch)

AA 271A. Dynamics and Control of Spacecraft and Aircraft—The dynamic behavior of aircraft and spacecraft, and the design of automatic control systems for them. For aircraft: non-linear and linearized longitudinal and lateral dynamics; linearized aerodynamics; natural modes of motion; autopilot design to enhance stability, control the flight path, and perform automatic landings. For spacecraft in orbit: natural longitudinal and lateral dynamic behavior and the design of attitude control systems. Prerequisites: AA 242A, ENGR 105.
3 units, Spr (Rock)

AA 272C. Global Positioning Systems—The principles of satellite navigation using GPS. Positioning techniques using code tracking, single and dual frequency, carrier aiding, and use of differential GPS for improved accuracy and integrity. Use of differential carrier techniques for attitude determination and precision position determination. Prerequisite: familiarity with matrix algebra.
3 units, Win (Enge)

AA 272D. Integrated Navigation Systems—Review of navigation satellites (GPS, GLONASS), GPS receivers, principles of inertial navigation for ships, aircraft, and spacecraft. Kalman Filters to integrate GPS and inertial sensors. Radio navigation aids (VOR, DME, LORAN, ILS). Doppler navigation systems. Prerequisites: 272C; ENGR 15, 105. Recommended: ENGR 205.
3 units (Enge) not given 2004-05

AA 273A,B. Modern Control Design I/II—(Enroll in ENGR 207A,B.)
3 units, **A:** *Win,* **B:** *Spr (Lall)*

AA 275. Introduction to Control Design Techniques—(Enroll in ENGR 205.)
3 units, Aut (Tomlin)

AA 276. Control System Design—(Enroll in ENGR 206.)
4 units, Spr (Niemeyer)

AA 277A. Analysis and Control of Nonlinear Systems—(Enroll in ENGR 209A.)
3 units, Win (Tomlin)

AA 277B. Advanced Nonlinear Control—(Enroll in ENGR 209B.)
3 units (Tomlin) alternate years, given 2005-06

AA 278. Optimal Control and Hybrid Systems—Models for continuous-time and discrete-event dynamic systems. Modeling techniques for hybrid systems. Optimization problems for continuous and discrete dynamic systems. Dynamic programming and the Hamilton-Jacobi equation. Differential games. Automatic verification and controller synthesis for hybrid systems. Hybrid systems simulation. Driving examples from flight management system logic, and automated air traffic systems. Prerequisites: EE 263, ENGR 209.
3 units, Spr (Tomlin)

AA 279. Space Mechanics—Orbits of near-earth satellites and interplanetary probes; transfer and rendezvous; decay of satellite orbits; influence of earth's oblateness; sun and moon effects on earth satellites. Prerequisite: ENGR 15 or equivalent.
3 units, Spr (West)

AA 283. Aircraft and Rocket Propulsion—Introduction to the design and performance of airbreathing and rocket engines. Topics: the physical parameters used to characterize propulsion system performance; gas dynamics of nozzles and inlets; cycle analysis of ramjets, turbojets, turbofans, and turboprops; component matching and the compressor map; introduction to liquid and solid propellant rockets; multistage rockets; hybrid rockets; thermodynamics of reacting gases. Prerequisites: undergraduate background in fluid mechanics and thermodynamics.
3 units, Win (Cantwell)

AA 284A. Propulsion System Design—Three-course series introducing propulsion systems engineering through the design and operation of a sounding rocket. Students work in small teams, experience a full project cycle from requirements definition, performance analysis, system design, and fabrication to ground testing, flight testing, and evaluation. Complete system including propulsion, vehicle structure, vehicle aerodynamics, avionics, payload, and recovery apparatus. Students grouped by area of interest. Prerequisite: 283 or equivalent; consent of instructor.
3 units, Spr (Karabeyoglu, Zilliac)

AA 284B. Propulsion System Design Laboratory—Prerequisite: 284A and consent of instructor.
3 units, Sum (Karabeyoglu, Zilliac)

AA 284C. Propulsion System Design Laboratory—Continuation of 284A,B. Prerequisite: 284B, and consent of instructor.
3 units, Aut (Karabeyoglu, Zilliac)

AA 290. Problems in Aero/Astro—(Undergraduates register for 190 or 199.) Experimental or theoretical investigation. Students may work in any field of special interest. Register for section belonging to your research supervisor.
1-5 units, Aut, Win, Spr, Sum (Staff)

AA 291. Practical Training—Educational opportunities in high-technology research and development labs in aerospace and related industries. Qualified graduate students engage in internship work and integrate that work into their academic program. Students register in the quarter of their internship work, and at the end of the quarter submit a research report outlining their work activity, problems investigated, key results, and any follow-on projects they expect to perform as part of further graduate education. Meets the requirements for Curricular Practical Training for students on F-1 visas. Sign up for section number corresponding to your academic adviser. Student is responsible for arranging own employment and should see department student services manager before enrolling.
1-3 units, Sum (Staff)

AA 294. Case Studies in Aircraft Design—Presentations by researchers and industry professionals. Registration for credit optional. May be repeated for credit. Optional research paper for additional credit.
1 unit, Spr (Jameson)

AA 297. Seminar in Guidance, Navigation, and Control—For graduate students; others welcome. Problems in all branches of vehicle control, guidance, and instrumentation presented by researchers on and off campus. Registration for credit optional. May be repeated for credit. (AU)
1 unit, Aut, Win, Spr (Staff)

AA 298. Seminar in Fluid Mechanics—(Enroll in ENGR 298.)
1 unit, Aut (Lele), Win (Pitsch), Spr (Fringer)

AA 300. Engineer Thesis—Thesis for degree of Engineer. Students register for section belonging to their thesis adviser.
1-15 units, Aut, Win, Spr (Staff)

AA 301. Ph.D. Dissertation—Prerequisite: completion of Ph.D qualifying exams. Register for section belonging to thesis adviser.
1-15 units, Aut, Win, Spr (Staff)

AA 351B. Advanced Fluid Mechanics—(Enroll in ME 451B.)
3 units (Lele) alternate years, given 2005-06

AA 351C. Advanced Fluid Mechanics—(Enroll in ME 451A.)
3 units (Staff) not given 2004-05

AA 366. Introduction to Fourier Optics—(Enroll in EE 366.)
3 units, Aut (Hesselink) alternate years, not given 2005-06

AA 459. Frontiers in Interdisciplinary Biosciences—(Crosslisted in departments in the schools of H&S, Engineering, and Medicine; student register through their affiliated departments; otherwise register for CHEMENG 459) See CHEMENG 459 or http://biox.stanford.edu/courses/459_announce.html.
1 unit, Aut, Win, Spr (Robertson)

BIOENGINEERING

Chair: Scott L. Delp
Co-Chair: Paul Yock
Professors: Dennis R. Carter, Gregory T. A. Kovacs (Electrical Engineering), Norbert J. Pelc, Stephen R. Quake, Matthew Scott, James R. Swartz
Associate Professor: Russ B. Altman (Genetics)
Assistant Professor: Jennifer R. Cochran, Karl Deisseroth, Charles Taylor (Mechanical Engineering)
Student Services: Clark Center, Room S-166
Mail Code: 94305-5444
Student Services Phone: (650) 723-8632
Web Site: http://bioengineering.stanford.edu/

Courses given in Bioengineering have the subject code BIOE. For a complete list of subject codes, see Appendix.

The mission of the Department of Bioengineering is to create a fusion of engineering and the life sciences that promotes scientific discovery and the invention of new technologies and therapies through research and education. The department encompasses both the use of biology as a new engineering paradigm and the application of engineering principles to medical problems and biological systems. The discipline embraces biology as a new science base for engineering.

Bioengineering is jointly supported by the School of Engineering and the School of Medicine. The facilities and personnel of the Department of Bioengineering are housed in the James H. Clark Center, Allen Center for Integrated Systems, William F. Durand Building for Space Engineering and Science, William M. Keck Science Building, and the Richard M. Lucas Center for Magnetic Resonance Spectroscopy and Imaging.

The departmental headquarters is located in the James H. Clark Center for Biomedical Engineering and Sciences, along with approximately 600 faculty, staff, and students from more than 20 University departments. The Clark Center is also home to Stanford's new Bio-X program, a collaboration of the Schools of Engineering, Medicine, Humanities and Sciences, and Earth Sciences.

Courses in the teaching program lead to the degrees of Master of Science and Doctor of Philosophy. The department collaborates in research and teaching programs with faculty members in Chemical Engineering, Mechanical Engineering, Electrical Engineering, and departments in the School of Medicine. Quantitative biology is the core science base of the department. The research and educational thrusts are in biomedical computation, biomedical imaging, biomedical devices, regenerative medicine, and cell/molecular engineering. The clinical dimension of the department includes cardiovascular medicine, neuroscience, orthopedics, cancer care, neurology, and environment.

UNDERGRADUATE PROGRAMS

Although primarily a graduate-level department, individually designed B.S. majors in Bioengineering, Biomechanical Engineering, or Biomedical Computation can be arranged. For detailed information, see the "School of Engineering" section of this bulletin and the *School of Engineering Undergraduate Handbook* at http://ughb.stanford.edu and available from the Office of the Dean of Engineering.

COTERMINAL B.S./M.S. PROGRAM

This option is available to outstanding Stanford undergraduates who wish to work simultaneously toward a B.S. in another field and an M.S. in Bioengineering. The degrees may be granted simultaneously or at the conclusion of different quarters, though the bachelor's degree cannot be awarded after the master's degree has been granted. As Bioengineering does not currently offer an undergraduate program, the B.S degree must be from another department. The University minimum requirements for the coterminal bachelor's/master's program are 180 units for the bachelor's degree plus 45 unduplicated units for the master's degree. A student may apply for the coterminal B.S. and M.S. program after 120 units are completed and they must be accepted into our program one quarter before receiving their degree. Students should apply directly to the Bioengineering Department. We require students interested in our coterminal degree to take the Graduate Record Examination (GRE); applications may be obtained at the Undergraduate Advising Program (UAP) or at http://www.gre.org. New coterminal applications and procedures are now available on the Office of the University Registrar web site. Access the new application form, instructions, and supporting documents online at http://bioengineering.stanford.edu/academics/coterminal.html; University regulations and forms concerning coterminal degree programs are available at http://registrar.stanford.edu/publications/#Coterm.

The application must provide evidence of potential for strong academic performance as a graduate student. The application is evaluated and acted by the graduate admissions committee of the department. Students are expected to enter with a series of core competencies in mathematics, biology, chemistry, physics, computing, and engineering. Typically, a GPA of at least 3.5 in engineering, science, and math is expected.

GRADUATE PROGRAMS

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

Admission—Students are expected to enter with a series of core competencies in mathematics, biology, chemistry, physics, computing, and engineering. The backgrounds of students entering the program are assessed by the examination of their undergraduate transcripts and research experiences. Specifically, we require that students have completed mathematics through multivariable calculus and differential equations, completed a series of undergraduate biology courses (equivalent to BIOSCI 41, 42, 43 series) and completed physics, chemistry, and computer sciences courses required of all undergraduate majors in engineering.

Qualified applicants are encouraged to apply for predoctoral national competitive fellowships, especially those from the National Science Foundation. Applicants to the Ph.D. program should consult with their financial aid officers for information and applications.

The deadline for receiving applications is January 4, 2005.

Further information and application forms for all graduate degree programs may be obtained from Graduate Admissions, the Registrar's Office, http://gradadmissions.stanford.edu/.

MASTER OF SCIENCE

The Master of Science in Bioengineering requires 45 units of course work. The curriculum consists of core bioengineering courses, technical electives, seminars and unrestricted electives. Core courses focus on quantitative biology and biological systems analysis. Approved technical electives are chosen by a student in consultation with his/her graduate adviser, and can be selected from graduate course offerings in mathematics, statistics, engineering, physical sciences, life sciences, and medicine. Seminars highlight emerging research in bioengineering and provide training in research ethics. Unrestricted electives can be freely chosen by the student in association with his/her adviser.

The department's requirements for the M.S. in Bioengineering are:

1. *Bioengineering courses* (12 units): these units must be selected from the approved list of bioengineering courses for the Master's degree requirements (6 units must be from BIOE 200A,B,C). These courses, together with the Approved Technical Electives, should form a cohesive course of study that provides depth and breadth.
2. *Approved Technical Electives* (24 units): these units must be selected from graduate courses in mathematics, statistics, engineering, physical science, life science, and medicine. They should be chosen in concert with the bioengineering courses to provide a cohesive degree program in a bioengineering focus area. Up to 9 units of directed study and research may be used as approved electives.
3. *Seminars* (3 units): the seminar units should be fulfilled by attendance at the BIOE 389, Bioengineering Forum, or BIOE 459, Frontiers in Interdisciplinary Biosciences. Other relevant seminar units could also be used with the approval of the faculty adviser. One of the seminar units must be MED 255, The Responsible Conduct of Research.
4. *Unrestricted Electives* (6 units).

Students are assigned an initial faculty adviser to assist them in designing a plan of study that creates a cohesive degree program with a concentration in a particular bioengineering focus area. These focus areas include, but are not limited to: Biomedical Computation, Regenerative Medicine/Tissue Engineering, Molecular and Cell Bioengineering, Biomedical Imaging, and Biomedical Devices.

To ensure that an appropriate program is pursued by all M.S. candidates, students who first matriculate at Stanford at the graduate level (a) submit an adviser approved "Program Proposal for a Master's Degree" form to the Student Service Office during the first month of the first quarter of enrollment and (b) obtain approval from the M.S. adviser and the Chair of Graduate Studies for any subsequent program change or changes. It is expected that the requirements for the M.S., Bioengineering can be completed within approximately one year. There is no thesis requirement for the M.S.

DOCTOR OF PHILOSOPHY

A student studying for the Ph.D. degree must complete a master's degree (45 units) and must fulfill the requirements for the Stanford M.S. degree in Bioengineering. A minimum of 135 units is required. Up to 45 units of master's degree residency units may be counted towards the degree. The maximum number of transfer units is 45. Students admitted to the Ph.D. program with an M.S. degree, must complete at least 90 units of work at Stanford.

Students are assigned an initial faculty adviser on the basis of the research interests expressed in their application. Initial faculty advisers assist students in selecting courses and identifying research opportunities. The department does not require formal lab rotations, but students are encouraged to explore research activities in two or three labs during their first academic year.

Prior to being formally admitted to candidacy for the Ph.D. degree, the student must demonstrate knowledge of bioengineering fundamentals and a potential for research by passing a qualifying oral examination.

Typically, the exam is taken shortly after the student earns a master's degree. The student is expected to have a nominal graduate Stanford GPA of 3.5 to be eligible for the exam. Students are encouraged to take the exam during the academic year and to work with their faculty sponsor to prepare . Once the student's faculty sponsor has agreed that the exam is to take place, the student must submit an application folder containing items including a curriculum vitae, research project abstract, and preliminary dissertation proposal to the student service office. Information about the exam may be obtained from the student service office.

In addition to the course requirements of the M.S. degree, doctoral candidates must complete a minimum of 15 additional units of approved formal course work (excluding research, directed study, and seminars).

Dissertation Reading Committee—Each Ph.D. candidate is required to establish a reading committee for the doctoral dissertation within six months after passing the department's Ph.D. Qualifying exams. Thereafter, the student should consult frequently with all members of the committee about the direction and progress of the dissertation research.

A dissertation reading committee consists of the principal dissertation adviser and at least two other readers. Reading committees in Bioengineering may include faculty from another department. It is expected that at least two members of the Bioengineering faculty be on each reading committee. The initial committee, and any subsequent changes, must be officially approved by the department Chair.

University Oral and Dissertation—The Ph.D. candidate is required to take the University oral examination after the dissertation is substantially completed (with the dissertation draft in writing), but before final approval. The examination consists of a public presentation of dissertation research, followed by substantive private questioning on the dissertation and related fields by the University oral committee (four selected faculty members, plus a chair from another department). Once the oral has been passed, the student finalizes the dissertation for reading committee review and final approval. Forms for the University oral scheduling and a one-page dissertation abstract should be submitted to the department student services office at least three weeks prior to the date of the oral for departmental review and approval.

COURSES

STANFORD INTRODUCTORY SEMINARS

BIOE 70Q. Medical Device Innovation—Stanford Introductory Seminar. Preference to sophomores. Commonly used medical devices in different medical specialties. Guest lecturers include Stanford medical school physicians, entrepreneurs, and venture capitalists. How to identify clinical needs and design device solutions to address these needs. The fundamentals of starting a company. Field trips to local medical device companies; workshops. No previous engineering training required.
3 units, Spr (Doshi, Mandato)

ADVANCED UNDERGRADUATE AND GRADUATE

BIOE 200A. Molecular and Cellular Engineering—Preference to Bioengineering graduate students. Molecular and cellular bases of life from an engineering perspective. Metabolism, information flow and feedback, signal transduction, and means for engineering these processes. Clinical motivations and practical applications.
3 units, Aut (Kovacs, Staff)

BIOE 200B. Systems Biology and Tissue Engineering—Preference to Bioengineering graduate students. The interaction, communication, and disorders of organ systems. Major organ systems and engineering means of probing them. Relevant developmental biology and tissue engineering from cells to complex organs.
3 units, Win (Kovacs, Staff)

BIOE 200C. Medical Devices, Diagnostics, and Pharmaceuticals: Technologies, Regulation, and Applications—Preference to Bioengineering graduate students. Design, regulatory matters, and applications in practical settings. Major classes of technologies, practical limitations, and feature trade-offs in clinical settings.
3 units, Spr (Kovacs, Staff)

BIOE 210. Introduction to Biomedical Informatics: Fundamental Methods—(Enroll in BIOMEDIN 210, CS 270.)
3 units, Aut (Musen)

BIOE 211. Genomics—(Enroll in GENE 211.)
3 units, Win (Cherry, Myers, Sidow, Sherlock)

BIOE 212. Biomedical Informatics Project Course—(Enroll in BIOMEDIN 212, CS 272.)
3 units, Aut (Altman, Cheng, Klein)

BIOE 214. Representations and Algorithms for Computational Molecular Biology—(Same as BIOMEDIN 214, CS 274.) Topics: algorithms for alignment of biological sequences and structures, computing with strings, phylogenetic tree construction, hidden Markov models, computing with networks of genes, basic structural computations on proteins, protein structure prediction, protein threading techniques, homology modeling, molecular dynamics and energy minimization, statistical analysis of 3D biological data, integration of data sources, knowledge representation and controlled terminologies for molecular biology, graphical display of biological data, and genetic algorithms and programming applied to biological problems. Prerequisites: programming skills and matrix algebra.
4 units, Spr (Altman)

BIOE 218. Computational Molecular Biology—(Enroll in BIOC 218.)
3 units (Brutlag) not given 2004-05

BIOE 220. Introduction to Imaging and Image-Based Human Anatomy—(Enroll in RAD 220.)
3 units, Win (Gold, Butts)

BIOE 222. Multi-modality Molecular Imaging in Living Subjects—Basic physics of each modality including PET, SPECT, MRI, CT, and optics; and chemistry and molecular assays to study cellular and molecular events in small animal and clinical models.
4 units, Aut (Gambhir)

BIOE 280. Skeletal Development and Evolution—(Same as ME 280.) The mechanobiology of skeletal growth, adaptation, regeneration, and aging is considered from developmental and evolutionary perspectives. Emphasis is on the interactions between mechanical and chemical factors in the regulation of connective tissue biology. Prerequisites: ME 80, or Human Biology core, or Biological Sciences core.
3 units, Spr (Carter)

BIOE 281. Biomechanics of Movement—(Same as ME 281.) Review of experimental techniques used to study human and animal movement including motion capture systems, EMG, force plates, medical imaging, and animation. The mechanical properties of muscle and tendon, and quantitative analysis of musculoskeletal geometry. Projects and demonstrations emphasize applications of mechanics in sports, orthopedics, neuroscience, and rehabilitation.
3 units, Aut (Delp)

BIOE 284A. Cardiovascular Bioengineering—(Same as ME 284A.) Bioengineering principles applied to the cardiovascular system. Anatomy of human cardiovascular system, comparative anatomy, and allometric scaling principles. Cardiovascular molecular and cell biology. Overview of continuum mechanics. Form and function of blood, blood vessels, and the heart from an engineering perspective. Normal, diseased, and engineered replacement tissues.
3-4 units, Aut (Taylor)

BIOE 284B. Cardiovascular Bioengineering—(Same as ME 284B.) Continuation of ME 284A. Integrative cardiovascular physiology, blood fluid mechanics, and transport in the microcirculation. Sensing, feedback, and control of the circulation. Overview of congenital and adult cardiovascular disease, diagnostic methods, and treatment strategies. Engineering principles to evaluate the performance of cardiovascular devices and the efficacy of treatment strategies.
3-4 units, Win (Taylor)

GRADUATE

BIOE 320A. Medical Imaging Systems I—(Enroll in EE 369A.)
3 units, Win (Nishimura)

BIOE 320B. Medical Imaging Systems II—(Enroll in EE 369B.)
3 units, Spr (Pauly)

BIOE 320C. Medical Image Reconstruction—(Enroll in EE 369C.)
3 units (Pauly) not given 2004-05

BIOE 321. In Vivo Magnetic Resonance Spectroscopy and Imaging—(Enroll in RAD 226.)
3 units, Win (Spielman)

BIOE 350. Principles of Cellular Systems—(Enroll in CHEMENG 350.)
3 units, Win (Kao)

BIOE 351. Introduction to Biotechnology—(Enroll in CHEMENG 450.)
3 units, Spr (Staff)

BIOE 355. Advanced Biochemical Engineering—(Same as CHEMENG 355.) The technological tools for exploiting the power offered by modern biology. Review of relevant biochemistry. How a cell interacts with and influences its environment, how a production organism is optimized, what technology is used for large scale production, how products are isolated and purified, how proteins can be made without living cells, how biopharmaceutical is formulated and delivered, and what the regulatory requirements are for drug approval and sale. Prerequisite: 350 or BIOSCI 42 or equivalent.
3 units, Spr (Swartz)

BIOE 360A. Tissue Engineering—(Same as ME 385A.) Tissue engineering is an expanding discipline that applies biological and engineering principles to create substitutes or replacements for defective tissues or organs. The principles of cell biology as a foundation for using engineering approaches to generate tissue structure and function. Emphasis is on how scaffolds, smart polymers, and mechanical forces can be used to reproduce the physical environment that acts, at the whole organ system level, to maintain specialized cellular function through molecular and genetic mechanisms.
2 units, Win (Smith, Carter)

BIOE 360B. Tissue Engineering Lab—(Same as ME 385B.) Hands-on experience in the fabrication of living engineered tissues. Techniques to be covered include sterile technique, culture of mammalian cells, creation of cell-seeded scaffolds, and the effects of mechanical loading on the metabolism of living engineered tissues. The underlying theory and background for each technique are described followed by a practical demonstration. Students are then given access to the lab and provided with supplies and expected to develop hands-on proficiency.
1 unit, Win (Jacobs)

BIOE 374A,B. Biodesign Innovation—(Same as ME 374A,B; MED 272A,B.)

BIOE 374A. Needs Finding and Concept Creation—Two-quarter sequence. Strategies for understanding and interpreting clinical needs, researching literature, and searching patents. Clinical and scientific literature review, techniques of intellectual property analysis and feasibility, basic prototyping, and market assessment. Students working in small entrepreneurial teams to create, analyze, and screen medical technology ideas, and select projects for future development.
3-4 units, Win (Makower, Yock, Zenios)

BIOE 374B: Concept Development and Implementation—Two-quarter sequence. Early factors for success; how to prototype inventions and refine intellectual property. Lectures guest medical pioneers and entrepreneurs about strategic planning, ethical considerations, new venture management, and financing and licensing strategies. Cash requirements; regulatory (FDA), reimbursement, clinical, and legal strategies, and business or research plans.
3-4 units, Spr (Makower, Yock, Zenios)

BIOE 381. Orthopaedic Bioengineering—(Same as ME 381.) Engineering approaches are applied to the musculoskeletal system in the context of surgical and medical care. Fundamental anatomy and physiology. Material and structural characteristics of hard and soft connective tissues and organ systems are considered and the role of mechanics in normal development and pathogenesis is addressed. Engineering methods used in the evaluation and planning of orthopaedic procedures, surgery, and devices.
3 units, Aut (Carter)

BIOE 382A,B. Biomedical Device Design and Evaluation—(Enroll in ME 382A,B.)
4 units, **A:** *Win,* **B:** *Spr (Andriacchi)*

BIOE 386. Neuromuscular Biomechanics—(Same as ME 386.) The interplay between mechanics and neural control of movement. State of the art assessment through a review of classic and recent journal articles. Emphasis is on the application of dynamics and control to the design of assistive technology for persons with movement disorders.
3 units (Delp) not given 2004-05

BIOE 390. Introduction to Bioengineering Research—(Same as MED 289.) Preference to medical and bioengineering graduate students. Bioengineering is an interdisciplinary field that leverages the disciplines of biology, medicine, and engineering to understand living systems, and engineer biological systems and improve engineering designs and human and environmental health. Topics include: imaging; molecular, cell, and tissue engineering; biomechanics; biomedical computation; biochemical engineering; biosensors; and medical devices. Limited enrollment.
1-2 units, Aut, Win (Taylor)

BIOE 391. Directed Study—May be used to prepare for research during a later quarter in 392. Faculty sponsor required.
1-6 units, Aut, Win, Spr, Sum (Staff)

BIOE 392. Directed Investigation—For Bioengineering graduate students. Previous work in 391 may be required for background; faculty sponsor required.
1-15 units, Aut, Win, Spr, Sum (Staff)

BIOE 393. Bioengineering and Biodesign Forum—(Same as ME 389.) Invited speakers present research topics at the interfaces of biology, medicine, physics, and engineering. (AU)
1 unit, Aut, Win, Spr (Staff)

BIOE 451. Protein Design and Engineering—(Enroll in SBIO 451.)
2 units, Aut (Pabo, Weis)

BIOE 454. Metabolic Engineering Methods and Applications—(Same as CHEMENG 454.) The analysis and optimization of industrial organisms. Applications illustrate the basic principles of metabolic pathway regulation, metabolic flux analysis, and traditional and new methods for genetic engineering. Examples: production of amino acids, protein synthesis and post-translational modification, and the production of isoprenoids, peptides, and polyketides. Prerequisites: CHEMENG 250, 355, or equivalent.
3 units, Spr (Swartz) alternate years, not given 2005-06

BIOE 459. Frontiers in Interdisciplinary Biosciences—(Crosslisted in departments in the schools of H&S, Engineering, and Medicine; student register through their affiliated departments; otherwise register for CHEMENG 459) See CHEMENG 459 or http://biox.stanford.edu/courses/459_announce.html.
1 unit, Aut, Win, Spr (Robertson)

BIOE 484. Computational Methods in Cardiovascular Bioengineering—(Same as ME 484.) Lumped parameter, one-dimensional nonlinear and linear wave propagation, and three-dimensional modeling techniques applied to simulate blood flow in the cardiovascular system system and evaluate the performance of cardiovascular devices. Construction of anatomic models and extraction of physiologic quantities from medical imaging data. Problems in blood flow within the context of disease research, device design, and surgical planning.
3 units, Spr (Taylor)

BIOE 485. Modeling and Simulation of Human Movement—(Same as ME 485.) The computational tools used to create simulations of human movement. Lecture/labs on animation of movement; kinematic models of joints; forward dynamic simulation; computational models of muscles, tendons, and ligaments; creation of models from medical images; control of dynamic simulations; and collision detection and contact models. Prerequisite: ME 281, ME 331, or equivalent.
3 units, Spr (Delp)

BIOE 500. Thesis (Ph.D.)
1-15 units, Aut, Win, Spr, Sum (Staff)

CHEMICAL ENGINEERING

Emeriti: (Professors) Andreas Acrivos, Michel Boudart, George M. Homsy
Chair: Curtis W. Frank
Professors: Curtis W. Frank, Gerald G. Fuller, Chaitan Khosla, Robert J. Madix, Channing R. Robertson, Eric S. G. Shaqfeh, James R. Swartz
Associate Professors: Zhenan Bao, Stacey F. Bent
Assistant Professors: Camilla M. Kao, Charles B. Musgrave
Lecturers: Shari Libicki, Anthony Pavone
Courtesy Professors: Steven Chu, Daniel Herschlag, Jeffrey R. Koseff, Franklin M. Orr, Jr., Robert M. Waymouth
Consulting Professors: Douglas C. Cameron, Kay Kanazawa, Wolfgang Knoll, Jaan Noolandi, Jürgen Rühe, Conrad Schadt, Robert Schwaar, Do Yeung Yoon
Visiting Professor: Subhash Risbud

Department Office: Stauffer III, Room 113
Student Services Office: Keck, Room 189
Mail Code: 94305-5025
Phone: (650) 723-4906; *Student Services:* (650) 723-1302
Email: information@chemeng.stanford.edu; *Graduate Admissions:* inquire@chemeng.stanford.edu
Web Site: http://chemeng.stanford.edu

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

Chemical Engineering is a discipline that relates to numerous areas of technology. In broad terms, 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 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 engineering is essential in these and other fields whenever processes involve the chemical or physical transformation of matter.

UNDERGRADUATE PROGRAM

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. Also see the "School of Engineering" section of this bulletin.

There are several B.S. plans for Chemical Engineering. Sample programs are available from the department's student services and faculty advisers for undergraduates, the Dean's Office in the School of Engineering, and in the *Handbook for Undergraduate Engineering Programs,* available at http://ughb.stanford.edu/. It is recommended that the student discuss a prospective program with a chemical engineering adviser, especially if transferring from biology, chemistry, physics, or another field in engineering. With some advanced planning, the student can usually arrange to attend one of the overseas campuses.

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

HONORS PROGRAM

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 at the end of 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 grade point average (GPA) of 3.5 or higher in Chemical Engineering courses are eligible to submit an application. Applications must be submitted no later than the second week of Autumn Quarter of the senior year, include an honors proposal, and be sponsored by both a thesis adviser and a second reader. The adviser must be a member of the Chemical Engineering faculty. Students should take advantage of university programs that support undergraduate research such as those sponsored by Undergraduate Research Programs; see http://urp.stanford.edu/StudentGrants/introstudentgrants.html. Students should start their honors research in their junior year and incorporate Summer Quarter research opportunities into their three quarter honors research proposal. Subject to faculty approval, it is recommended that students include one quarter of ENGR 102S, Writing: Special Projects, or its equivalent, in the second quarter of their honors project.

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

1. Maintain a grade point average (GPA) of a least 3.5 in Chemical Engineering courses.
2. Complete at least 3 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. Submit a completed thesis simultaneously to both the adviser and the reader, no later than the first day of the End-Quarter period.
4. Participate in the Chemical Engineering Honors Symposium with a poster and oral presentation of thesis, held at the end of Spring Quarter.
5. Submit to Chemical Engineering student services two final copies of the honors thesis as approved by the adviser and second reader. The deadline is the last day of the End-Quarter period.

GRADUATE PROGRAMS

The University's 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, up to 6 units of research, or a combination of research units and no more than 3 units of 459 or other 1- or 2-unit seminar courses in other departments, may be substituted for up to 6 units of the required additional lecture course 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 and no later than the End-Quarter period 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 prior to degree conferral, to permit amendment of the final quarter's study list if indicated. Students with questions should contact student services.

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

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 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.

Residency Requirement—See General Requirements in the "Graduate Degrees" section of this bulletin.

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.

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) and 45 units of course work is required for the Engineer degree, including (1) 300, 310A, 345, 355 and (2) 3 units of 699. The remaining 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 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).

Residency Requirement—See General Requirements in the "Graduate Degrees" section of this bulletin and the "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 all 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 total units, including 45 units of course work, is required for the Ph.D. degree. The following courses are required: 300, 310A, 345, and 355, plus two courses from one of the areas of concentration in the 440, 450, or 460 series. These must be taken at Stanford, and all petitions to substitute another graduate-level Stanford course for any of these core courses must be approved by the chair. The remaining courses may be chosen from the basic sciences and engineering according to the guidelines given in the "Master of Science" section above and with the approval of the faculty advisers. An aggregate of 6 units maximum of the required minimum of 45 units of course work may include such courses as 459 and 699. Students admitted to Ph.D. candidacy should enroll each quarter in the 500 series, 600, and 699 as appropriate and as study list unit maxima permit. Predoctoral students may apply for the M.S. degree once the requirements for that degree have been fulfilled (see the "Master of Science" section above). The conferral of the M.S. degree must be made within the University's time limit for completion of a master's degree.

Residency Requirement—See General Requirements in the "Graduate Degrees" section of this bulletin.

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.

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, assists the faculty in their deliberations as to 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. It also precludes any financial aid beyond that already pledged; however, the student may continue to work toward an M.S. degree (see "Master of Science" section above). Students who pass the preliminary examination take the second part of the qualifying examination at the beginning of their second year, or fifth quarter. This second examination before the faculty is an oral presentation and defense of their current research work. Students who successfully pass both examinations submit applications for candidacy for a doctoral degree and form 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 reading committee meetings. 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 four to 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 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 a faculty 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. 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 at a minimum. 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 course work (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, with the exception of 250A if it is taken in conjunction with 250. 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 on the Department of Chemical Engineering's web site at http://chemeng.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 enrollment 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 on our web site at http://chemeng.stanford.edu. Any students interested in graduate admissions should click on the admissions link. Current Stanford students interested in graduate work in Chemical Engineering are encouraged to contact the department and must follow an internal application process. All other students should go to http://gradadmissions.stanford.edu/ for additional guidelines regarding application requirements and processes. Potential applicants also can obtain the essentials by first emailing apply@chemeng.stanford.edu and then contacting the department's student services manager in Keck, room 189, or at cosby@stanford.edu.

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—Faculty and alumni of the Chemical Engineering Department present and discuss a variety of career paths available to chemical engineering graduates in an informal seminar setting. Examples of topics: preparing for graduate school (M.S. and Ph.D.) in Chemical Engineering; opportunities in areas related to the environment; opportunities in areas related to soft and hard materials; opportunities in areas related to biotechnology; preparing for graduate work in other professional schools (law, business, medicine, other engineering); non-traditional opportunities.

1 unit, Aut (Frank)

CHEMENG 20. Introduction to Chemical Engineering—(Enroll in ENGR 20.)

3 units, Spr (Robertson)

CHEMENG 25. Biotechnology—(Enroll in ENGR 25.)

3 units, Spr (Kao)

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:2b

3 units, Aut (Robertson, Libicki)

CHEMENG 100. Chemical Process Modeling, Dynamics, and Control—Mathematical methods are 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: MATH 53 or 130, or CME 102 (formerly ENGR 155A), or equivalent; ENGR 20.

3 units, Aut (Kao)

CHEMENG 110. Equilibrium Thermodynamics—Thermodynamic properties, equations of state, properties of non-ideal systems including mixtures, and phase and chemical equilibria.

3 units, Win (Bao)

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 (formerly ENGR 155A), or equivalent.

4 units, Win (Shaqfeh)

CHEMENG 120B. Energy and Mass Transport—Introduction to 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, 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 (Shaqfeh)

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 (Musgrave)

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.

3 units, Spr (Bao)

CHEMENG 150. Biochemical Engineering—(Same as 250.) Principles used in the biological production of fine biochemicals, with emphasis on protein pharmaceuticals as a fundamental paradigm. Basic and applied principles in applied biochemistry, enzyme kinetics, cellular physiology, recombinant DNA technology, metabolic engineering, fermentation development and scale up, product isolation and purification, protein folding and formulation, and biobusiness and regulatory issues. Prerequisite: BIOSCI 41 or equivalent. Corequisite: 150A/250A.

3 units, Aut (Swartz)

CHEMENG 150A. BioProcess Design Laboratory—(Same as 250A.) Small groups design, evaluate, and optimize processes for the manufacture of products such as commodity biochemicals, industrial enzymes, and pharmaceutical proteins. Product cost and quality targets are developed to satisfy market needs. Uses and reinforces concepts introduced in 150/250. Prerequisite: BIOSCI 41 or equivalent. Corequisite: 150/250 or consent of instructor.

1 unit, Aut (Swartz)

CHEMENG 160. Polymer Science and Engineering—(Same as 260.) Morphology of amorphous and semicrystalline polymers, linear viscoelasticity, and rheology. Applications of polymers in biomedical devices and microelectronics. Prerequisite: organic chemistry or consent of instructor.

3 units, Win (Frank)

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- and unsteady-state operation of reactors; conversion and limitations of thermodynamic equilibrium. Enzymes and heterogeneous catalysis and catalytic reaction mechanisms. Prerequisites: 110, 120A,B; CHEM 173.

3 units, Aut (Bent)

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)

CHEMENG 185A. Chemical Engineering Laboratory—Investigation of the experimental aspects of chemical engineering science, emphasizing development of communications skills. Experiments illustrating lecture subjects are conducted by groups of students. Lab. WIM
4 units, Aut (Khosla)

CHEMENG 187. Biochemistry—(Same as 287, BIOSCI 187/287, CHEM 187.) Structure and function of biological molecules, enzyme kinetics and mechanisms, bioenergetics, pathways of intermediary metabolism and their control, and membrane structure and function. Lectures on special topics. Clinical correlations. Prerequisites: organic chemistry, cell biology, or consent of instructor. GER:2a
4 units, Win (Khosla)

CHEMENG 190. Undergraduate Research in Chemical Engineering—Lab or theoretical work under direct 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 students who have declared the Chemical Engineering B.S. honors major and have obtained approval of a topic for research from the faculty adviser. Oral presentation of written thesis required.
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)

CHEMENG 250. Biochemical Engineering—(Same as 150; see 150.)
3 units, Aut (Swartz)

CHEMENG 250A. BioProcess Design Laboratory—(Same as 150A; see 150A.)
1 unit, Aut (Swartz)

CHEMENG 260. Polymer Science and Engineering—(Same as 160; see 160.)
3 units, Win (Frank)

CHEMENG 287. Biochemistry—(Same as 187, BIOSCI 287; see 187.)
4 units, Win (Khosla)

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 chromotography. 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, 104 (formerly ENGR 155A,B), or equivalents.
3 units, Aut (Shaqfeh)

CHEMENG 310A. Microscale Fluid Dynamics—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)

CHEMENG 340. Molecular Thermodynamics—Review of classical thermodynamics. Introduction to statistical thermodynamics; ensembles and partition functions. Application to phase equilibrium of solids and liquids, phase diagrams, and molecular dynamics simulation. Intermolecular forces, and distribution functions, liquid state theory, integral equations, and perturbation theory.
3 units (Staff) not given 2004-05

CHEMENG 345. Applied 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 quantum mechanics.
3 units, Win (Bent)

CHEMENG 350. Principles of Cellular Systems—Biochemistry and cell biology for engineering students with no training in biology. Recommended: undergraduate physical and organic chemistry.
3 units, Win (Kao)

CHEMENG 355. Advanced Biochemical Engineering—(Same as BIOE 355.) The technological tools for exploiting the power offered by modern biology. Review of relevant biochemistry. How a cell interacts with and influences its environment, how a production organism is optimized, what technology is used for large scale production, how products are isolated and purified, how proteins can be made without living cells, how biopharmaceutical is formulated and delivered, and what the regulatory requirements are for drug approval and sale. Prerequisite: 350 or BIOSCI 41 or equivalent.
3 units, Spr (Swartz)

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 and kinetics of adsorption processes, surface diffusion, and surface reactions. Molecular structure of the adsorbates. Current topics in surface structure and reactivity including systems for heterogeneous catalysis and semiconductor processing.
3 units, Spr (Bent) alternate years, not given 2005-06

CHEMENG 444A. 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: undergraduate quantum mechanics.
3 units, Win (Musgrave)

CHEMENG 444B. Quantum Simulations: Materials Micro Mechanics—(Enroll in ME 444B.)
3 units (Staff) not given 2004-05

CHEMENG 450. Introduction to Biotechnology—(Same as BIOC 450.) Faculty from the schools of Medicine, Humanities and Sciences, and Engineering, and industrial speakers review the interrelated elements of modern biotechnology. Topics: development of recombinant protein pharmaceuticals, bacterial fermentation and scale-up, mammalian cell culture and scale-up, transgenic animals, transgenic protein production in plants, isolation and purification of protein pharmaceuticals, formulation and delivery of pharmaceutical proteins, environmental biotechnology, metabolic engineering, industrial enzymes, diagnostic devices, transcriptomics and proteomics, drug delivery systems. Prerequisite: graduate student or upper-division undergraduate in sciences or engineering.
3 units, Spr (Staff)

CHEMENG 452. Protein Science and Engineering—(Same as CHEM 232.) The physio-chemical interactions that govern the structure and function of proteins. Topics: protein function and structure, techniques for probing protein structure and function, mechanisms of protein function, design of proteins with novel properties. Examples from literature on enzymes. Recommended: background in physical and organic chemistry.
3 units (Khosla) not given 2004-05

CHEMENG 454. Metabolic Engineering Methods and Applications—(Same as BIOE 454.) The analysis and optimization of industrial organisms. Applications illustrate the basic principles of metabolic pathway regulation, metabolic flux analysis, and traditional and new methods for genetic engineering. Examples: production of amino acids, protein synthesis and post-translational modification, and the production of isoprenoids, peptides, and polyketides. Prerequisites: 250, 355 or equivalent.
3 units, Spr (Swartz) alternate years, not given 2005-06

CHEMENG 459. Frontiers in Interdisciplinary Biosciences—(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. Recommended: basic knowledge of mathematics, biology, chemistry, and physics.
1 unit, Aut, Win, Spr (Robertson)

CHEMENG 460. Polymer Surfaces and Interfaces—Basic principles of interfacial thermodynamics and polymer physics are 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 lubrication, adhesion, and biocompatibility. Prerequisite: prior exposure to principles of polymer science or consent of instructor.
3 units, Spr (Frank) alternate years, not given 2005-06

CHEMENG 462. Dynamics of Complex Liquids—The connection between the microstructural dynamics of complex liquids and their rheology, i.e., stress-strain rate relationship, developed sequentially from non-Brownian suspensions, to colloidal suspensions, to polymer solutions and melts. The fundamental concepts of rheology, the origins of stress in complex liquids, how Brownian motion can create stress, and how rheometric measurements can elucidate stress producing mechanisms in complex fluids. A spectrum of microstructural and molecular models are examined including those for dilute and concentrated polymer solutions and melts, and, if time permits, liquid crystals and surfactants. Prerequisites: 300, 310A.
3 units (Shaqfeh) not given 2003-04

CHEMENG 500. Special Topics in Protein Biotechnology—Recent developments and current research. Prerequisites: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Swartz)

CHEMENG 501. Special Topics in Semiconductor Processing—Recent developments and current research. Prerequisites: graduate standing and consent of instructor.
1 unit, Aut, Win, Spr, Sum (Bent)

CHEMENG 502. Special Topics in Computational Materials Science—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Musgrave)

CHEMENG 503. Special Topics in Biocatalysis—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Khosla)

CHEMENG 504. Special Topics in Bioengineering—Discussion of recent developments and current research in bioengineering.
1 unit, Aut, Win, Spr, Sum (Robertson)

CHEMENG 505. Special Topics in Microrheology—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Fuller)

CHEMENG 506. Special Topics in Surface and Interface Science—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Madix)

CHEMENG 507. Special Topics in Polymer Physics and Molecular Assemblies—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Frank)

CHEMENG 509. Special Topics in Statistical Mechanics of Dispersed Systems—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Gast)

CHEMENG 510. Special Topics in Transport Mechanics—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Shaqfeh)

CHEMENG 512. Special Topics in Functional Genomics—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Kao)

CHEMENG 513. Special Topics in Functional Organic Materials for Electronic and Optical Devices—Recent developments and current research.
1 unit, Aut, Win, Spr, Sum (Bao)

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. (AU)
1 unit, Aut, Win, Spr (Staff)

CIVIL AND ENVIRONMENTAL ENGINEERING

Emeriti: (Professors) James Douglas, John W. Fondahl, Joseph B. Franzini, James M. Gere, George Herrmann, En Y. Hsu, Paul Kruger, Gilbert M. Masters,* Perry L. McCarty,* Henry W. Parker, George A. Parks, Paul V. Roberts, Haresh C. Shah, Paul M. Teicholz, Victor K. Thompson (Architecture)
Chair: Richard G. Luthy
Associate Chair: Gregory G. Deierlein
Professors: Ronaldo I. Borja, Gregory G. Deierlein, Anne S. Kiremidjian, Peter K. Kitanidis, Jeffrey R. Koseff, Helmut Krawinkler (on leave Spring), Kincho H. Law, James O. Leckie (on leave Winter, Spring), Raymond E. Levitt, Richard G. Luthy, Stephen G. Monismith, Leonard Ortolano, Boyd C. Paulson, Jr. (on leave Autumn, Spring), Robert L. Street, Clyde B. Tatum
Associate Professors: Craig S. Criddle, Martin A. Fischer, David L. Freyberg, Lynn M. Hildemann, Mark Z. Jacobson, Alfred M. Spormann
Assistant Professors: Sarah L. Billington, Alexandria B. Boehm, Oliver B. Fringer, Charles A. Menun, Eduardo Miranda
Professors (Research): C. Allin Cornell, Martin Reinhard
Lecturers: Stan Christensen, William M. Critchfield, Renate Fruchter, Mark R. Kroll, John Kunz, Alexander P. Robertson, Mark Vranicar
Courtesy Professors: Peter M. Pinsky, David D. Pollard, Stephen H. Schneider, George S. Springer
Courtesy Assistant Professor: Margot G. Gerritsen
Consulting Professors: Roger Borcherdt, James E. Cloern, Russell G. Clough, Weimin Dong, Angelos N. Findikakis, Robert F. Hickey, Alan D. Jassby, Michael C. Kavanaugh, Francis L. Ludwig, Douglas M. MacKay, Martin W. McCann, Jr., William A. McDonough, Richard L. Meehan, Paul K. Meyer, Piotr D. Moncarz, Wayne R. Ott, Harry E. Ridgway, Benedict R. Schwegler, Avram S. Tucker, Michael W. Walton
Consulting Associate Professors: Amatzia Genin, Thomas L. Holzer, Stephanie A. King, Jonathan G. Koomey, Michael E. London, Colin Ong, Melody Spradlin, Joel N. Swisher, James M. Williams, Jane Woodward
Consulting Assistant Professors: Paolo Bazzurro, William J. Behrman, Fotini K. Chow, Olaf A. Cirpka, Murray D. Einarson, Edward S. Gross, Charles S. Han, Lisa V. Lucas, Michael L. MacWilliams, Jie Wang
Shimizu Visiting Professor: Azadeh Tabazadeh
MAP/Ming Visiting Professor: Ashok J. Gadgil

* Recalled to active duty.

Department Offices: Terman Engineering Center, Room M42
Mail Code: 94305-4020
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Web Site: http://cee.stanford.edu

Courses in Civil and Environmental Engineering have the subject code CEE. For a complete list of subject codes, see Appendix.

The undergraduate Civil Engineering major provides a pre-professional program balancing the fundamentals common to many special fields of civil engineering with specialization in Environmental and Water Studies or Structures and Construction. The undergraduate Environmental Engineering major offers a more focused program in Environmental and Water Studies. Laboratory facilities are available to students in building energy, construction, environmental engineering and science, experimental stress analysis, fluid mechanics, structural and earthquake engineering, and advanced sensing technologies.

At least one year of graduate study is strongly recommended for professional practice. Students who contemplate advanced study at Stanford should discuss their plans with their advisers in the junior year. The coterminal B.S.-M.S. program should be considered by students who want an integrated five-year program. Potential coterminal students in Environmental Engineering and Science should be aware that applications are considered once a year, near the beginning of Winter Quarter.

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

The Department of Civil and Environmental Engineering (CEE), in collaboration with other departments of the University, offers graduate degree programs in:

Construction Engineering and Management
Design/Construction Integration
Environmental and Water Studies
- Environmental Engineering and Science
- Environmental Fluid Mechanics and Hydrology

Structural Engineering and Geomechanics
- Geomechanics
- Structural Engineering

Research work and instruction under these programs are carried out in the following facilities: Building Energy Laboratory, Environmental Fluid Mechanics Laboratory (EFML), Geotechnical Engineering Laboratory, Structural Engineering Laboratory, and water quality control research and teaching laboratories. Research in earthquake engineering is conducted in the John A. Blume Earthquake Engineering Center. Research on control of hazardous substances is coordinated within the Western Region Hazardous Substance Research Center. Research and advanced global teamwork education is conducted in the Project Based Learning (PBL) Laboratory. In collaboration with the Department of Computer Science, the Center for Integrated Facility Engineering (CIFE) employs advanced CAD, artificial intelligence, communications concepts, and information management to integrate the presently fragmented participants in the facility development process and to support design and construction automation.

PROGRAMS OF STUDY

ATMOSPHERE/ENERGY

Energy and Atmosphere are linked in two primary ways. First, fossil-fuel derived energy use contributes to air pollution and climate change. Second, atmospheric winds and solar radiation are major sources of renewable energy. Because atmospheric problems can be mitigated best by increasing the efficiency with which energy is used, optimizing the use of natural energy resources, and understanding the effects of energy technologies on the atmosphere, the areas of Energy and Atmosphere are naturally coupled together.

Students in this program receive a transcript designation of Atmosphere/Energy. Courses available include those in energy resources, indoor and outdoor air pollution, energy efficient buildings, climate change, renewable energy, weather and storm systems, energy technologies in developing countries, energy systems, and air quality management, among others.

Some of the current research in the program includes projects on wind energy distribution and statistics, indoor exposure to air pollutants, the effects of a hydrogen economy on atmospheric pollution and climate, measurements of particulate matter and vehicle exhaust, hydrogen and other fuel generation by bacteria, numerical modeling of the effects of vehicles and power plants on climate, numerical weather prediction, improving the energy efficiency of buildings, improving the links between wind farms and the transmission grid, and studying the effects of aerosol particles on UV radiation and climate, among others.

Within the department, the program links to studies of water quality, environmental biotechnology, environmental fluid mechanics, sustainable construction, green buildings, and risk management. Outside the department, it links to Earth Systems, Management Science and Engineering, Mechanical Engineering, Petroleum Engineering, Urban Studies, Aeronautics and Astronautics, and Biology, among others. In addition, the program has natural connections with the Stanford Institute for the Environment (SIE), the Interdisciplinary Graduate Program in Environment and Resources (IPER), and the Global Climate and Energy Program (GCEP).

CONSTRUCTION

The Construction Engineering and Management (CEM) program prepares technically qualified students for responsible roles in all phases of the sustainable development of major constructed facilities. It emphasizes engineering and management techniques useful in planning, coordinating, and controlling the activities of diverse specialists (designers, contractors, subcontractors, and client representatives) within the unique project environment of the construction industry. By appropriate choice of elective subjects, students wishing to work for a contractor, construction management consultant, a design-build firm, or the facilities department of an owner's organization, or a construction technology firm, can design a program for their needs.

Courses offered include building systems, construction administration, construction finance and accounting, design and construction of housing, real estate development, equipment and methods, estimating, international construction, labor relations, managing human resources, planning and control techniques, productivity improvement, and project and company organizations. Additional related course work is available from other programs within the department, from other engineering departments, and from other schools in the University such as Earth Sciences and the Graduate School of Business.

The program leads to the degrees of Master of Science (M.S.), Engineer, and Ph.D. Students with undergraduate degrees in chemical, electrical, mechanical, mining, and petroleum engineering, or in architecture who do not wish to satisfy the undergraduate prerequisite courses for the M.S. in Civil and Environmental Engineering, Construction Engineering and Management, have the option of meeting the same graduate course requirements as the above and obtaining the M.S. in Engineering. Many M.S.-level graduate students and most Ph.D. candidates are supported each year through research and teaching assistantships, and through fellowships.

The Construction Program faculty and students are active participants in the Center for Integrated Facility Engineering (CIFE). In collaboration with Computer Science and other departments, CIFE conducts research on the automation, integration, and management of technology in the construction industry. The Collaboratory for Research on Global Projects (CRGP) carries out research on the special challenges of international projects in partnership with CIFE.

The program maintains close ties with the construction industry through the Stanford Construction Institute. Students participate in weekly discussions with visiting lecturers from all sectors of the U.S. construction industry.

DESIGN/CONSTRUCTION INTEGRATION

To better prepare graduates for successful careers as design and construction professionals making major contributions to integrated projects, the department offers a Master of Science (M.S.), Engineer, and Ph.D. degree field in Design/Construction Integration (DCI).

This program aims to educate design and construction professionals to understand the goals and concerns of the many other project stakeholders, and to prepare for multidisciplinary, collaborative teamwork to develop sustainable buildings and infrastructure facilities in an integrated design and construction process.

The field of Design/Construction Integration is open to applicants with backgrounds in engineering and science. Applicants should also have a background in the planning, design, or construction of facilities by virtue of previous work experience and/or their undergraduate education. Knowledge in basic subjects from the traditional areas of civil engineering is necessary for students to receive the degree and to satisfy prerequisite requirements for some of the required graduate courses.

The M.S. Degree in Design/Construction Integration requires 45 quarter units, which are normally completed in one academic year. This includes core courses in design/construction integration, structural and geotechnical engineering, and construction engineering and management, along with approved electives.

The department offers three programs related to the design and construction of facilities: Structural Engineering and Geomechanics (SEG), Construction Engineering and Management (CEM), and Design/Construction Integration (DCI).

The SEG program prepares students for careers as designers, engineering analysts, engineering risk managers, specialty consultants, or tool developers. It encompasses structural analysis and design, dynamics, earthquake engineering, risk and reliability analysis, modern computational methods, and geomechanics.

The CEM program prepares technically qualified students for responsible engineering and management roles in all phases of the development of major constructed facilities. It emphasizes management techniques useful in organizing, planning, and controlling the activities of diverse specialists working within the unique project environment of the construction industry. The program also includes the engineering aspects of heavy, industrial, and building construction.

The DCI program prepares students for multidisciplinary collaborative teamwork in an integrated design and construction process. The program extends a student's design or construction background with core courses in each of these areas and develops the background needed to understand the concerns and expertise of the many project stakeholders. It includes a comprehensive project-based learning experience.

Prospective students should use their intended career path as the primary criterion in selecting between these three programs. SEG best fits students planning to focus on designing facilities; CEM is for students planning to emphasize building facilities or managing teams and operations. Both of these degree options provide background for many different types of careers in design and construction, with some emphasis on preparation for working on projects using traditional forms of contracting and organization. Students planning careers with design or construction firms that emphasize design-build, EPC, or turnkey projects should consider DCI. All three of the degree options include substantial flexibility for students to tailor their program of study to career interests.

ENVIRONMENTAL AND WATER STUDIES

This program covers a broad spectrum of specialties, including environmental engineering and science, environmental fluid mechanics, environmental planning, and hydrology. Course offerings are scheduled to permit either intensive study in a single area or interrelated study between areas. Seminars provide a broad coverage of environmental problems. The programs are kept flexible to foster interaction among students and to encourage the development of individual programs suitable for a broad range of engineering and science backgrounds and career goals. The Stanford laboratories for water quality control and environmental fluid mechanics are well equipped and instrumented for advanced research and instruction.

Students with backgrounds in all areas of engineering and science who are interested in applying their specialized abilities to solving environmental and water problems are welcome. Comprehensive introductory courses in each major area of study are given to provide common understanding among those with dissimilar backgrounds. Courses from many other programs and departments both complement and supplement these course offerings. Some examples include Computer Science (numerical methods), Geological and Environmental Sciences (geostatistics, hydrogeology), Mechanical Engineering (applied math, experimental methods, fluid mechanics, heat transfer), Petroleum Engineering (reservoir engineering, well-test analysis), and Statistics (probability and statistics). The major areas of specialization in the two programs, environmental engineering and science, and environmental fluid mechanics and hydrology, are described below. Admissions to these two programs are handled separately; prospective students should clearly indicate their preference on their application by specifying one or the other area of specialization.

The Environmental Engineering and Science Program (EES) emphasizes the chemical and biological processes involved in water quality engineering, pollution treatment, remediation, and environmental protection. Course offerings include the biological, chemical, and engineering aspects of water supply; the movement and fate of pollutants in surface and ground waters, soil, and the atmosphere; hazardous substance control; molecular environmental biotechnology; and water and air pollution. Companion courses in the Environmental Fluid Mechanics and Hydrology Program (EFMH) include environmental planning and impact assessment, as well as environmental fluid mechanics, hydrology, and transport modeling. Research on hazardous substances is coordinated through the Western Region Hazardous Substance Research Center. The objective of this center, sponsored by the U.S. Environmental Protection Agency, is to promote through fundamental and applied research the development of alternative and advanced physical, chemical, and biological processes for the treatment of hazardous substances in the environment, with emphasis on groundwater contamination.

The Environmental Fluid Mechanics and Hydrology Program focuses on developing an understanding of the physical processes controlling the movement of mass, energy, and momentum in the water environment and the atmosphere. The program also considers environmental and institutional issues involved in planning water resources development projects. Environmental fluid mechanics courses address experimental methods; fluid transport and mixing processes; the fluid mechanics of stratified flows; natural flows in coastal waters, estuaries, lakes, and open channels; and turbulence and its modeling. Hydrology courses consider flow and transport in porous media, stochastic methods in both surface and subsurface hydrology, and watershed hydrology and modeling. Atmosphere-related courses deal with climate, weather, storms and air pollution and their modeling. Planning courses emphasize environmental policy implementation and sustainable water resources development. The research of this group is focused primarily in the Environmental Fluid Mechanics Laboratory, which includes the P. A. McCuen Environmental Computer Center.

STRUCTURAL ENGINEERING AND GEOMECHANICS

Structural engineering at Stanford encompasses computational mechanics, computer-aided engineering, risk and reliability analysis, structural analysis and design, and teaching and research programs in earthquake engineering and structural dynamics. The programs are designed to provide a broad knowledge in these fields and to prepare students for industrial or academic careers. Academic programs can be designed to meet the needs of students wishing to launch careers as consultants on large and small projects, designers, and engineering analysts. Students have the opportunity to balance strong engineering fundamentals with modern computational methods.

Course work in earthquake engineering and structural dynamics provides an understanding of the earthquake phenomenon, the resulting ground shaking, and in-depth knowledge on the behavior, analysis, and design of various types of structures under seismic or other dynamic forces. Automated structural monitoring devices and control systems, and the utilization of advanced materials for civil infrastructures and seismic retrofits, are part of the ongoing research activities. Advanced analytical and experimental research in earthquake engineering is conducted at the John A. Blume Earthquake Engineering Center, which houses static and dynamic testing equipment including two shaking tables.

Reliability and risk analysis focuses on instruction and research in advanced methods for structural safety evaluation and design, including methods for loss estimation from damage and failures of structures and lifeline systems. Course work combines a strong background in structural analysis and design with probability theory and statistics. Research deals with regional loss and damage evaluation, reliability of marine systems, seismic risk and reliability of large structural systems, and wind hazards.

Courses and research in structural analysis and design focus on the conceptual and detailed design of structural systems and on computational methods for predicting the static and dynamic, linear and non-linear response of structures. Included are courses that emphasize earthquake resistant design, design with high-performance materials, and computer-based design concepts. Related course work is available from other departments such as Computer Science, Materials Science and Engineering, and Mechanical Engineering. In collaboration with CIFE, issues involving design for constructibility, engineering information management and collaborative engineering are addressed as an integral part of the research.

Computational mechanics emphasizes the application of modern computing methods to structural engineering and geomechanics. It draws on the disciplines of computer science, mathematics, and mechanics, and encompasses numerical structural and geotechnical analysis, including finite element analysis and boundary element methods. There is collaborative research in high performance computing with the Scientific Computing and Computational Mathematics Program.

Students with primary interests in the application of the principles of applied mechanics to problems involving geologic materials have the option of enrolling in a degree program in geomechanics. This program focuses on instruction and research in theoretical soil and rock mechanics, computational methods, and analysis and design of foundations and earth structures. In addition to the program's offerings, related courses are available in construction engineering, earth sciences, structural engineering, and the water resources program.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

The B.S. in Civil Engineering is an ABET accredited program as is the newly initiated B.S. in Environmental Engineering. High priority is placed on integrating research with engineering education. Four major objectives structure both degree programs:

1. To provide an understanding of engineering principles and the analytical, problem solving, design, and communication skills to continue succeeding and learning in diverse careers.
2. To prepare for successful engineering practice with a longer term perspective that takes into account new tools such as advanced information technology and biotechnology, and increasingly complex professional and societal expectations.
3. To prepare for possible graduate study in engineering or other professional fields.
4. To develop the awareness, background, and skills necessary to become responsible citizens and leaders in service to society.

Students who major in Civil Engineering or in Environmental Engineering must complete the appropriate requirements for the B.S. degree listed under Undergraduate Programs in the "School of Engineering" section of this bulletin. Elective units may be used in any way the student desires, including additional studies in civil and environmental engineering. Because the undergraduate engineering curriculum is designed to ensure breadth of study, students who intend to enter professional practice in civil or environmental engineering should plan to obtain their professional education at the graduate level.

A number of undergraduate programs at Stanford may be of interest to students seeking to specialize in environmental studies. In addition to the two majors offered within our own department, interested students should examine related programs such as Earth Systems, Geological and Environmental Sciences, Urban Studies, and Human Biology.

HONORS PROGRAM

This program leads to a B.S. with Honors in Civil Engineering or in Environmental Engineering. It is designed to encourage highly qualified students in an engineering major to undertake a more intensive study of civil and environmental engineering than is required for the normal major via a substantial, independent research project.

The program involves an in-depth research study in an area proposed to and agreed to by a Department of Civil and Environmental Engineering (CEE) faculty adviser and completion of a thesis of high quality. A written proposal for the research to be undertaken must be submitted and approved in the fourth quarter prior to graduation. At the time of application, the student must have an overall grade point average (GPA) of at least 3.3 for course work at Stanford; this GPA must be maintained to graduation. The thesis is supervised by a CEE faculty adviser and must involve input from the School of Engineering Writing Program by means of ENGR 102S or its equivalent. The written thesis must be approved by the thesis adviser. Students are encouraged to present their results in a seminar for faculty and other students. Up to 10 units of CEE 199H, Undergraduate Honors Research in Civil and Environmental Engineering, may be taken to support the research and writing (not to duplicate ENGR 102S). These units are beyond the normal Civil Engineering or Environmental Engineering program requirements.

MINOR IN CIVIL ENGINEERING OR ENVIRONMENTAL ENGINEERING

The department offers B.S. minor programs in both Civil Engineering and Environmental Engineering. Departmental expertise and undergraduate course offerings are available in the areas of Architectural Engineering, Construction Engineering, Construction Management, Structural/Geotechnical Engineering, Environmental Engineering and Science, Environmental Fluid Mechanics and Hydrology, and in Energy. The courses required for the minors typically have prerequisites; students need to check what these are for their choice of minor. The minimum prerequisite for a Civil Engineering minor is MATH 42 (or MATH 21); however, many courses of interest require PHYSICS 53 and/or MATH 51 as prerequisites. Students should recognize that minors are not ABET-accredited programs.

Since undergraduates having widely varying backgrounds may be interested in obtaining a minor, no single set of course requirements is appropriate for all students. Instead, interested students are encouraged to propose their own set of courses within prescribed guidelines and submit it for review and approval by the undergraduate minors adviser for the department, Professor Robert Street. Guidelines on a minor for either Civil Engineering or Environmental Engineering and example programs are available in the department's office of student services in Terman Engineering, Room M42, or at http://cee.stanford.edu.

GRADUATE PROGRAMS

The University requirements governing the M.S., Engineer, and Ph.D. are described in the "Graduate Degrees" section of this bulletin.

Admission—Applications require online submission of the application form and statement of purpose, followed by three letters of recommendation, results of the General Section of the Graduate Record Examination, and transcripts of courses taken at colleges and universities. Go to http://gradadmissions.stanford.edu/. Policies for each of the department's programs are available by referring to http://cee.stanford.edu.

Successful applicants are advised as to the degree and program for which they are admitted. If students wish to shift from one CEE program to another after being accepted, an application for the intradepartmental change must be filed within the department; they will then be advised whether the change is possible. If, after enrollment at Stanford, students wish to continue toward a degree beyond the one for which they were originally admitted, a written application must be made to the Department of Civil and Environmental Engineering.

Financial Assistance—The department maintains a continuing program of financial aid for graduate students. Applications for financial aid and assistantships should be filed by December 14, 2004; it is important that Graduate Record Examination scores be available at that time. Applicants not requesting financial assistance have until March 29, 2005 for the online submission.

Teaching assistantships carry a salary for as much as one-half time work to assist with course offerings during the academic year. Up to half-time research assistantships also are available. Engineer and Ph.D. candidates may be able to use research results as a basis for the thesis or dissertation. Assistantships and other basic support may be supplemented by fellowship and scholarship awards or loans. Continued support is generally provided for further study toward the Engineer or Ph.D. degree based on the student's performance, the availability of research funds, and requisite staffing of current projects.

MASTER OF SCIENCE

The following programs are available leading to the M.S. degree in Civil and Environmental Engineering: Atmosphere/Energy, Construction Engineering and Management, Design/Construction Integration, Environmental Engineering and Science, Environmental Fluid Mechanics and Hydrology, Geomechanics, and Structural Engineering.

Students admitted to graduate study with a B.S. in Civil Engineering (or its equivalent) from an accredited curriculum can satisfy the requirements for the M.S. degree in Civil and Environmental Engineering by completing a minimum of 45 units of study beyond the B.S. All 45 units must be taken at Stanford. A minimum 2.75 grade point average (GPA) is required for candidates to be recommended for the M.S. degree. No thesis is required.

The program of study must be approved by the faculty of the department and should include at least 45 units of courses in engineering, mathematics, science, and related fields unless it can be shown that other work is pertinent to the student's objectives.

Candidates for the M.S. in Civil and Environmental Engineering who do not have a B.S. in Civil Engineering may, in addition to the above, be required to complete those undergraduate courses deemed important to their graduate programs. In such cases, more than three quarters is often required to obtain the degree. Students may, with the approval of their academic adviser, select a program that satisfies the requirements for the M.S. in Engineering.

Forms required for the degree may be secured from the department's office of student services.

ENGINEER

A student with an M.S. in Civil Engineering may satisfy the requirements of the degree of Engineer in Civil and Environmental Engineering by completing 45 unduplicated course work and research units for the degree and minimum residency of 90 total units. Engineer candidates must submit an acceptable thesis (12 to 15 units) and maintain a minimum GPA of 3.0. The program of study must be approved by a faculty member in the department.

This degree is recommended for those desiring additional graduate education, especially those planning a career in professional practice. The thesis normally should be started in the first quarter of graduate study after the M.S. degree. Programs are offered in the fields of specialization mentioned for the M.S. degree. The Engineer thesis topic, for students who will continue study toward a CEE Ph.D., must be significantly different from their doctoral research.

DOCTOR OF PHILOSOPHY

The Ph.D. is offered under the general regulations of the University as set forth in the "Graduate Degrees" section of this bulletin. This degree is recommended for those who expect to engage in a professional career in research, teaching, or technical work of an advanced nature. The Ph.D. program is rigorous and should be undertaken only by students with ability for independent work. It requires a total of 135 units of graduate study, at least two years of which must be at Stanford with a minimum GPA of 3.0 in post-M.S. course work. Experience has shown that few students complete the Ph.D. within the minimum residence period. Prospective doctoral students should anticipate the possibility of at least one extra year. All candidates for the Ph.D. degree are required to complete CEE 200 in conjunction with a one-quarter teaching assistantship/course assistantship to gain training and instructional experience. Further information on Ph.D. requirements and regulations is found in the department handbook.

The first year of graduate study can be represented by the M.S. program described above. The second year is devoted partly to additional graduate courses and partly to preliminary work toward a dissertation. The third and subsequent years are applied to further course work and to the completion of an acceptable dissertation.

The program of study is arranged by the prospective candidate at the beginning of the second year with the advice of a faculty committee whose members are nearest in the field of interest to that of the student. The chair of the committee serves as the student's pro tem adviser until such time as a member of the faculty has agreed to direct the dissertation research. Insofar as possible, the program of study is adapted to the interests and needs of the student within the framework of the requirements of the department and the University.

In the second year of graduate study, the student is expected to pass the department's General Qualifying Examination (GQE) to be admitted to candidacy for the doctoral degree. The purpose of the GQE is to ensure that a student is adequately prepared to undertake doctoral research and has a well planned research topic. The exam may take the form of (1) a written and/or oral general examination of the candidate's major field, (2) a presentation and defense of the candidate's doctoral research dissertation proposal, or (3) a combination research proposal and general examination. The GQE is administered by an advisory committee consisting of at least three Stanford faculty members, including a chair who is a faculty member in Civil and Environmental Engineering. All members are normally on the Stanford Academic Council. A petition for appointment of one advisory committee member who is not on the Academic Council may be made if the proposed person contributes an area of expertise that is not readily available from the faculty. Such petitions are subject to approval by the department chair.

PH.D. MINOR

A Ph.D. minor is a program outside a major department. Requirements for a minor are established by the minor department. Acceptance of the minor as part of the total Ph.D. program is determined by the major department. Application for Ph.D. minor must be approved by both the major and the minor department, and the minor department may be represented at the University oral examination.

A student desiring a Ph.D. minor in Civil and Environmental Engineering (CEE) must have a minor program adviser who is a regular CEE faculty member in the program of the designated subfield. This adviser must be a member of the student's University oral examination committee and the reading committee for the doctoral dissertation.

The program must include at least 20 units of graduate-level course work (that is, courses numbered 200 or above, excluding special studies and thesis) in CEE completed at Stanford University. The list of courses must form a coherent program and must be approved by the minor program adviser and the CEE chair. A minimum GPA of at least 3.0 must be achieved in these courses.

HONORS COOPERATIVE PROGRAM

Some of the department's graduate students participate in the Honors Cooperative Program (HCP), which makes it possible for academically qualified engineers and scientists in industry to be part-time graduate students in Civil and Environmental Engineering while continuing professional employment. Prospective HCP students follow the same admissions process and must meet the same admissions requirements as full-time graduate students. For more information regarding the Honors Cooperative Program, see the "School of Engineering" section of this bulletin.

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).

UNDERGRADUATE

CEE 31. Accessing Architecture Through Drawing—Same content as 31Q except offered as a regular course. Limited enrollment.
4 units, Win (Barton)

CEE 31Q. Accessing Architecture Through Drawing—Stanford Introductory Seminar. Preference to sophomores. Drawing architecture provides a deeper understanding of the intricacies and subtleties that characterize contemporary buildings. How to dissect buildings and appreciate the formal elements of a building, including scale, shape, proportion, colors and materials, and the problem solving reflected in the design. Students construct conventional architectural drawings, such as plans, elevations, and perspectives. Limited enrollment.
4 units, Aut (Walters)

CEE 46Q. Fail Your Way to Success—Stanford Introductory Seminar. Preference to sophomores. How to turn failures into successes; cases include minor personal failures and devastating engineering disasters. How personalities and willingness to take risks influence the way students approach problems. Field trips, case studies, and guest speakers applied to students' day-to-day interactions and future careers. Goal is to redefine what it means to fail. GER:2b
3 units, Spr (Clough)

CEE 63. Weather and Storms—(Graduate students register for 263C.) Survey of daily and severe weather, and global climate. Topics: structure and composition of the atmosphere, fog and cloud formation, rainfall, local winds, global circulation, jet streams, high and low pressure systems, inversions, el Niño, la Niña, atmosphere-ocean interactions, fronts, cyclones, thunderstorms, lightning, tornadoes, hurricanes, pollutant transport, global climate, and atmospheric optics. GER:2a
3 units, Aut (M. Jacobson)

CEE 64. Air Pollution: From Urban Smog to Global Change—(Graduate students register for 263D.) Survey of urban through global-scale air pollution. Topics: the evolution of the earth's atmosphere, indoor air pollution, urban smog formation, effects of exposure to air pollution, visibility, acid rain, global climate change, stratospheric ozone reduction, Antarctic ozone destruction, air pollution transport across political boundaries, the effects of meteorology on air pollution, and the effects of air pollution and stratospheric ozone on human exposure to ultraviolet radiation. GER:2a
3 units, Spr (M. Jacobson)

CEE 66. Energy Production and its Impact on the Atmosphere—Physical and technical issues associated with current and future energy use. The physics of energy including solar, chemical, thermal, and nuclear. How to calculate or estimate the energy content of systems. What are likely sources of future energy needs? Projected changes during the 21st century, basic scientific information needed to make informed choices, and potential renewable energy resources.
3 units, Aut (Tabazadeh)

CEE 70. Environmental Science and Technology—Introduction to environmental quality and technical background for understanding environmental issues, controlling environmental degrading, and preserving air and water quality. Material balance concepts for tracking substances in the environmental and engineering systems. Environmental laws relating to water and air quality, and control of hazardous materials; the technical basis for policy and environmental risk. Three-day field project to quantify the flux of pollutants from a local watershed outlet to the ocean or bay. GER:2b
3 units, Aut (Boehm)

CEE 80N. The Art of Structural Engineering—Stanford Introductory Seminar. Preference to freshmen. The history of modern bridges, buildings, and other large-scale structures. Principles of structural engineering through case studies. Analysis of structural form with scientific, social, and symbolic considerations. Field trip to Bay Area landmark and hands-on exercises including building and testing a model bridge. Goal is appreciation of modern structures, their social context, and the art of structural engineering. Students from all backgrounds welcome. GER:2b
4 units, Aut (Billington)

CEE 99A,B,C. Environmental Issues Seminar
1 unit, **A:** *(Staff) not given 2004-05,* **B:** *Win (Kitanidis),*
C: *(Staff) not given 2004-05*

CEE 100. Managing Sustainable Building Projects—The facility life cycle and project delivery organization emphasizing life cycle concerns including cost, first cost, project schedule and organization, and sustainability. Techniques for organizing, and executing civil engineering projects from conception to completion. Project objectives such as scope, quality, cost, time, and safety from multiple perspectives. Roles, responsibilities, and risks for project participants including owners, designer, and builders. Time and cost planning and control including scheduling and cost estimating techniques using information technology. Virtual design and construction technologies. Small team, real world projects; individual paper. Recommended: CEE 111. GER:2b,WIM
3-4 units, Aut (Fischer)

CEE 101A. Mechanics of Materials—Introduction to beam and column theory. Normal stress and strain in beams under various loading conditions; shear stress and shear flow; deflections of determinate and indeterminate beams; analysis of column buckling; structural loads in design; strength and serviceability criteria. Lab experiments. Prerequisites: ENGR 14. GER:2b
4 units, Win (Staff)

CEE 101B. Mechanics of Fluids—Physical properties of fluids and their effect on flow behavior; equations of motion for incompressible ideal flow, including the special case of hydrostatics; continuity, energy, and momentum principles; control volume analysis; laminar and turbulent flows; internal and external flows in specific engineering applications including pipes, open channels, estuaries, and wind turbines. Prerequisites: PHYSICS 53, MATH 51. GER:2b
4 units, Spr (Koseff)

CEE 101C. Geotechnical Engineering—Introduction to the principles of soil mechanics. Soil classification, shear strength and stress-strain behavior of soils, consolidation theory, analysis and design of earth retaining structures, introduction to shallow and deep foundation design, slope stability. Lab projects. Prerequisite: ENGR 14. Recommended: 101A. GER:2b
3-4 units, Aut (Borja)

CEE 101D. Mathematical Laboratory Applications in Civil and Environmental Engineering—(Graduate students register for 201D.) Use of commercial professional software in the design and analysis of civil and environmental engineering systems. MATLAB 5 is applied to relevant problems and issues that students encounter in subsequent courses and in engineering practice. Limited enrollment.
2 units, Aut (Kitanidis)

CEE 102. Legal Aspects of Engineering and Construction—Introduction to the U.S. legal system as it applies to civil engineering and construction. Fundamental concepts of contract and tort law, claims, risk management, business formation and licensing, agency, insurance and bonding, and real property.
3 units, Win (London)

CEE 111. 3D Modeling Plus Analyses—Modeling, visualization, and graphical communication of civil engineering projects, 3D CAD and use of 3D models for analysis including 4D modeling and sustainability concerns such as energy simulation and lighting analysis. Underlying computer representations, applications of 3D models and related analyses in design, construction, and building operations. Lab exercises, class project. Coordinated with CEE100. Prerequisite: 100 or consent of instructor. GER:2b
3 units, Aut (Fischer)

CEE 115A,B,C,D. Industry Seminar and Internship Program—(Graduate student register for 215.) Each Wednesday, a civil engineering industry representative facilitates a noon brown bag class on a topic relevant to an industry segment. 10-20 speakers per year. During the year, students and companies match interests and make employment arrangements for the following summer. Students write brief reports to faculty and industry advisers for class credit.
1 unit, **A:** *Aut (Clough),* **B:** *Win (Fischer),* **C:** *Spr (Clough),* **D:** *Sum (Staff)*

CEE 122A,B. Computer Integrated Architecture/Engineering/Construction (A/E/C)—(Undergraduates serve as apprentices in 222A,B; see 222A,B.)
2 units, **A:** *Win (Fruchter),* **B:** *Spr (Fruchter)*

CEE 130. Introduction to Architecture Studio—Principles of and approaches to architectural design. Architectural models as a primary design tool. Incrementally staged design projects explore conventional design guidelines and creative design strategies. Final project applies aesthetic principles and individual strategies to the design of a simple building. Limited enrollment.
4 units, Win (Walters)

CEE 131. Architectural Design Process—Fundamental issues in the architectural profession including design theory, professional practice concerns, site analysis. and design process. Building/landscape design case study project in model form and using architectural graphics exercises.
4 units, Spr (Blake, Todd)

CEE 132. Interplay of Architecture and Engineering—Requirements that drive a building's design including architecture, engineering, constructability, building codes, and budget. Case studies illustrate how structural and mechanical systems are integrated into building types including residential, office, commercial, and retail. In-class studio work.
4 units, Win (Katz)

CEE 134. The Architecture of the House—Studio course on the design of the single family home. Emphasis is on identification and review of the typical house form and its elements. Architectural form in the context of local planning regulations, space making fundamentals, structure, concept, and sustainability. Students work in drawings, model, and computer as appropriate.
4 units, Aut (Barton)

CEE 135. Building Modeling Workshop—(Formerly URBANST 168.) Computer-aided drafting, modeling, and rendering techniques. The capabilities and applications of leading architectural design tools such as AutoCAD, Revit, Viz, and Photoshop in four intensive training sessions. Supervised work on computers. Assignments apply these tools to build CAD models of familiar building projects. Five course meetings; limited enrollment.
2 units, Aut (Katz)

CEE 136. Green Architecture—Goal is to develop a working definition of ecologically sustainable design and strategies for greening the built environment. Readings, discussion, and research lay the groundwork for an architectural design studio which explores the student and faculty inspired green dorm initiative. Limited enrollment. Preference to students with design or environmental engineering experience. GER:2b
4 units, Aut (B. Jacobson)

CEE 137. Architectural Design of Individual Buildings: Ethics, Community Service, and Social Responsibility—Community service oriented studio course emulates a design office and requires students to prepare concept-level designs for real projects. Projects may involve small on-campus facilities such as a campus bicycle repair facility, or off-campus facilities for economically disadvantaged communities in developing countries such as an orphanage or teen center in a Mexican town. Prerequisite: at least one other Architecture Studio course, or consent of instructor. Limited enrollment.
3-6 units, Spr (Jann)

CEE 139. Design Communication Methods—Preference to students in CEE, Urban Studies, and Art. Students present designs completed in other studio courses to communicate design intentions and other aspects of their work. Instruction in photography. Preparation of a design portfolio. Oral presentation workshops offered through the Center for Teaching and Learning. Limited enrollment. Prerequisites: two Art or Architecture Studio courses, or consent of instructor.
3 units, Spr (Barton, Walters)

CEE 140. Field Surveying Laboratory—Friday afternoon laboratory provides practical surveying experience. Some additional morning classes to prepare for afternoon sessions. Operation of common field survey tools; introduction to the newest generation of digital measuring, positioning, and mapping tools. Emphasis is on using field data as the basis for subsequent engineering and economic decisions. GER:2b
3 units, Spr (Williams)

CEE 141. Project for ASCE: Design and Construction of Steel Bridge—Design, construction, and testing of steel bridge; selection of materials and construction methods; participation in regional competition.
1 unit, Aut, Win, Spr (Staff)

CEE 143. Virtual Design and Construction—(Graduate students register for 243.) Computer-based models in building design and construction. Virtual design and construction (VDC) is the use of multidisciplinary performance models of design-construction projects, including the product (facilities), work processes, organization of the design-construction-operation team, and economic impact (model of both cost and value of capital investments) in order to support business objectives. Successful participation may allow students a 4-day mini-internship at an A/E/C company over Spring break. Recommended: 241, 242.

3-4 units, Win (Kunz)

CEE 147. Cases in Personality, Leadership, and Negotiation—(Graduate students register for 247.) Case studies target leadership, risk willingness, and life skills essential for real world success. Personality and thinking styles of the student and difficult people. Failures, successes, and risk willingness examined in individual and group tasks based on the professor's thirty years of experience as a small business owner and construction engineer. Required full afternoon field trips to local sites. Limited to matriculating students; mandatory first class attendance.

4 units, Spr (Clough)

CEE 148. Design and Construction of Affordable Housing—Planning, design, engineering, and construction in the development of affordable housing. Topics: the socioeconomic context of affordable housing; stages in property development; issues in design; types of structures, methods, and materials used in housing construction; and property management. Students apply what they learn in assignments where they interact with non-profit housing developers, city planning officials, and architects. Two Saturday field trips to affordable housing developments. GER:2b

3-4 units, Win (Paulson)

CEE 151. Negotiation—(Graduate students register for 251; same as MS&E 285, ME 207.) Introduction to negotiation styles and processes in order to help students conduct and review negotiations. Workshop format integrating intellectual and experiential learning. Students analyze the negotiation process through exercises, live and field examples, individual and small group reviews. Students must apply before the first day of class. See course website for details. Enrollment limited to 50.

3 units, Aut, Spr (Christensen)

CEE 154. Cases in Estimating Costs—(Graduate students register for 254.) Case studies of business decisions based on rational cost estimating in competitive markets. Emphasis is on the fundamental forces driving the construction industry as seen on site visits; general principles applicable to any competitive business. Cases based on the professor's thirty years of experience as a small business owner and construction engineer. Full afternoon field trips to local sites. Prerequisite: matriculating student; mandatory first class attendance. GER:2b

3 units, Aut (Clough)

CEE 156. Building Systems—(Graduate students register for 256.) Design concepts, options for increased sustainability, integration issues, construction materials, and installation operations for heating, ventilating, and air conditioning systems. Overview of other building systems. Corequisite for undergraduates: 156A. GER:2b

3 units, Win (Staff)

CEE 156A. Building System Design Experience—Design of the heating, ventilating, and air conditioning system for a commercial building project shared with 181A/B. Types of design constraints. Corequisite: 156.

1 unit, Win (Staff)

CEE 160. Mechanics of Fluids Laboratory—Lab experiments and demonstrations illustrate conservation principles and flows of real fluids. Corequisite: 101B.

2 units, Spr (Monismith)

CEE 161A. Rivers, Streams, and Canals—(Graduate students register for 264A.) Introduction to the movement of water through natural and engineered channels, streams, and rivers. Basic equations and theory (mass, momentum, and energy equations) for steady and unsteady descriptions of the flow. Application of theory to the design of flood-control and canal systems. Flow controls such as weirs and sluice gates; gradually varied flow; Saint-Venant equations and flood waves; and method of characteristics. Open channel flow laboratory experiments: controls such as weirs and gates, gradually varied flow, and waves. Students taking lab section register for 4 units. Prerequisites: 101B, 160. GER:2b

3-4 units, Aut (Street)

CEE 162. Modeling and Simulation for Civil and Environmental Engineers—Introduction to mathematical and computational methods for modeling and simulation and the use of the Simulink toolbox in Matlab to cover topics including transport, air and water quality, reservoir, and global climate modeling. Course is application driven; students work in groups on three projects with an extensive final project. Prerequisites: CME 100, 102 (formerly ENGR 154, 155A) or equivalent. GER:2a

3 units, Spr (Fringer)

CEE 164. Introduction to Physical Oceanography—(Graduate students register for 262D; same as EARTHSYS 164.) Introduction to the dynamic basis of physical oceanography. Topics: a general description of the physical environment of the ocean; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; the thermohaline circulation of the deep oceans; and tides. Prerequisite: PHYSICS 53. GER:2a

4 units, Win (Fong)

CEE 166A. Watersheds and Wetlands—(Graduate students register for 266A.) An introduction to the occurrence and movement of water in the natural environment and its role in creating and maintaining terrestrial, wetland, and aquatic habitat. Hydrologic processes, including precipitation, evaporation, transpiration, snowmelt, infiltration, subsurface flow, runoff, and streamflow. Rivers and lakes, springs and swamps. Emphasis is on observation and measurement, data analysis, modeling, and prediction. Prerequisite: 101B or equivalent. GER:2b

3 units, Aut (Freyberg)

CEE 166B. Floods and Droughts, Dams and Aqueducts—(Graduate students register for 266B.) Sociotechnical systems associated with human use of water as a resource and the hazards posed by too much or too little water. Potable and non-potable water use and conservation. Irrigation, hydroelectric power generation, rural and urban water supply systems, storm water management, flood damage mitigation, and water law and institutions. Emphasis is on engineering design. Prerequisite: 166A or equivalent. GER:2b

3 units, Win (Freyberg)

CEE 166D. Water Resources and Water Hazards Field Trips—(Graduate students register for 266D.) Introduction to water use and water hazards via weekly field trips to local and regional water resources facilities (dams, reservoirs, fish ladders and hatcheries, pumping plants, aqueducts, hydropower plants, and irrigation systems) and flood damage mitigation facilities (storm water detention ponds, channel modifications, flood control dams, and reservoirs). Each trip preceded by an orientation lecture.

2 units, Win (Freyberg)

CEE 169. Environmental and Water Resources Engineering Design—Application of fluid mechanics, hydrology, water resources, environmental sciences, and engineering economy fundamentals to the design of a system addressing a complex problem of water in the natural and constructed environment. Problem changes each year, generally drawn from a challenge confronting the University or a local community. Student teams prepare proposals, progress reports, oral presentations, and a final design report. Prerequisite: senior in Civil Engineering or Environmental Engineering; 166B.

5 units (Freyberg) alternate years, given 2005-06

CEE 171. Environmental Planning Methods—For juniors and seniors. Use of microeconomics and mathematical optimization theory in the design of environmental regulatory programs; tradeoffs between equity and efficiency in designing regulations; techniques for predicting visual, noise, and traffic impacts in environmental impact assessments. Prerequisites: 70, MATH 51. GER:2b

3 units, Win (Ortolano)

CEE 172. Air Quality Management—Quantitative introduction to the engineering methods used to study and seek solutions to current air quality problems. Topics: global atmospheric changes, urban sources of air pollution, indoor air quality problems, design and efficiencies of pollution control devices, and engineering strategies for managing air quality. Prerequisites: 70, MATH 51. GER:2b

3 units, Win (Hildemann)

CEE 173A. Energy Resources—(Graduate students register for 207A; same as EARTHSYS 103.) Overview of oil, natural gas, coal, nuclear, hydro, solar, geothermal, biomass, wind, and ocean energy resources in terms of supply, distribution, recovery and conversion, environmental impacts, economics, policy, and technology. The opportunities for energy efficiency, electric power basics, the changing role of electric utilities, transportation basics, and energy use in developing countries. Field trips. Recommended: 70. GER:2b

4-5 units, Aut (Woodward)

CEE 173B. The Coming Energy Revolution—(Graduate students register for 207B.) The forces driving an energy revolution: environmental pressures; global, social, and economic revolution; and technological change. Assessment of evolution versus revolution, developed versus developing countries, transportation, electric power, resource development and extraction, end use technologies, deregulation, privatization and globalization, barriers to change, and the mechanisms to overcome them. Enrollment limited to 15. Prerequisite: 173A. GER:2b

4 units (Woodward) not given 2004-05

CEE 173G. Technology Implementation for Sustainable Development in Developing Countries—(Graduate students register for 207G.) Case studies: societal, institutional, and technological contexts; scientific, engineering, and economic aspects; technical suitability; implementation; and potential societal impact.

3 units, Win (Gadgil)

CEE 175. Environmental Economics and Policy—(Enroll in ECON 155, EARTHSYS 112.)

5 units, Spr (Goulder)

CEE 176A. Energy Efficient Buildings—Analysis and design. Thermal analysis of building envelope, heating and cooling requirements, daylighting, and HVAC systems. Emphasis is on residential passive solar design, and solar water heating. Lab. Prerequisite: 173A. GER:2b

3-4 units, Win (Masters) alternate years, not given 2005-06

CEE 176B. Electric Power: Renewables and Efficiency—Renewable and efficient electric power systems emphasizing analysis and sizing of photovoltaic arrays and wind turbines. Basic electric power generation, transmission and distribution, distributed generation, combined heat and power, fuel cells. End use demand, including lighting and motors. Lab. Prerequisite: 173A. GER:2b

3-4 units (Masters) alternate years, given 2005-06

CEE 176F. Energy Systems Field Trips

1-2 units, Win (Masters)

CEE 177. Aquatic Chemistry and Biology—Undergraduate-level introduction to the chemical and biological processes in the aqueous environment. Basic aqueous equilibria; the structure, behavior, and fate of major classes of chemicals that dissolve in water; redox reactions; the biochemistry of aquatic microbial life; and biogeochemical processes that govern the fate of nutrients and metals in the environment and in engineered systems. Prerequisite: CHEM 31. GER:2b

4 units, Aut (Criddle)

CEE 177S. Design for a Sustainable World—(Graduate students register for 277S.) Technology-based problems faced by developing communities worldwide. Student groups partner with organizations abroad to work on concept, feasibility, design, implementation, and evaluation phases of various projects. Projects this year include a water and health initiative, green school design, seismic safety, and HIV interventions. Admission based on written application and interview; see http://esw.stanford.edu/application.fft before first class for application.

1-5 units, Aut, Win, Spr (Burney, Walewijk)

CEE 178. Introduction to Human Exposure Analysis—(Graduate students register for 276.) Scientific and engineering issues involved in quantifying human exposure to toxic chemicals in the environment. Pollutant behavior, inhalation exposure, dermal exposure, and assessment tools. Overview of the complexities, uncertainties, and physical, chemical, and biological issues relevant to risk assessment. Lab projects. Recommended: MATH 51. GER:2b

3 units, Spr (Leckie)

CEE 179A. Water Chemistry Laboratory—(Graduate students register for 273A.) Laboratory application of techniques for the analysis of natural and contaminated waters, emphasizing instrumental techniques.

2 units, Win (Leckie)

CEE 179B. Process Design for Environmental Biotechnology—(Graduate students register for 275B.) Alternates with 169. Preference to juniors and seniors in CEE. Design of a water or wastewater treatment system using biological processes to remove contaminants. Student teams characterize contaminants in water or wastewater, design and operate bench- and pilot-scale units, and develop a full-scale design. Limited enrollment. Prerequisites: 177, 179A. GER:2b

5 units, Spr (Criddle)

CEE 180. Structural Analysis—Beams, trusses, frames; method of indeterminate analysis by consistent displacement, least work, superposition equations, moment distribution. Matrix methods and computer methods of structural analysis. Prerequisites: 101A, ENGR 14. GER:2b

4 units, Aut (Kiremidjian)

CEE 181. Design of Steel Structures—Concepts of the design of steel structures with a load and resistance factor design (LRFD) approach; types of loading; structural systems; design of tension members, compression members, beams, beam-columns, and connections; and design of trusses and frames. Prerequisite: 180. Corequisite: 181A. GER:2b

3 units, Win (Deierlein)

CEE 181A. Building Design Experience: Steel Structures—Design alternatives through conceptual design; exogenous constraints and execution of one design alternative through design development, using steel structural systems. Prerequisite: 183 or graduate standing. Corequisite: 181.

1 unit, Win (Deierlein)

CEE 182. Design of Reinforced Concrete Structures—Properties of concrete and reinforcing steel; behavior of structural elements subject to bending moments, shear forces, torsion, axial loads, and combined actions; design of beams, slabs, columns and footings; strength design and serviceability requirements; design of simple structural systems for buildings. Prerequisite: 180. Corequisite: 182A. GER:2b

3 units (Krawinkler) not given 2004-05

CEE 182A. Building Design Experience: Reinforced Concrete Structure—Exploration of design alternatives through conceptual design, considering exogenous constraints and execution of one design alternative through design development using reinforced concrete structural systems. Prerequisite: 183 or graduate standing.

1 unit (Krawinkler) not given 2004-05

CEE 183. Introduction to Building Design—Scope of a building design experience; owner, architectural, and MEP constraints; regulatory and social considerations; foundation considerations; structural loading and load paths; thermal loading and heat paths; constructibility issues; and project processes for design and construction. Pre- or corequisites: 101A, 180.

2 units, Aut (Tatum)

CEE 190. Near-Surface Geophysics—(Enroll in GEOPHYS 190.)
3 units, Spr (Knight)

CEE 195. Structural Geology and Rock Mechanics—(Same as GES 111.) Methodology for understanding tectonic processes and their structural products by combining quantitative field data with conceptual and mechanical models of rock deformation and flow. Topics include: mapping techniques using GPS; characterization of structures using differential geometry; dimensional analysis; kinematics of deformation; stress analysis; elasticity, brittle fracture and faulting; viscosity and flow of rock; modeling geological structures using continuum mechanics. Applications include the role of geological structures in the evolution of the earth's crust and the mitigation of geologic hazards. Prerequisites: GES 1, MATH 51, 52. GER:2a
3 units, Win (Pollard)

CEE 196. Engineering Geology Practice—(Same as GES 115.) The application of geologic fundamentals to the planning and design of civil engineering projects. Field exercises and case studies emphasize the impact of site geology on the planning, design, and construction of civil works such as buildings, foundations, transportation facilities, excavations, tunnels and underground storage space, and water supply facilities. Topics: Quaternary history and tectonics, formation and physical properties of surficial deposits, site investigation techniques, geologic hazards, and professional ethics. Prerequisite: GES 1 or consent of instructor. GER:2a
3 units, Spr (Holzer) alternate years, not given 2005-06

CEE 197. Professional Development Seminar—Weekly presentations by practicing engineers on topics relevant to students planning to enter the engineering profession. Environmental, structural, and construction perspectives.
1 unit, Win (Staff)

CEE 198. Directed Reading or Special Studies in Civil Engineering—Written report or oral presentation required. Students must obtain a faculty sponsor.
2-3 units, Aut, Win, Spr, Sum (Staff)

CEE 199. Undergraduate Research in Civil and Environmental Engineering—Written report or oral presentation required. Students must obtain a faculty sponsor.
2-3 units, Aut, Win, Spr, Sum (Staff)

CEE 199H. Undergraduate Honors Thesis—For students who have declared the Civil Engineering B.S. honors major and have obtained approval of a topic for research under the guidance of a CEE faculty adviser. Letter grade only. Written thesis or oral presentation required.
2-3 units, Aut, Win, Spr, Sum (Staff)

PRIMARILY FOR GRADUATE STUDENTS

CEE 200A,B,C. Teaching of Civil and Environmental Engineering—Required of CEE Ph.D. students. Strategies for effective teaching and introduction to engineering pedagogy. Topics: problem solving techniques and learning styles, individual and group instruction, the role of TAs, balancing other demands, grading. Teaching exercises. Register for quarter of teaching assistantship.
1 unit, **A:** *Aut,* **B:** *Win,* **C:** *Spr (Staff)*

CEE 201D. Mathematical Laboratory Applications in Civil and Environmental Engineering—(Undergraduates register for 101D; see 101D.)
2 units, Aut (Kitanidis)

CEE 202. Laboratory Methods in Geophysics—(Enroll in GEOPHYS 162.)
1-3 units, Spr (Prasad)

CEE 203. Probabilistic Models in Civil Engineering—Introduction to probability modeling and statistical analysis in civil engineering. Emphasis is on the practical issues of model selection, interpretation, and calibration. Application of common probability models used in civil engineering including Poisson processes and extreme value distributions. Parameter estimation. Linear regression.
3-4 units, Aut (Menun)

CEE 204. Structural Reliability—Procedures for evaluating the safety of structural components and systems. First-and second-order estimates of failure probabilities of engineered systems. Sensitivity of failure probabilities to assumed parameter values. Measures of the relative importance of random variables. Reliability of systems with multiple failure modes. Reliability updating. Simulation methods and variance reduction techniques. Prerequisite: 203 or equivalent.
3-4 units (Staff) alternate years, given 2005-06

CEE 205. Structural Materials Testing and Simulation—Material failure phenomena such as fracture and plastic yielding in metals and polymeric- and cement-based composites. Material response and behavior presented through experimental observation, theories for predicting response and methods for computational simulation. Practical considerations for material use in civil infrastructure. Lab meetings and group project involving fabrication, experimentation, and simulation of materials.
3-4 units, Win (Billington)

CEE 207A. Energy Resources—(Undergraduates register for 173A; see 173A; same as EARTHSYS 103.)
4-5 units, Aut (Woodward)

CEE 207B. The Coming Energy Revolution—(Undergraduates register for 173B; see 173B.)
4 units (Woodward) not given 2004-05

CEE 207G. Technology Implementation for Sustainable Development in Developing Countries—(Undergraduates register for 173G; see 173G.)
3 units, Win (Gadgil)

CEE 207H. Technologies for Sustainable Societies—Seminar. Technologies that address major societal needs in the context of rapidly growing populations, increasing demands for resources, and stressed local, regional, and global environmental systems. How technologies can contribute to sustainability in buildings, water, food, energy, and transportation. Student presentations.
3 units, Spr (Gadgil)

CEE 215A,B,C,D. Industry Seminar and Internship Program—(Undergraduates register for 115; see 115.)
1 unit, **A:** *Aut: (Clough),* **B:** *Win (Fischer),* **C:** *Spr (Clough),* **D:** *Sum (Staff)*

CEE 222A. Computer Integrated Architecture/Engineering/Construction (A/E/C)—(Undergraduates serve as apprentices, register for 122A.) Crossdisciplinary, collaborative, geographically distributed, project-based, teamwork environment. Round table A/E/C panel discussions, lectures, and labs on collaborative technologies provide a global perspective of the A/E/C industry and cutting edge information technologies. Students exercise theoretical discipline knowledge in architecture, structural, engineering, construction management, and the information technologies in a multidisciplinary context focusing on the concept development phase of a comprehensive building project.
3 units, Win (Fruchter)

CEE 222B. Computer Integrated A/E/C—(Undergraduates serve as apprentices, register for 122B.) Comprehensive team project, including project development and documentation, and final project presentation of product and process. Design and construction alternatives are subject to examination by rapid computational prototyping, concurrent multidisciplinary evaluation, and trade-off analysis. Prerequisite 222A.
2 units, Spr (Fruchter)

CEE 223A. Design and Construction of Steel Structures—Using a 15-story steel building project, students analyze the implications of design decisions on the fabrication and erection of steel structures. Emphasis is on integration of design and construction of different types of steel structures. The implications on structural performance, cost and construction schedule, and evaluation of design alternatives. Economic considerations. Other topics include planning for lead times, floor systems and lateral load resisting systems, composite floor systems, innovative lateral load resisting systems, economics of steel structures,

design and construction of steel connections, implication of design decisions related to welding and bolting. Prerequisite: 181 or equivalent.
3 units, Aut (Miranda)

CEE 223B. Design and Construction of Concrete Structures—How to evaluate the implications of design decisions in structural performance, cost, and construction schedule of concrete structures. Emphasis is on integration of design and construction of concrete structures and economic considerations. Reinforced and pre-stressed concrete structures. Evaluation of design alternatives. Economic considerations in selecting floor systems and lateral resisting systems for buildings. Design and construction of beams, one-way and post-tensioned slabs, structural walls, coupled structural walls. Precast and post-tensioned elements, and connections in precast elements. Prerequisite: 182 or equivalent.
3 units, Win (Miranda)

CEE 224. Preconstruction Planning for Design/Construction Integration—Overview of marketing, planning commission, fire and building codes, team building, schedule development, and budget development using the design construction integration approach. Topics are explored using various types of projects (entertainment, museums, educational, high-tech, semi-conductor, housing, biotech).
3 units, Win (Spradlin)

CEE 237. Introduction to Biotechnology—(Enroll in CHEMENG 450, BIOC 450.)
3 units, Spr (Staff)

CEE 238. Frontiers in Interdisciplinary Biosciences—(Crosslisted in departments in the schools of H&S, Engineering, and Medicine; student register through their affiliated departments; otherwise register for CHEMENG 459) See CHEMENG 459 or http://biox.stanford.edu/courses/459_announce.html.
1 unit, Aut, Win, Spr (Robertson)

CEE 240. Analysis and Design of Construction Operations—Planning and management of construction work at the field operations level. Data collection, analysis, modeling, and design. Emphasis is on work methods development, productivity, safety, and total quality management. Requires four full days on Friday, working on a local residential building project to gain experience with concepts taught in class.
4 units (Paulson) not given 2004-05

CEE 241. Techniques of Project Planning and Control—Fundamental concepts of project planning and control; current and future project information technologies; project planning and control systems at the firm and project level. Topics: cost estimating at conceptual, schematic, detailed, and bid stages, measurement and pricing of work; work breakdown structures; planning and scheduling techniques, including CPM, PERT, LOB; resource allocation; project control; supply chain models; treatment of uncertainty; virtual design and construction, electronic integration of time and cost planning and control, and 4D modeling. Group term project including technical report and presentation. Prerequisite: 100 or equivalent, or consent of instructor.
3-4 units, Win (Fischer)

CEE 242. Organization Design for Projects and Companies—Introduction to organizational behavior. Information-processing theory of organizational design for projects and companies and computer-based organizational analysis tools. Groups of 12 students practice running problem-focused meetings. Case studies focus on facility/product design and construction/manufacturing organizations; concepts are applicable to project-focused teams and companies in all industries.
4 units, Aut (Levitt)

CEE 243. Virtual Design and Construction—(Undergraduates register for 143; see 143.)
3-4 units, Win (Kunz)

CEE 244A. Fundamentals of Construction Accounting and Finance—Introduces the concepts and fundamentals of financial accounting and economics in general, and specifically in the construction industry. Financial statement understanding and analysis, accounting concepts, project accounting methods, and the nature of project costs. Case study of major construction contractor. Ownership structure, working capital, and the sources and uses of funds.
2 units, Aut (Tucker, Meyer)

CEE 244B. Advanced Construction Accounting, Financial Issues, and Claims—Continuation of 244A. Emphasis is on advanced construction accounting and economic issues, the recovery of project overruns, and construction industry financial disclosures. Construction claims, project cost overrun analysis, and cost recovery methods related to: labor, equipment, indirect costs, overhead, cost of capital, and profit claims. Schedule delay analysis in the context of claims.
2 units, Win (Tucker, Meyer)

CEE 245. International Construction Management—Introduction to management tools for strategy, structure, personnel, and culture of global projects. International construction markets, major players, financing, and joint ventures. All phases of the life cycle of global projects: prequalification, bid preparation, contract negotiations, joint venture agreements, startup of projects, execution of work, and closure. Case studies to develop a model of international construction joint ventures.
3 units, Win (Brockmann)

CEE 246. Managing Engineering and Construction Companies—Management of design and construction companies in the architecture-engineering-construction industry. Focus is on management of risks inherent in the A/E/C industry: developing business strategies and organizations to cope with cyclical demand, alternative contracting approaches, managing receivables and cash flow, administration of human resources, safety, quality, insurance, and bonding. Students play different management roles in a computer simulation of a construction company. Prerequisites: introductory accounting course such as ENGR 60, CEE 244A, or MS&E 140.
4 units, Spr (Levitt)

CEE 247. Cases in Personality, Leadership, and Negotiation—(Undergraduates register for 147; see 147.)
4 units, Spr (Clough)

CEE 248. Real Estate Development—Overview of the real estate development process emphasizing critical activities and key participants. Topics: conceptual and feasibility studies, market perspectives, the public roles, steps for project approval, project finance, contracting and construction, property management, and sales. Group term projects focus on actual developments now in the planning stage. Enrollment limited to 18 students with priority to graduate majors in the department's CEM or DCI programs. Prerequisites: 241, 244A or equivalent, ENGR 60.
3 units, Spr (Kroll)

CEE 249. Labor and Industrial Relations in Construction—The history, laws, institutions, and social and economic forces affecting labor and industrial relations in construction, covering the union and open shop sectors. Comparative labor relations (other nations), simulated collective bargaining and arbitration exercises; field trip.
2 units, Spr (Walton)

CEE 251. Negotiation—(Undergraduates register for 151, see 151; same as MS&E 285, ME 207.)
3 units, Aut, Spr (Christensen)

CEE 252. Construction Engineering for Concrete and Steel Structures—Technical overview of materials, methods and field operations required for construction of steel and concrete structures. Steel work includes detailing, fabricating, erecting, connecting. Concrete work includes batching, transporting, placing, finishing, curing and formwork. Introduction to activities required to provide technical support for field operations Group analysis of technical operation or support activity.
4 units, Win (Tatum)

CEE 253. Construction Equipment and Methods—Methods and machinery to build projects planned by engineers and architects. Application of engineering fundamentals to the selection and design of equipment and systems to carry out production operations in construction; analysis of production output and costs; application of engineering economy to equipment and process decision making. Prerequisites: 100, and ENGR 60, PHYSICS 21 or 53.
3-4 units, Spr (Staff)

CEE 254. Cases in Estimating Costs—(Undergraduates register for 154; see 154.)
3 units, Aut (Clough)

CEE 256. Building Systems—(Undergraduates register for 156; see 156.) Corequisite for graduate students: 256A.
3 units, Win (Staff)

CEE 256A. Building System Design Experience—Graduate students engage in group project involving analysis of design and construction for a building system. Corequisite: 256.
1 unit, Win (Staff)

CEE 257. Building Better: Technical and Sustainable Construction—Technical overview of design and construction for high tech facilities and sustainable construction operations. High tech includes high purity systems, cleanrooms, control systems, laboratories, biotech plants, and semiconductor fabs. Sustainable construction includes permit requirements, green materials and operations, and compliance programs and monitoring. Field trips and reports; group analysis of technical project, system, or sustainable operations.
3 units, Spr (Tatum)

CEE 258A,B,C. Donald R. Watson Seminar in Construction Engineering and Management—Required of graduate students in the CEM program; all students including undergraduates welcome. Weekly interactions and discussions with speakers from industry and government.
1 unit, **A:** *Aut (Clough),* **B:** *Win (Fischer),* **C:** *Spr (Clough)*

CEE 259A,B,C. Construction Problems—Analysis of group-selected problems in construction techniques, equipment, or management, followed by preparation of oral and/or written reports. Students consult specialists from the construction industry and make use of University facilities. See 299 for individual studies. Prerequisites: graduate standing in CEM program and consent of instructor.
1-3 units, Aut, Win, Spr (Staff)

CEE 260A. Physical Hydrogeology—(Same as GES 230.) Theory of underground water, analysis of field data and pumping tests, geologic groundwater environments, solution of field problems, groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.
4 units, Aut (Gorelick)

CEE 260B. Surface and Near-Surface Hydrologic Response—(Same as GES 237.) Quantitative review of process-based hydrology and geomorphology. Introduction to finite-difference and finite-element methods of numerical analysis. Topics: biometeorology, unsaturated and saturated subsurface fluid flow, overland and open channel flow, erosion and mass wasting, and physically-based simulation of coupled surface and near-surface hydrologic response and landscape evolution. Links hydrogeology, soil physics, and surface water hydrology.
4 units, Aut (Loague) alternate years, not given 2005-06

CEE 260C. Contaminant Hydrogeology—(Same as GES 231.) For earth scientists and engineers. Environmental and water resource problems involving contaminated groundwater. The processes affecting contaminant migration through porous media including interactions between dissolved substances and solid media. Conceptual and quantitative treatment of advective-dispersive transport with reacting solutes. Predictive models of contaminant behavior controlled by local equilibrium and kinetics. Modern methods of contaminant transport simulation and optimal aquifer remediation. Prerequisite: 260A or GES 230 or equivalent.
4 units, Spr (Staff)

CEE 262A. Hydrodynamics—The flow of incompressible viscous fluid; emphasis is on developing an understanding of fluid dynamics that can be applied to environmental flows. Topics: kinematics of fluid flow; equations of mass and momentum conservation (including density variations); some exact solutions to the Navier-Stokes equations; appropriate analysis of fluid flows including Stokes flows, potential flows, and laminar boundary layers; and an introduction to the effects of rotation and stratification through scaling analysis of fluid flows. Prerequisites: 101B or consent of instructor; and some knowledge of vector calculus and differential equations.
3-4 units, Aut (Monismith)

CEE 262B. Transport and Mixing in Surface Water Flows—Application of fluid mechanics to problems of pollutant transport and mixing in the water environment. Mathematical and numerical models of advection, diffusion, and dispersion. Application of theory to problems of transport and mixing in rivers, estuaries, and lakes and reservoirs. Recommended: 262A and CME 102 (formerly ENGR 155A) or equivalents.
3-4 units, Win (Monismith)

CEE 262D. Introduction to Physical Oceanography—(Undergraduate students register for 164; see 164; same as EARTHSYS 164.)
4 units, Win (Fong)

CEE 263A. Air Pollution Modeling—Introduction to the numerical modeling of urban, regional, and global air pollution with a focus on gas chemistry and radiative transfer. Stratospheric, free-tropospheric, and urban chemistry. Methods for solving stiff systems of chemical ordinary differential, including the Multistep Implicit-Explicit method, Gear's method with sparse-matrix techniques, and the family method. Numerical methods of solving radiative transfer, coagulation, condensation, and chemical equilibrium problems. Project involves the development of a basic chemical ordinary differential equation solver. Prerequisite: CS 106A or equivalent.
3-4 units (M. Jacobson) not given 2004-05

CEE 263B. Numerical Weather Prediction—Introduction to numerical weather prediction. Continuity equations for air and water vapor, the thermodynamic energy equation, and momentum equations are derived for the atmosphere. Numerical methods of solving partial differential equations, including finite-difference, finite-element, semi-Lagrangian, and pseudospectral methods. Time-stepping schemes: the forward-Euler, backward-Euler, Crank-Nicolson, Heun, Matsuno, leapfrog, and Adams-Bashforth schemes. Boundary-layer turbulence parameterizations, soil moisture, and cloud modeling. Project developing a basic mesoscale model. Prerequisite: CS 106A or equivalent.
3-4 units, Win (M. Jacobson)

CEE 263C. Weather and Storms—(Undergraduates register for 63; see 63.)
3 units, Aut (M. Jacobson)

CEE 263D. Air Pollution: From Urban Smog to Global Change—(Undergraduates register for 64; see 64.)
3 units, Spr (M. Jacobson)

CEE 264A. Rivers, Streams, and Canals—(Undergraduates register for 161A; see 161A.)
3-4 units, Aut (Street)

CEE 265A. Sustainable Water Resources Development—Alternative criteria for judging the sustainability of projects. Application of criteria to evaluate sustainability of water resources projects in several countries. Case studies illustrate the role of political, social, economic, and environmental factors in decision making. Evaluation of benefit-cost analysis and environmental impact assessment as techniques for enhancing the sustainability of future projects. Limited enrollment. Prerequisite: graduate standing in Environmental and Water Studies, or consent of instructor.
3 units, Spr (Staff)

CEE 265B. Privatization of Water Supply and Sanitation—Theory and practice of private sector participation in the water and sanitation sector in developing and industrialized countries, and its effects on efficiency, customer responsiveness, risk allocation, equity, and environment. Objectives, strengths, and weaknesses of alternative arrangements including small-scale independent providers and large-scale concession agreements. Case studies. Limited enrollment. Prerequisites: familiarity with water and sanitation sector or public service delivery, and consent of instructor.
3 units, Aut (Davis)

CEE 266A. Watersheds and Wetlands—(Undergraduates register for 166A; see 166A.)
3 units, Aut (Freyberg)

CEE 266B. Floods and Droughts, Dams and Aqueducts—(Undergraduates register for 166B; see 166B.)
3 units, Win (Freyberg)

CEE 266D. Water Resources and Water Hazards Field Trips—(Undergraduates register for 166D; see 166D.)
2 units, Win (Freyberg)

CEE 267. Data Analysis and Uncertainty—Probabilistic and statistical methods with emphasis on basic concepts and tools, illustrated with applications from environmental and water studies. Topics: exploratory data analysis; probability theory; classical statistics; Bayesian statistics; geostatistics; and inverse problems.
3 units, Spr (Kitanidis)

CEE 268. Groundwater Flow—Study of flow and mass transport in porous media through analytical techniques. Applications of potential flow theory to practical groundwater problems: flow to and from wells, rivers, lakes, drainage ditches; flow through and under dams; streamline tracing; capture zones of wells; and mixing schemes for in-situ remediation. Prerequisites: calculus and introductory fluid mechanics.
3-4 units, Win (Kitanidis)

CEE 269. Environmental Fluid Mechanics and Hydrology Seminar—Problems in all branches of water resources, with talks by visitors, faculty, and students.
1 unit, Spr (Monismith)

CEE 270. Movement and Fate of Organic Contaminants in Waters—Transport of chemical constituents in surface and groundwater including advection, dispersion, sorption, interphase mass transfer, and transformation; impacts on water quality. Emphasis is on physicochemical processes and the behavior of hazardous waste contaminants. Prerequisites: undergraduate chemistry and calculus. Recommended: 101B.
3 units, Aut (Luthy)

CEE 271A. Physical and Chemical Treatment Processes—Physical and chemical unit operations for water treatment, emphasizing process combinations for drinking water supply. Application of the principles of chemistry, rate processes, fluid dynamics, and process engineering to define and solve water treatment problems by flocculation, sedimentation, filtration, disinfection, oxidation, aeration, and adsorption. Investigative paper on water supply and treatment. Prerequisites: 101B, 270. Recommended: 273.
3 units, Win (Luthy)

CEE 271B. Environmental Biotechnology—Stoichiometry, kinetics, and thermodynamics of microbial processes for the transformation of environmental contaminants. Design of dispersed growth and biofilm-based processes. Applications include treatment of municipal and industrial waste waters, detoxification of hazardous chemicals, and groundwater remediation. Prerequisites: 270; 177 or 274A or equivalents.
4 units, Win (Criddle)

CEE 272. Coastal Contaminants—Coastal pollution and its effects on ecosystems and human health. The sources, fate, and transport of human pathogens, nutrients, heavy metals, persistent organics, endocrine disrupters, and toxic algae. Background on coastal ecosystems and coastal transport phenomena including tides, waves, and cross shelf transport. Undergraduates may enroll with consent of instructor.
4 units, Win (Boehm)

CEE 273. Aquatic Chemistry—Chemical principles and their application to the analysis and solution of problems in aqueous geochemistry (temperatures near 25 C and atmospheric pressure). Emphasis is on the analysis of natural water systems and the understanding and solution of specific chemical problems in water purification technology and water pollution control. Prerequisites: CHEM 31 and 33, or equivalents.
3 units, Aut (Leckie)

CEE 273A. Water Chemistry Laboratory—(Undergraduates register for 179A; see 179A.)
2 units, Win (Leckie)

CEE 274A. Environmental Microbiology I—The fundamental aspects 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, or equivalents.
3 units, Aut (Spormann), Sum (Staff)

CEE 274B. Environmental Microbiology II—Microbial biochemistry of organic pollutant degradation. Metabolic logic of biochemical pathways and predicting biodegradation. Metabolic ecology: reciprocal interactions of microbial activities and the environment. Microbial biofilms and biofilm communities. Cell-cell communication and gene transfer. Constructing microbial biofilms for pollutant degradation. Mechanisms of molecular evolution. Genomic evolution and microbial ecology. Detection of microorganisms in the environment (gene probes, immuno probes, enzyme probes). Prerequisite: 274A.
3 units, Win (Spormann)

CEE 274C. Environmental Microbiology Laboratory—Microbiological and molecular techniques for characterizing microbes. Enrichment and isolation of microbes from their natural environment. Determination of growth parameters. Visualizing microbes in biofilms. Detection of microbes in the environment. Horizontal gene transfer and evolution of microbes with new metabolic capacity. Prerequisites: 274A,B.
3 units, Spr (Spormann)

CEE 274D. Pathogens and Disinfection—Introduction to epidemiology, major pathogens and infectious diseases, the immune system, movement and survival of pathogens in the environment, transfer of virulence and antibiotic resistance genes, and pathogen control, with an emphasis on public health engineering measures (disinfection). Prerequisite: 274A.
3 units (Criddle) not given 2004-05

CEE 274E. Pathogens in the Environment—Sources, fates, movement, and ecology of waterborne pathogens in the natural environment and disinfection systems. Epidemiology and microbial risk assessment. Focus is on human virus, bacteria, and protists. How to evaluate peer-reviewed papers. No microbiology background required; undergraduates may enroll with consent of instructor.
3 units, Spr (Boehm)

CEE 275B. Process Design for Environmental Biotechnology—(Undergraduates register for 179B; see 179B.)
5 units, Spr (Criddle)

CEE 276. Introduction to Human Exposure Analysis—(Undergraduates register for 178; see 178.)
3 units, Spr (Leckie)

CEE 277S. Design for a Sustainable World—(Undergraduates register for 177S; see 177S.)
1-5 units, Aut, Win, Spr (Burney, Walewijk)

CEE 278A. Air Pollution Physics and Chemistry—The sources and health effects of pollutants. The influence of meteorology on pollution: atmospheric energy balance, temperature profiles, stability classes, inversion layers, turbulence. Atmospheric diffusion equations, downwind dispersion of emissions from point and line sources. Tropospheric chemistry: mechanisms for ozone formation, photochemical reactions, radical chain mechanisms, heterogeneous chemical reactions. Prerequisites: MATH 51, CHEM 31, or equivalents. Recommended: 101B, 273 or CHEM 135, or equivalents.
3 units, Aut (Hildemann)

CEE 278B. Atmospheric Aerosols—The characterization of atmospheric particulate matter: size distributions, chemical composition, health effects. Atmospheric diffusion and transport of particles: removal by convection, impaction, gravitational settling. Effect of aerosols on visibility: light scattering and absorption, reduction of visual range. Mechanics influencing ambient size distributions: Brownian coagulation, laminar shear flow, homogeneous nucleation, heterogeneous condensation. Prerequisite: MATH 51, or equivalent. Recommended: 101B or equivalent.
3 units, Spr (Hildemann)

CEE 279. Environmental Engineering Seminar—Current research, practice, and thinking in environmental engineering and science. Attendance at seminars is self-directed, and may be accrued throughout the school year. See instructor for syllabus.
1 unit, Spr (Staff)

CEE 280. Advanced Structural Analysis—Theoretical development and computer implementation of direct stiffness method of structural analysis; virtual work principles; computation of element stiffness matrices and load vectors; direct assembly procedures; equation solution techniques. Analysis of two- and three-dimensional truss and frame structures, thermal loads, and substructuring and condensation techniques for large systems. Practical modeling techniques and programming assignments. Introduction to nonlinear analysis concepts. Prerequisites: elementary structural analysis and matrix algebra.
3-4 units, Aut (Deierlein)

CEE 281. Finite Element Structural Analysis—Formulation and implementation of frame, plane stress, plane strain, axisymmetric, torsional, solid, plate, and shell elements. Topics: strong and weak forms of the problem, variational principles and the principle of minimum potential energy, the finite element method as an extension of the Rayleigh-Ritz methods, shape functions, isoparametric mapping, numerical integration, convergence requirements, and error estimation. Techniques for application to modeling structural systems. Prerequisite: 280 or equivalent.
3 units, Win (Staff)

CEE 282. Nonlinear Structural Analysis—Introduction to methods of geometric and material nonlinear analysis, emphasizing modeling approaches for framed structures. Large-displacement analysis, concentrated and distributed plasticity models, and nonlinear solution methods. Applications to frame stability and performance-based seismic design. Assignments emphasize computer implementation and applications. Prerequisites: 280, 286 or equivalent.
3 units, Spr (Deierlein)

CEE 283. Structural Dynamics—Vibrations and dynamic response of simple structures under time dependent loads; dynamic analysis of single and multiple degrees of freedom systems; support motion; response spectra.
3-4 units, Aut (Law)

CEE 284. Computational Methods in Structural Dynamics—Methods of structural dynamics for discretized and continuous systems in free and forced vibration, modal analysis; numerical methods; introduction to nonlinear dynamics; advanced topics. Prerequisites: 280, 283.
3 units (Law) alternate years, given 2005-06

CEE 285. Behavior of Structural Systems for Buildings—Basic design concepts, performance criteria, loading, methods of design, types of structural systems, behavior under gravity and lateral loads, approximate methods of analysis, preliminary conceptual design, performance assessment, behavior of structural elements. Prerequisites: basic courses in design of steel and reinforced concrete structures.
3-4 units, Win (Krawinkler)

CEE 286. Advanced Structural Design—Strength, stiffness, and ductility considerations in the design of structural elements and systems made of steel, reinforced concrete, and other materials. Concepts of redistribution and strength of structures (element versus system behavior). Design of two-way slab systems. Prerequisites: basic courses in design of steel and reinforced concrete structures.
3-4 units, Aut (Krawinkler)

CEE 287. Earthquake Resistant Design and Construction—Evaluation, design, and construction of structures in seismic regions. Factors influencing earthquake ground motions, design spectra, design of linear and nonlinear single- and multiple-degree-of-freedom-system structures, design of structures to minimize damage, force-based and displacement-based design methods, capacity design, detailing and construction of steel and reinforced concrete structures, performance-based design, seismic isolation, and energy dissipation. Prerequisites: 283, 285. Recommended: 286, 288.
3 units, Spr (Miranda)

CEE 288. Earthquake Hazard and Risk Analysis—Earthquake phenomena, faulting, ground motion, study of past major earthquakes, effects of earthquakes on manmade structures, response spectra, Fourier spectra, power spectra, soil effects on ground motion and structural damage, methods for structural damage evaluation, current research in earthquake engineering. Prerequisites: 203, 283.
3 units, Win (Kiremidjian)

CEE 289. Random Vibrations—Introduction to random processes. Correlation and power spectral density functions. Stochastic dynamic analysis of multi-degree-of-freedom structures subjected to stationary and non-stationary random excitations. Crossing rates, first-excursion probability, and distributions of peaks and extremes. Applications in earthquake, wind, and ocean engineering. Prerequisite: 203 or equivalent.
3-4 units (Staff) not given 2004-05

CEE 290. Structural Performance and Failures—Basic concepts in the definition of satisfactory structural performance; key elements in structural performance; types of failures, ranging from reduced serviceability to total collapse; failure sources and their root cause allocation, emphasizing design/construction process failures; failure prevention mechanisms; illustration with real life examples.
2 units, Spr (Moncarz)

CEE 291. Advanced Structural Concrete Modeling and Design—Emphasis is on prestressed concrete bridge design. Basic concepts of strut and tie modeling, prestressed concrete design, and design and behavior of concrete box girder bridges. Introduction to innovative precast systems for bridge design. Course project integrating computer simulation and physical experimentation of a structural concrete subassembly designed using the strut and tie method.
3 units, Spr (Billington)

CEE 292. Computer Methods in Structural Engineering—Basic techniques for the development of structural engineering analysis and design software. Topics: basic data structure; computer representation of engineering systems; implementation of advanced numerical methods and engineering software; automated conformance checking of design codes and standards. Prerequisites: CS 106A or equivalent.
3 units, Win (Law)

CEE 293. Foundation Engineering—Types, characteristics, analysis, and design of shallow and deep foundations; rigid and flexible retaining walls; braced excavations; settlement of footings in sands and clays; slope stability analysis by method of slices including search algorithms for the critical slip surface. Special seminars by guest speakers; computing assignment. Prerequisite: 101C or equivalent.
3 units, Win (Borja)

CEE 294. Computational Geomechanics—Continuum and finite element formulations of steady-state and transient fluid conduction problems in geomechanics; elliptic, parabolic, and hyperbolic systems; variational inequality and free-boundary problems; three-dimensional consolidation theory; undrained condition, mesh locking, B-bar and strain projection methods; finite element formulations of multiphase dynamic problems. Computing assignments. Prerequisite: ME 335A or equivalent.
3 units (Borja) alternate years, given 2005-06

CEE 295. Plasticity Modeling and Computation—Theory of plasticity; micromechanical basis; classical yield models; return-mapping algorithm; multi-surface and bounding surface models; material instabilities; localization and bifurcation. Prerequisite: ME 338A or equivalent.
3 units, Spr (Borja) alternate years, not given 2005-06

CEE 296. Modeling of Models in Geotechnical Engineering—Physical and numerical modeling in geomechanics. Primitive geotechnical models illustrate three-dimensional seepage and strain localization in simple shear and triaxial devices. Finite element modeling and simulations conducted using ANSYS. Numerical simulations demonstrate the 3D, solid-mesh generation capabilities of the program and the limitations of deformation analysis in the softening regime. Prerequisite: 101C or equivalent. Corequisite: course in finite element method.
2 units, Win (Borja)

CEE 297. Issues in Geotechnical and Environmental Failures—Causes and consequences of the failure of buildings, earth structures, waste storage, and high hazard facilities in contact with the environment; technical, ethical, economic, legal, and business aspects; failure analysis and forensic problems; prevention, liability, and dispute management. Case histories including earthquake, flood, and hazardous waste facilities. Student observation, participation in active lawsuits where possible.
3 units, Aut (Meehan)

CEE 297G. Advanced Structural Geology and Rock Mechanics—(Same as GES 215.) Solutions to initial and boundary-value problems of continuum mechanics integrated with quantitative field and laboratory data to develop conceptual and computational models for tectonic processes and the development of geological structures. Topics include: techniques for structural mapping and data analysis; differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; traction and stress analysis; conservation laws; mechanical properties of rock (elasticity, viscosity, strength, friction, fracture toughness). Models formulated and solutions visualized using MATLAB. Prerequisites: GES 1, calculus, MATLAB or equivalent.
3-5 units, Aut (Pollard)

CEE 298. Structural Engineering and Geomechanics Seminar—Recommended for all graduate students. Lectures on topics of current interest in professional practice and research.
1 unit, Win (Staff)

CEE 299. Independent Study in Civil Engineering—Directed study for graduate students on subjects of mutual interest to students and faculty. Student must obtain faculty sponsor.
1-3 units, Aut, Win, Spr, Sum (Staff)

CEE 300. Thesis (Engineer Degree)—Research by Engineer candidates.
1-15 units, Aut, Win, Spr, Sum (Staff)

CEE 310. Post-Master's Seminar—For post-master's students to serve as orientation to the selection of a research topic.
1 unit, Aut, Win, Spr (Staff)

CEE 316. Research Methods in Facility Engineering—For CEE Ph.D. students interested in facility planning, design, management, and operation. Research philosophy and methods seminar. Experimental design: ethnography, case study, survey, classical experiment (natural, synthetic, or computational). Data analysis: ANOVA, regression, correlation. Introduction to modeling social systems. Publication strategies. Final project to develop and refine research proposal and publication plan.
3-4 units (Levitt) alternate years, given 2005-06

CEE 320. Integrated Facility Engineering—Individual and group presentations on goals, research, and state-of-practice of virtual design and construction in support of integrated facility engineering, including objectives for the application and further development of virtual design and construction technologies.
1 unit, Aut, Spr (Kunz, Fischer)

CEE 333. Water Policy Seminar—(Same as IPER 333.) Student-organized interdisciplinary seminar. Focus is on creation, implementation, and analysis of policy affecting the use and management of water resources. Weekly speakers from academia and local, state, national, and international agencies and organizations. Previous topics include water policy in California and developing countries.
1 unit, Spr (Freyberg)

CEE 342. Computational Modeling of Organizations—For post-M.S. students interested in formal techniques for organization design. Computer simulation of organizations are used to conduct virtual experiments for developing organization theory or to analyze the performance of virtual organizations with different structures and decision support and communication technologies. Goals: introduce research on computational modeling and design of real-world organizations. Paper serves as a research proposal. Prerequisite: 242 or equivalent introductory organization design class.
4 units, Win (Levitt) alternate years, not given 2005-06

CEE 362A. Advanced Topics in Mathematical Analysis of Flow Transport—Topics vary each year and include vector and tensor analysis, perturbation and asymptotic methods, Lagrangian methods such as particle tracking and travel-time solutions, and selected numerical methods for flow and transport problems.
1 unit, Aut (Kitanidis)

CEE 363A. Mechanics of Stratified Flows—(Formerly 363.) The effects of density stratification on flows in the natural environment. Basic properties of linear internal waves in layered and continuous stratification. Flows established by internal waves. Internal hydraulics and gravity currents. Turbulence in stratified fluids. Prerequisites: 262A,B, CME 204 (formerly ME 300B).
3 units (Fong) alternate years, given 2005-06

CEE 363B. Geophysical Fluid Dynamics—(Formerly 364B.) Focus is on fluid dynamics of the ocean at scales where the influence of the earth's rotation is important. Topics include geostrophic and quasi-geostrophic flows, planetary waves, potential vorticity, the Rossby adjustment problem, effects of stratification, and flows on the sea plane. Hydrodynamic stability of rotating and stratified flows. Prerequisite: 363A.
3 units (Fringer) alternate years, given 2005-06

CEE 363C. Ocean and Estuarine Modeling—Advanced topics including methods for the shallow water, primitive, and nonhydrostatic equations on Cartesian, curvilinear, and unstructured finite-volume grid systems. Free-surface methods, nonhydrostatic solvers, and advanced Eulerian and Lagrangian advection techniques. Focus is on studies of existing techniques and code packages and their methodologies including POM, ROMS, TRIM, ELCOM, and STUNTANS. Problem sets and final project. Prerequisite: CME 204 (formerly ME 300B) or equivalent.
3 units, Aut (Fringer) alternate years, not given 2005-06

CEE 365A,B,C,D. Advanced Topics in Environmental Fluid Mechanics and Hydrology—Students must obtain a faculty sponsor.
2-6 units, **A:** *Aut,* **B:** *Win* **C:** *Spr,* **D:** *Sum (Staff)*

CEE 370A,B,C,D. Environmental Research—For first-year Ph.D. students in the Environmental Engineering and Science program. 15-18 hours/week on research over three quarters. 370A requires written literature survey on a research topic; 370B requires oral presentation on experimental techniques and research progress; 370C requires written or oral presentation of preliminary doctoral research proposal. Students must obtain a faculty sponsor.
5-6 units, **A:** *Aut,* **B:** *Win,* **C:** *Spr,* **D:** *Sum (Staff)*

CEE 371. Frontiers in Environmental Research—How to evaluate environmental research.
1-2 units, Aut, Win, Spr (Spormann)

CEE 372. Environmental Mass Transfer—Mass transport physics and mathematics. Focus is on environmental engineering applications including chemical sorption, biofilm growth, aggregate formation, and pollutant transport in rivers, lakes, and oceans.
3 units (Boehm) not given 2004-05

CEE 376. Organic Analyses in Environmental Sciences—Theory and practice of instrumental methods used in environmental engineering and sciences, emphasizing determination of organic substances by gas chromatography, mass spectrometry, and high pressure liquid chromatography. Interpretation of mass spectra adaptation of techniques to specific environmental matrices. Case studies.
2-3 units, Spr (Reinhard)

CEE 377. Research Proposal Writing in Environmental Engineering and Science—For first- and second-year post-master's students preparing for thesis defense. Students develop progress reports and agency-style research proposals, and present a proposal in oral form. Prerequisite: consent of thesis adviser.
1-3 units, Aut, Win, Spr, Sum (Staff)

CEE 398. Report on Civil Engineering Training—On-the-job training under the guidance of experienced, on-site supervisors; meets the requirements for Curricular Practical Training for students on F-1 visas. Students submit a concise report detailing work activities, problems worked on, and key results. Prerequisite: qualified offer of employment and consent of adviser as per I-Center procedures.
1 unit, Aut, Win, Spr, Sum (Staff)

CEE 399. Advanced Engineering Problems—Individual graduate work under direction of a faculty sponsor on a subject of mutual interest. Written report usually required.
1-5 units, Aut, Win, Spr, Sum (Staff)

CEE 400. Thesis (Ph.D. Degree)—For students who have successfully completed the department general qualifying examination. Research and dissertation for the Ph.D. degree.
1-15 units, Aut, Win, Spr, Sum (Staff)

OVERSEAS STUDIES

These courses are approved for the Civil and Environmental Engineering major and taught overseas at the campus indicated. Students should discuss with their major advisers which courses would best meet individual needs. Descriptions are in the "Overseas Studies" section of this bulletin, or at the Overseas Studies Office, 126 Sweet Hall.

SANTIAGO

CEE 33X. The Built Environmental History of Chile
3 units, Spr (Kunz)

CEE 143X. Virtual Design and Construction: Visualizing a 50-Year Evolution of the Heart of Santiago
4 units, Spr (Kunz)

INSTITUTE FOR COMPUTATIONAL AND MATHEMATICAL ENGINEERING

Director: Parviz Moin

Professors: Stephen Boyd (Electrical Engineering), Persi Diaconis (Mathematics), David Donoho (Statistics), Charbel Farhat (Mechanical Engineering), Peter Glynn (Management Science and Engineering), Gene Golub (Computer Science), Pat Hanrahan (Computer Science, Electrical Engineering), Sanjiva Lele (Mechanical Engineering), Brad Osgood (Electrical Engineering), George Papanicolaou (Mathematics), Eric Shaqfeh (Chemical Engineering, Mechanical Engineering), Yinyu Ye (Management Science and Engineering)

Assistant Professors: Eric Darve (Mechanical Engineering), Ronald Fedkiw (Computer Science), Oliver Fringer (Civil and Environmental Engineering), Margot Gerritsen (Petroleum Engineering), Ashish Goel (Management Science and Engineering), Charles Taylor (Mechanical Engineering, Surgery)

Associate Professor: Juan Alonso (Aeronautics and Astronautics)

Professors (Research): Walter Murray (Management Science and Engineering), Michael A. Saunders (Management Science and Engineering)

Consulting Professors: Bertil Gustaffson, Vadim Khayms, Pat Langley, Andrew Pohorille

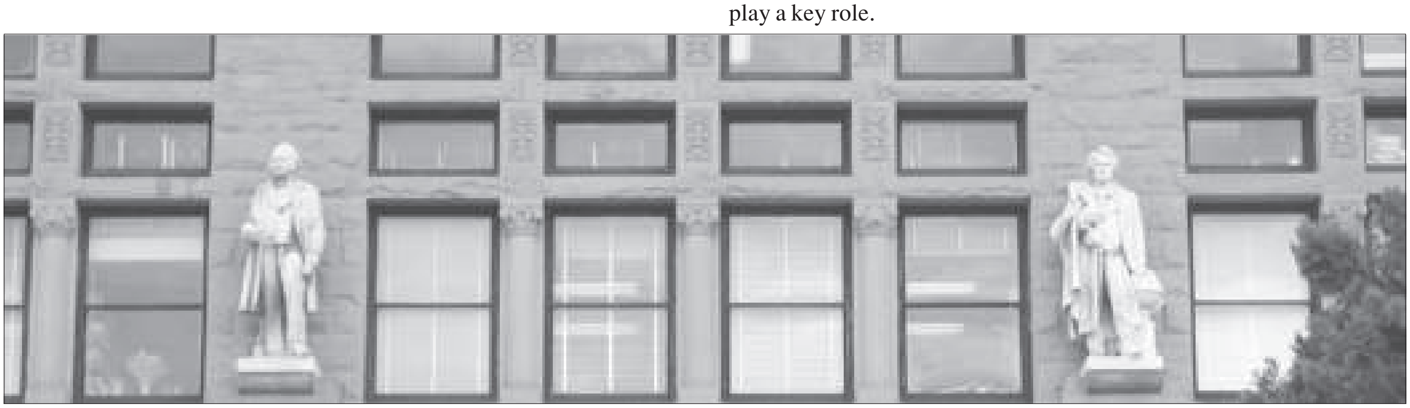
Web Site: http://icme.stanford.edu

Courses given in Computational and Mathematical Engineering have the subject code CME. For a complete list of subject codes, see Appendix.

Recent years have seen rapid expansion in the role of mathematical modeling of engineering systems using computer simulation technology. Of equal importance in discovery-driven engineering research, along with theory and physical experiments, is numerical simulation. The Institute for Computational and Mathematical Engineering leverages Stanford's strengths in engineering applications and the physical, biological, and earth sciences to guide the development of modern methods for research and education in computational mathematics. ICME's central research mission is to develop sophisticated algorithmic and mathematical tools that will have an impact in many applied disciplines.

ICME's central teaching mission is to ensure that Stanford's computational engineers be well versed in mathematical modeling and computer programming for numerical computation. ICME strives to integrate numerical computation in all its course offerings to facilitate application of mathematical techniques and theories to real world problems.

ICME research will cover broad mathematical and computational areas of interest to all engineering departments from discrete mathematics, including computational probability and combinatorial optimization, to numerical solution of partial differential equations representing physical devices. The institute identifies research areas that can benefit from a multidisciplinary approach in which computational mathematics will play a key role.



A unique strength of ICME is its multidisciplinary intellectual environment, with attendant interaction among students and faculty with diverse backgrounds and expertise. ICME offers service courses for undergraduates and graduate students to fulfill departmental requirements, core courses for M.S. and Ph.D. students in Scientific Computing and Computational Mathematics, and specialized electives in various application areas.

COURSES

CME 100. Vector Calculus for Engineers—(Formerly ENGR 154.) Computation and visualization using MATLAB. Differential vector calculus: analytic geometry in space, functions of several variables, partial derivatives, gradient, unconstrained maxima and minima, Lagrange multipliers. Integral vector calculus: multiple integrals in Cartesian, cylindrical, and spherical coordinates, line integrals, scalar potential, surface integrals, Green's, divergence, and Stokes' theorems. Examples and applications drawn from various engineering fields. Prerequisites: MATH 41 and 42, or 10 units AP credit. GER:2c
5 units, Aut (Khayms)

CME 102. Ordinary Differential Equations for Engineers—(Formerly ENGR 155A.) Analytical and numerical methods for solving ordinary differential equations arising in engineering applications. Solution of initial and boundary value problems, series solutions, Laplace transforms, and non-linear equations. Numerical methods for solving ordinary differential equations, accuracy of numerical methods, linear stability theory, finite differences. Introduction to MATLAB programming as a basic tool kit for computations. Problems from various engineering fields. Prerequisite: CME 100 (formerly ENGR 154) or MATH 51. GER:2c
5 units, Win (Darve), Spr (Taylor)

CME 104. Linear Algebra and Partial Differential Equations for Engineers—(Formerly ENGR 155B.) Linear algebra: matrix operations, systems of algebraic equations, Gaussian elimination, undetermined and overdetermined systems, coupled systems of ordinary differential equations, eigensystem analysis, normal modes. Fourier series with applications, partial differential equations arising in science and engineering, analytical solutions of partial differential equations. Numerical methods for solution of partial differential equations: iterative techniques, stability and convergence, time advancement, implicit methods, von Neumann stability analysis. Examples and applications from many engineering fields. GER:2c
5 units, Spr (Khayms)

CME 106. Introduction to Probability and Statistics for Engineers—(Formerly ENGR 155C.) Probability: random variables, independence, and conditional probability. Discrete and continuous distributions, moments, distributions of several random variables. Topics in mathematical statistics: random sampling, point estimation, confidence intervals, hypothesis testing, non-parametric tests, regression and correlation analyses. Applications in engineering, industrial manufacturing, medicine, biology, and other fields. Prerequisite: CME 100 (formerly ENGR 154) or MATH 51. GER:2c
4 units, Win (Khayms)

CME 108. Introduction to Scientific Computing—(Same as CS 137.) Fundamentals of numerical computation for mathematical, computational and physical sciences and engineering. Numerical solution of systems of algebraic equations, least squares, quadrature, minimization of a function, banded matrices, non-linear equations, numerical solution of ordinary and partial differential equations. Truncation error, numerical stability for time dependent problems, stiffness, boundary value problems. Prerequisites: CS 106A or familiarity with MATLAB. For students who have taken MATH 51,52,53; not appropriate for students who have taken CME 102, 104 (formerly ENGR 155A,B). GER:2b
3-4 units, Win (Moin)

CME 200. Linear Algebra with Application to Engineering Computations—(Formerly ME 300A.) The theory of linear algebra; basis, linear independence, column space, null space, rank. Emphasis is on computer solutions of the linear system of algebraic and differential equations. Roundoff errors, pivoting, and ill-conditioned matrices. Quadratic forms, norm and condition numbers, projection and least-squares, operation counts, eigenvalues, eigenvectors, and their computation. The canonical diagonal form, functions of a matrix. Unitary, Hermitian, and normal matrices. Principal stresses and axes. Recommended: familiarity with computer programming; MATH 103, 130, or equivalent.
3 units, Aut (Gerritsen)

CME 204. Partial Differential Equations in Engineering—(Formerly ME 300B.) Geometric interpretation of partial differential equations (PDEs), characteristics, solution of first-order equations, characteristics and classification of second-order PDEs, separation of variables, special functions, eigenfunction expansions, Fourier integrals and transforms, Laplace transforms, method of characteristics, analytic and numerical techniques, self-similarity. Prerequisite: CME 200 (formerly ME 300A).
3 units, Win (Lele)

CME 206. Introduction to Numerical Methods for Engineering—(Formerly ME 300C.) Numerical methods from a user's point of view. Lagrange interpolation, splines. Integration: trapezoid, Romberg, Gauss, adaptive quadrature. Numerical solution of ordinary differential equations: explicit and implicit methods, multistep methods, Runge-Kutta and predictor-corrector methods, boundary value problems, eigenvalue problems. Systems of differential equations, stiffness. Emphasis is on the analysis of numerical methods for accuracy, stability, and convergence. Introduction to numerical solutions of partial differential equations. Von Neumann stability analysis. Alternating direction implicit methods, non-linear equations. Prerequisite: CME 200 (formerly ME 300A).
3 units, Spr (Farhat)

CME 208. Mathematical Programming and Combinatorial Optimization—(Same as MS&E 112/212.) Combinatorial and mathematical programming (integer and non-linear) techniques for optimization. Topics: linear program duality and LP solvers; integer programming; combinatorial optimization problems on networks including minimum spanning trees, shortest paths, and network flows; matching and assignment problems; dynamic programming; linear approximations to convex programs; NP-completeness. Hands-on exercises. Prerequisites: CS 106A or X; ENGR 62 or MATH 103. GER:2b
3 units, Spr (Goel)

CME 210. Multiscale Methods in Engineering—Topics may include: subdivision surfaces in computer graphics; image compression and wavelet analysis; solving partial differential equations using multigrid methods; fast multipole methods for scene illumination. Prerequisites: Matlab, CME 204 (formerly ME 300B).
3 units, Spr (Darve, Donoho)

CME 212. Introduction to Large-Scale Computing in Engineering—The application of programming methodologies for the solution of fundamental engineering problems using algorithms with pervasive application across disciplines. Performance tuning techniques and computer architectures. Algorithms used include multilevel/multiscale decompositions, graph partitioning, sparse matrix linear algebra, and optimization. Prerequisites: CME 200 or 202, and CS106X or equivalent level of programming.
3 units, Win (Fringer)

CME 218. Introduction to Combinatorics and its Applications—Topics: graphs, trees (Cayley's theorem, application to phylogony), eigenvalues, basic enumeration (permutations, Stirling and Bell numbers), recurrences, generating functions, basic asymptotics. Topics illustrated with engineering applications. Final project based on real-world applications. Prerequisites: MATH 51 or 103 or equivalent.
3 units, Aut (Diaconis)

CME 291. Master's Research—Students require faculty sponsor.
1-5 units, Aut, Win, Spr (Staff)

CME 302. Numerical Linear Algebra—(Same as CS 237A.) First in a three quarter graduate sequence. Solution of systems of linear equations: direct methods, error analysis, structured matrices; iterative methods and least squares. Parallel techniques. Prerequisites: CS 137, MATH 103 or 113.
3 units, Aut (Golub)

CME 304. Numerical Optimization—(Same as MS&E 315.) Solution of nonlinear equations; unconstrained optimization; linear programming; quadratic programming; global optimization; general linearly constrained optimization. Theory and algorithms to solve these problems. Prerequisite: background in analysis and numerical linear algebra.
3 units, Win (Murray)

CME 306. Numerical Solution of Partial Differential Equations—(Same as CS 237C.) Hyperbolic partial differential equations: stability, convergence and qualitative properties. Nonlinear hyperbolic equations and systems. Combined solution methods from elliptic, parabolic, and hyperbolic problems. Examples include: Burgers equation, Euler equations for compressible flow, Navier Stokes equations for incompressible flow. Prerequisites: CS 205, or 237A,B; MATH 130, 131; or equivalents.
3 units, Spr (Fedkiw)

CME 308. Stochastic Methods in Engineering—Review of basic probability; stationary processes; estimation, prediction, and filtering; Markov chains in discrete and continuous time; stochastic differential equations. Examples from engineering disciplines. Prerequisites: exposure to probability and background in real variables and analysis.
3 units, Spr (Glynn)

CME 320. Matrix Computations with Applications to Data Mining and IT—Basic matrix factorizations, numerical stability, updating/downdating procedures. Data mining and knowledge discovery, application to information retrieval, text mining, search engines, character recognition, medical informatics, bioinformatics. Mathematical, numerical, and statistical techniques. Prerequisites: CS 106A; MATH 103 or 113; or equivalents.
3 units, Win (Golub)

CME 322. Spectral Methods in Computational Physics—(Formerly ME 408.) Data analysis, spectra and correlations, sampling theorem, non-periodic data, and windowing. Spectral methods for numerical solution of ordinary and partial differential equations. Accuracy and computational cost. Fast Fourier transform. Galerkin, collocation, and Tau methods. Spectral and pseudospectral methods based on Fourier series and eigenfunctions of singular Sturm-Liouville problems. Chebyshev, Legendre, and Laguerre representations. Convergence of eigen function expansions. Discontinuities and Gibbs phenomenon. Aliasing errors and control. Efficient implementation of spectral methods. Spectral methods for complicated domains. Time differencing and numerical stability. Data management methods for the Navier-Stokes equations.
3 units (Moin) not given 2004-05

CME 324. Advanced Methods in Matrix Computation—(Same as CS 336.) Eigenvalue problems: perturbation theory, Lanczos method, Jacobi method. Parallel implementation. Singular value problems. Generalized eigenvalue problems. Polynomial equations. Prerequisite: CS 237A.
3 units, Spr (Golub)

CME 326. Numerical Methods for Initial Boundary Value Problems—(Same as CS 337.) Initial boundary value problems are solved in different areas of engineering and science modeling phenomena, such as wave propagation and vibration, and fluid flow. Numerical techniques for such simulations in the context of applications. Emphasis is on stability and convergence theory for methods for hyperbolic and parabolic initial boundary value problems, and the development of efficient methods for these problems.
3 units, Win (Gustaffson)

CME 330. Applied Mathematics in the Chemical and Biological Sciences—(Same as CHEMENG 300.) 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 chromotography. 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, 104, or equivalents.
3 units, Aut (Shaqfeh)

CME 332. Computational Methods for Scientific Reasoning and Discovery—Methods to represent, utilize, and infer scientific knowledge. Formation of taxonomies, induction of descriptive laws, and construction of explanatory models. Examples include reconstructions from the history of physics and chemistry, and generation of new results in biology and Earth science. Prerequisites: familiarity with artificial intelligence and list processing; ability to think computationally in terms of knowledge structures and mechanisms that operate on them.
3 units, Spr (Langley)

CME 334. Advanced Methods in Numerical Optimization—(Same as MS&E 312.) Topics include interior-point methods, relaxation methods for nonlinear discrete optimization, sequential quadratic programming methods, and decomposition methods. Topic chosen in first class.
3 units, Aut (Murray)

CME 336. Linear and Conic Optimization with Applications—(Same as MS&E 314.) Linear, semidefinite, conic, and convex nonlinear optimization problems as generalizations of classical linear programming. Algorithms include the simplex method, interior-point methods, barrier function methods, cutting plane methods. Related convex analysis, including the separating hyperplane theorem, Farkas lemma, dual cones, optimality conditions, and conic inequalities. Complexity and/or computation efficiency analysis. Applications to max-cut problems, Markov chain mixing times, support vector machines for data mining and classification, graph partitioning, robust portfolio selection, and Euclidian distance geometry. Prerequisite: MS&E 211, or equivalent.
3 units, Spr (Ye)

CME 338. Large-Scale Numerical Optimization—(Same as MS&E 318.) The main algorithms for general constrained optimization emphasizing the sparse-matrix techniques required for their implementation. Sparse factorizations and updating. Iterative methods for linear equations and least squares. Their use in simplex, reduced-gradient, SQP, LCL, and interior methods. Software implementing such methods. Prerequisites: linear algebra and optimization. Recommended: MS&E 310, 311, 312, 314 or 315; CS 137 or 237A.
3 units, Spr (Saunders)

CME 340. Computational Methods in Data Mining—Project course. Focus is on very large scale data mining. Topics include computational methods in supervised and unsupervised learning, association mining, and collaborative filtering. Individual or group applications-oriented programming project. Prerequisites: statistics and linear algebra at the level of MATH 103 and STATS 116; programming at the level of CS 108. Recommended: machine learning at the level of CS 229 or STATS 202.
3 units, Spr (Kamvar)

CME 342. Parallel Methods in Numerical Analysis—(Same as CS 238.) Techniques for obtaining maximum parallelism in numerical algorithms, especially those occurring when solving matrix problems and partial differential equations, and subsequent mapping onto the computer. Implementation issues on parallel computers. Topics: parallel architecture, programming models, matrix computations, FFT, fast multiple methods, domain decomposition, and graph partitioning. Prerequisite: CS 237A or CME 200 (formerly ME 300A), or consent of instructor. Recommended: familiarity with differential equations, and advanced programming language such as C or C++.
3 units, Spr (Alonso)

CME 400. Ph.D. Research
1-15 units, Aut, Win, Spr (Staff)

CME 500. Computational and Mathematical Engineering Seminar—Weekly research lectures by experts from academia, national laboratories, industry, and doctoral students.
1 unit, Aut, Win, Spr (Staff)

COMPUTER SCIENCE

Emeriti: (Professors) Tom Binford, George B. Dantzig, Edward Feigenbaum, Donald E. Knuth,* John McCarthy,* William F. Miller, Nils J. Nilsson, Joseph Oliger, Vaughan Pratt,* Jeffrey D. Ullman,* Gio Weiderhold*
Chair: William J. Dally
Assistant Chair for Education: Margaret Johnson
Professors: Alex Aiken, David Cheriton, William J. Dally, David Dill, Hector Garcia-Molina, Gene H. Golub, Leonidas J. Guibas, Patrick Hanrahan, John Hennessy, Mark A. Horowitz, Oussama Khatib, Monica Lam, Jean-Claude Latombe, Zohar Manna, Edward J. McCluskey, John Mitchell, Rajeev Motwani, Yoav Shoham, Jennifer Widom, Terry Winograd
Associate Professors: Dan Boneh, Michael Genesereth, Daphne Koller, Marc Levoy, Nick McKeown, Serge A. Plotkin, Balaji Prabhakar, Mendel Rosenblum, Sebastian Thrun
Assistant Professors: Serafim Batzoglou, Dawson Engler, Ronald P. Fedkiw, Armando Fox, Scott Klemmer, Christoforos Kozyrakis, Christopher Manning, Andrew Ng, Tim Roughgarden
Professors (Research): Richard Fikes, John K. Salisbury
Professor (Teaching): Eric S. Roberts
Courtesy Professors: Giovanni De Micheli, Bernd Girod, Martin Kay, Michael Levitt, Teresa Meng, Grigori Mints, Clifford I. Nass, Fouad A. Tobagi
Courtesy Associate Professors: Russ Altman, Martin Fischer, John Gill, Dan Jurafsky, Oyekunle Olukotun
Courtesy Assistant Professors: Ashish Goel, Benjamin Van Roy
Senior Lecturer: Margaret Johnson
Lecturers: Gerald Cain, Nicholas J. Parlante, Robert Plummer, Mehran Sahami, Patrick Young, Julie Zelenski
Consulting Professors: Cynthia Dwork, Kurt Konolige, Pandurang Nayak, Prabhakar Raghavan
Consulting Associate Professors: Mary G. Baker, Pei Cao, Feng Zhao
Consulting Assistant Professors: Brian Jeffrey Fogg, Anand Rajaraman
Visiting Associate Professor: Sheila McIlraith
Visiting Assistant Professor: Satoshi Oyama

* Recalled to active duty.

Mail Code: 94305-9025
Phone: (650) 723-2273
Web Site: http:// www.cs.stanford.edu/

Courses given in Computer Science have the subject code CS. For a complete list of subject codes, see Appendix.

The Department of Computer Science (CS) operates and supports computing facilities for departmental education, research, and administration needs.

All CS students have access to the departmental student machine, a four CPU Dell PowerEdge 7150 Itanium, as well as computer labs with public workstations located in the Gates Building. In addition, most students have access to systems located in their research areas.

Each research group in Computer Science has systems specific to its research needs. These systems include PCs, Mac, high-end multi-CPU computer clusters, and file servers. Servers and workstations manufactured by SUN, SGI, Dell, and Apple are commonplace.

Support for course work and instruction is provided on systems available through Information Technology Systems and Services (ITSS).

UNDERGRADUATE PROGRAMS

The department offers both a major and a minor in Computer Science. The requirements for these programs are outlined in the "School of Engineering" section of this bulletin and described in more detail in the *Handbook for Undergraduate Engineering Programs* published by the School of Engineering. The department has an honors program, which is described in the following section.

In addition to Computer Science itself, Stanford offers several interdisciplinary degrees with a substantial computer science component. The Computer Systems Engineering major (also in Engineering) allows the study of issues of both computer hardware and software, bridging the gap between traditional CS and Electrical Engineering majors. The Symbolic Systems major (in the School of Humanities and Sciences) offers a chance to explore computer science and its relation to linguistics, philosophy, and psychology. Finally, the Mathematical and Computational Sciences major (also Humanities and Sciences) allows students to explore computer science along with more mathematics, statistics, and operations research.

HONORS

The Department of Computer Science (CS) offers an honors program for selected undergraduates whose academic records and personal initiative indicate that they have the necessary skills to undertake high-quality research in computer science. Admission to the program is by application only. To apply for the honors program, students must be majoring in Computer Science, have a grade point average (GPA) of at least 3.6 in courses that count toward the major, and achieve senior standing (135 or more units) by the end of the academic year in which they apply. Coterminal master's students are eligible to apply as long as they have not already received their undergraduate degree. Beyond these requirements, students who apply for the honors program must also find a Computer Science faculty member who agrees to serve as the thesis adviser for the project. Thesis advisers must be members of Stanford's Academic Council.

Students who meet the eligibility requirements and wish to be considered for the honors program must submit a written application to the CS undergraduate program office by May 1 of the year preceding the honors work. The application must include a letter describing the research project, a letter of endorsement from the faculty sponsor, and a transcript of courses taken at Stanford. Each year, a faculty review committee selects the successful candidates for honors from the pool of qualified applicants.

In order to receive departmental honors, students admitted to the honors program must, in addition to satisfying the standard requirements for the undergraduate degree, do the following:

1. Complete at least 9 units of CS 191 or 191W under the direction of their project sponsor.
2. Attend a weekly honors seminar Spring Quarter.
3. Complete an honors thesis deemed acceptable by the thesis adviser and at least one additional faculty member.
4. Present the thesis at a public colloquium sponsored by the department.
5. Maintain the 3.6 GPA required for admission to the honors program.

GRADUATE PROGRAMS

The University's basic requirements for the M.S. and Ph.D. degrees are discussed in the "Graduate Degrees" section of this bulletin.

MASTER OF SCIENCE

In general, the M.S. degree in Computer Science is intended as a terminal professional degree and does not lead to the Ph.D. degree. Most students planning to obtain the Ph.D. degree should apply directly for admission to the Ph.D. program. Some students, however, may wish to complete the master's program before deciding whether to pursue the Ph.D. To give such students a greater opportunity to become familiar with research, the department has instituted a program leading to a master's degree with distinction in research. This program is described in more detail in a subsequent section.

Applications for admission to the M.S. program, and all of the required supporting documents, must be received by December 2, 2004. Exceptions are made for applicants who are already students at Stanford and are applying to the coterminal program. Information on these deadlines is available from the department.

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

REQUIREMENTS

A candidate is required to complete a program of 45 units. At least 36 of these must be graded units, passed with a grade point average (GPA) of 3.0 (B) or better. The 45 units may include no more than 21 units of courses from those listed below in Requirements 1 and 2. Thus, students needing to take more than seven of the courses listed in Requirements 1 and 2 actually complete more than 45 units of course work in this program. Only extremely well-prepared students may expect to finish the program in one year; most complete the program in six quarters. Students hoping to complete the program with 45 units should already have a substantial background in computer science, including course work or experience equivalent to all of Requirement 1 and some of the courses in Requirement 2.

Requirement 1—The following courses may be needed as prerequisites for other courses in the program: CS 103X, 107, 108; EE 108B; MATH 109 or 120.

Requirement 2—Students must demonstrate breadth of knowledge in the field by completing the following courses:

1. Area A: Mathematical and Theoretical Foundations:
   a) Required:
      1) Statistics (STATS 116 *or* MS&E 220)
      2) Algorithms (CS 161)
      3) Automata (CS 154)
   b) Choose one of:
      1) Numerical Analysis (CS 137 or 237A)
      2) Logic (CS 157, 257, 258, *or* PHIL 160A)
      3) Mathematical Methods (CS 205)
2. Area B: Computer Systems:
   a) Required: Architecture (EE 108B or 282)
   b) Choose two of:
      1) Operating Systems (CS 140)
      2) Compilers (CS 143)
      3) Introduction to Computer Networks (CS 244A *or* EE 284)
3. Area C: AI and Applications:
   a) Choose two of the following, with at least one 200-level course:
      1) AI (CS 121 or 221)
      2) Databases (CS 145 or 245)
      3) Graphics (CS 148 or 248)

Individual specializations are free to narrow the set of choices in specific areas of the breadth requirement; see the individual specialization sheets in the department office for details. Breadth courses are waived only if evidence is provided that similar or more advanced courses have been taken, either at Stanford or another institution. Courses that are waived rather than taken may not be counted toward the M.S. degree. Breadth courses may be taken on a satisfactory/no credit basis provided that a minimum of 36 graded units is presented within the 45-unit program.

Requirement 3—At least 1 but no more than 3 units of 500-level seminars must be taken.

Requirement 4—A program of 21 units in an area of specialization must be completed. All courses in this area must be taken for letter grades. Seven approved programs are listed below. Students may propose to the M.S. program committee other coherent programs that meet their goals and satisfy the basic requirements.

1. Numerical Analysis/Scientific Computation
   a) CS 237A, 237B, 237C
   b) At least two of: CS 205, 260, MS&E 121, MATH 131, 132, 220A, 220B, 220C, STATS 200
   c) At least two of: CS 223A, 238, 326A, 327A, 328, 336, 337, 339, AA 214A, 214B, STATS 227
2. Systems
   a) CS 240, 242
   b) At least three of: CS 243, 244A, 245, 248, 348B, EE 271, 275
   c) At least 6 more units selected from '2b' and from the following: CS 194, 222, 241, 244B, 244C, 246, 249, 255, 259, 262, 270, 271, 272, 276, 315A, 315B, 342, 343, 344, 345, 346, 347, 348A, 349, 374, 448, EE 281, 318, 319, 384A, 384B, 384C, 384M, 384S, 384X, 384Y, 482A, 482B, 488, 489
3. Software Theory
   a) CS 242, 243, 256, 258
   b) At least one of: CS 244A, 245, 342, 343, 345
   c) At least one course from the following: CS 255, 261, 351, 355, 356, 361A, 361B, 365, 368
   d) At least one additional course selected from '3b,' '3c,' CS 346
4. Theoretical Computer Science
   a) CS 256, 258, 261 (361A, 361B, or 365 may be substituted for 261)
   b) At least 12 more units from CS 228, 255, 345, 351, 352, 353, 355, 356, 357, 358, 359,* 361A, 361B, 365, 367A, 367B, 368, 369*, MS&E 310

5. Artificial Intelligence
   a) At least four of: CS 222, 223A, 223B, 224M, 224N, 224S, 226, 227, 228, 229, 326A
   b) A total of 21 units from the above and from the following: CS 205, 206, 225A, 225B, 246, 256, 257, 262, 270, 274, 276, 277, 323, 324, 327A, 328, 329, 354, 374, 377,* 379,* 426, ECON 286, EE263, 376A, ENGR 205, 209A; LINGUIST 235, 238, 239A; MS&E 251, 252, 339, 351, 352, 353, PHIL 160B, 169, 298, PSYCH 202, 203, 205; STATS 202, 315A, 315B
6. Human-Computer Interaction
   a) CS 147, 247A, 247B
   b) At least 6 units from: CS 148 or 248, 377 (may be taken repeatedly), 378, 447
   c) A total of 21 units from the above and from the following: COMM 269, 272, CS 249, 270, 271, 272, 348A, 348B, 448, MS&E 234, 284, LINGUIST 238, ME 101, 115, 313, PSYCH 203, 205, 221, 267
7. Real-World Computing
   a) At least two of: CS 223A, 223B, 248
   b) At least three of: CS 205, 237A, 237B, 237C, 249, 262, 277, 326A, 348A, 348B, 368, 374
   c) A total of 21 units from the above and from the following: CS 225A, 225B, 228, 229, 247A, 270, 271, 272, 273, 274, 327A, 328, 336, 448, PSYCH 267

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* With consent of specialization chair.

Requirement 5—Additional elective units must be technical courses (numbered 100 or above) related to the degree program and approved by the adviser. Elective courses may be taken on a satisfactory/no credit basis provided that a minimum of 36 graded units is presented within the 45-unit program.

MASTER OF SCIENCE WITH DISTINCTION IN RESEARCH

A student who wishes to pursue the M.S./CS with distinction in research must first identify a faculty adviser who agrees to supervise and support the research work. The research adviser must be a member of the Academic Council and must hold an appointment in Computer Science. The student and principal adviser must also identify another faculty member, who need not be in the Department of Computer Science, to serve as a secondary adviser and reader for the research report. In addition, the student must complete the following requirements beyond those for the regular M.S./CS degree:

1. *Research Experience:* the program must include significant research experience at the level of a half-time commitment over the course of three academic quarters. In any given quarter, the half-time research commitment may be satisfied by a 50 percent appointment to a departmentally supported research assistantship, 6 units of independent study (CS 393, 395, or 399), or a prorated combination of the two (such as a 25 percent research assistantship supplemented by 3 units of independent study). This research must be carried out under the direction of the primary or secondary adviser.
2. *Supervised Writing and Research:* in addition to the research experience outlined in the previous requirement, students must enroll in at least 3 units of independent research (CS 393, 395, or 399) under the direction of their primary or secondary adviser. These units should be closely related to the research described in the first requirement, but focused more directly on the preparation of the research report described in the next section. Note that the writing and research units described in parts (1) and (2) must be taken in addition to the 21 units required for the specialization, although they do count toward the 45 units required for the degree.
3. *Research Report:* students must complete a significant report describing their research and its conclusions. The research report represents work that is publishable in a journal or at a high-quality conference, although it is presumably longer and more expansive in scope than a typical conference paper. Two copies of the research report must be submitted to the Student Services office in the department three weeks before the beginning of the examination period in the student's final quarter. Both the primary and secondary adviser must approve the research report before the distinction-in-research designation can be conferred.

DOCTOR OF PHILOSOPHY

Applications to the Ph.D. program and all supporting documents must be received by December 2, 2004. Visit http://cs.stanford.edu/admissions/ for complete up-to-date information. The following are department requirements (see the Computer Science Ph.D. administrator for further details, or visit http://cs.stanford.edu/Degrees/phd.php):

1. A student should plan and successfully complete a coherent program of study covering the basic areas of computer science and related disciplines. The student's adviser has primary responsibility for the adequacy of the program, which is subject to review by the Ph.D. program committee.
2. Each student, to remain in the Ph.D. program, must satisfy the breadth requirement covering introductory level graduate material in major areas of computer science. Once a student fulfills six of eight whole areas of the breadth requirement, he or she may apply for admission to candidacy for the Ph.D. prior to the second year in the program. The student must completely satisfy the breadth requirement by the end of nine quarters (excluding summers), and must pass a qualifying exam in the general area of the expected dissertation.
3. As part of the training for the Ph.D., the student is required to complete at least 4 units (a unit is 10 hours per week for one quarter) as a teaching assistant or instructor for courses in Computer Science numbered 100 or above.
4. The most important requirement is the dissertation. After passing the qualifying examination, each student must secure the agreement of a member of the department faculty to act as the dissertation adviser. (In some cases, the dissertation adviser may be in another department.)
5. The student must pass a University oral examination in the form of a defense of the dissertation. It is usually held after all or a substantial portion of the dissertation research has been completed.
6. The student is expected to demonstrate the ability to present scholarly material orally, both in the dissertation defense and by a lecture in a department seminar.
7. The dissertation must be accepted by a reading committee composed of the principal dissertation adviser, a second member from within the department, and a third member chosen from within the University. The principal adviser and at least one of the other committee members must be Academic Council members.

PH.D. MINOR

For a minor in Computer Science, a candidate must complete 20 unduplicated units of computer science course work numbered 200 or above. At least three of the courses have to be master's core courses to provide breadth and one course numbered 300 or above to provide depth. One of the courses taken must include a significant programming project to demonstrate programming efficiency. All courses must be taken for a letter grade and passed with a grade of 'B' or better.

TEACHING AND RESEARCH ASSISTANTSHIPS

Graduate student assistantships are available. Half-time assistants receive a tuition scholarship for 8, 9, or 10 units per quarter during the academic year, and in addition receive a monthly stipend.

Duties for half-time assistants during the academic year involve approximately 20 hours of work per week. Teaching assistants (TAs) help an instructor teach a course by conducting discussion sections, consulting with students, grading examinations, and so on. Research assistants (RAs) help faculty and senior staff members with research in computer science. Most teaching and research assistantships are held by Ph.D. students in the Department of Computer Science. If there is an insufficient number of Ph.D. students to staff teaching and research assistantships, then these positions are open to a limited number of master's students in the department. However, master's students should not plan on being appointed to an assistantship.

Students with fellowships may have the opportunity to supplement their stipends by serving as graduate student assistants.

COURSES

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

GUIDE TO SELECTING INTRODUCTORY COURSES

Students arriving at Stanford have widely differing backgrounds and goals, but most find that the ability to use computers effectively is beneficial to their education. The department offers many introductory courses to meet the needs of these students.

For students whose principal interest is an exposure to the fundamental ideas behind computer science and programming, CS 105 is the most appropriate course. It is intended for students in nontechnical disciplines who expect to make some use of computers, but who do not expect to go on to more advanced courses. CS 105 meets the Area 2b General Education Requirement and includes an introduction to programming and the use of modern Internet-based technologies. Students interested in learning to use the computer should consider CS 1C, Introduction to Computing at Stanford.

Students who intend to pursue a serious course of study in computer science may enter the program at a variety of levels, depending on their background. Students with little prior experience or those who wish to take more time to study the fundamentals of programming should take 106A followed by 106B. Students in 106A need not have prior programming experience. Students with significant prior exposure to programming or those who want an intensive introduction to the field should take 106X, which covers most of the material in 106A and B in a single quarter. CS106A uses Java as its programming language; CS106B and X use C++. No prior knowledge of these languages is assumed, and the prior programming experience required for 106X may be in any language. In all cases, students are encouraged to discuss their background with the instructors responsible for these courses.

After the introductory sequence, Computer Science majors and those who need a significant background in computer science for related majors in engineering should take 103, 107 and 108. CS 103 offers an introduction to the mathematical and theoretical foundations of computer science. CS 107 exposes students to a variety of programming paradigms that illustrate critical strategies used in systems development; 108 builds on this material, focusing on the development of large interactive programs based on the object-oriented programming paradigm.

In summary:

For exposure: 1C
For nontechnical use: 105
For scientific use: 106A
For a technical introduction: 106A
For significant use: 106A,B or 106X, along with 103, 107, and 108

NUMBERING SYSTEM

The first digit of a CS course number indicates its general level of sophistication:

001-099 service courses for nontechnical majors
100-199 other service courses, basic undergraduate
200-299 advanced undergraduate/beginning graduate
300-399 advanced graduate
400-499 experimental
500-599 graduate seminars

The tens digit indicates the area of Computer Science it addresses:

00-09 Introductory, miscellaneous
10-19 Hardware Systems
20-29 Artificial Intelligence
30-39 Numerical Analysis
40-49 Software Systems
50-59 Mathematical Foundations of Computing
60-69 Analysis of Algorithms
70-79 Typography and Computational Models of Language
90-99 Independent Study and Practicum

NONMAJOR

CS 1C. Introduction to Computing at Stanford—For those with limited experience on computers or who want to learn more about Stanford's computing environment. The basics of computing, and a variety of programs. Topics include email, word processing, spreadsheets, the web and the Internet, and computing resources at Stanford. Macintosh and PC systems. One-hour lecture/demonstration in dormitory clusters prepared and administered weekly by the Resident Computer Coordinator (RCC). Weekly assignments and final project. Not a programming course.
1 unit, Aut (Smith)

CS 2C. Intermediate Computing at Stanford—Continuation of 1C. Topics: advanced web pages, Photoshop, Dreamweaver, DV editing, Unix. One-hour lecture/demonstration in dormitory clusters prepared and administered weekly by the Resident Computer Coordinator (RCC). Final project. Not a programming course.
1 unit, Win (Staff)

CS 48N. The Science of Art—Stanford Introductory Seminar. Preference to freshmen. The interwoven histories of science and Western art from the Renaissance to the 19th century. Emphasis is on the revolutions in science and mathematics that inspired parallel revolutions in the visual arts such as Brunelleschi's invention of linear perspective, Newton's discoveries in geometric optics, and the theories of color vision proposed by Goethe, Young, and Helmholtz. The scientific principles behind image making including digital image synthesis and computer graphics. No programming experience required. Limited enrollment. GER:2b
3 units, Spr (Levoy)

CS 51. Introduction to Quantum Computing and Quantum Information Theory—Topics: quantum algorithms (including Shor's polynomial time algorithm for integer factorization, Grover's database search algorithm, quantum tree search, quantum wavelets), quantum information theory, quantum cryptography, breaking the RSA cryptosystem, quantum teleportation, circuit design, quantum error correction, and examples of prototype quantum computers. Prerequisites: familiarity with elementary matrix algebra and complex numbers.
2 units, Spr (Williams)

CS 68N. Technological Visions of Utopia—Stanford Introductory Seminar. Preference to freshmen. The role of computers and other technologies in literary visions of utopian and anti-utopian societies. Readings include classical utopian texts including More's *Utopia* and Bellamy's *Looking Backward*, along with recent books and films in which technology plays a more central role. GER:2b
3 units, Aut (Roberts)

CS 73N. Business on the Information Highways—Stanford Introductory Seminar. Preference to freshmen. Understanding the capabilities of the Internet and its services. Writing for the web. The effect on commerce, education, government, and health care. Technical and business alternatives. Who will be hurt and who will benefit from the changes? Participants develop web publications.
2 units, Spr (Wiederhold)

CS 74N. Digital Dilemmas—Stanford Introductory Seminar. Preference to freshmen. The history and evolution of computing and communication technology, and how it affects the fabric of society. Topics: the military-academic-industrial research complex, the Cold War, and the public good; intellectual property and the Internet; the balance between individual privacy and freedom and the security and stability of the state, and the effect of strong cryptography on this balance. Readings, discussion, debates, guest speakers, one or more field trips. GER:2b
3 units, Aut (Dill, Fox)

UNDERGRADUATE

CS 103A. Discrete Mathematics for Computer Science—The fundamental mathematical foundations required for computer science. Topics: propositional and predicate logic, proof techniques, induction, recursion, combinatorics, and functions. Corequisite: 106A or X. GER:2c
3 units, Aut (Plummer), Win (Johnson)

CS 103B. Discrete Structures—Continuation of 103A. Topics: analysis of algorithms, recurrence relations, mathematical formulations of basic data models (sets, relations, linear models, trees and graphs), regular expressions, grammars, and finite automata. Corequisite: 106B or X. GER:2c

3 units, Win, Spr (Sahami)

CS 103X. Discrete Structures (Accelerated)—Covers the material in 103A and B in a single quarter. Students who take 103X should feel comfortable with mathematical formalism and be willing to solve mathematically demanding problems. GER:2c

3-4 units, Win (Cain)

CS 105. Introduction to Computers—For non-technical majors. What computers are and how they work. Practical experience in programming. Construction of computer programs and basic design techniques. A survey of Internet technology and the basics of computer hardware. Students in technical fields and students looking to acquire programming skills should take 106A or 106X. Students with prior computer science experience at the level of CS106 or above must receive consent of instructor. Prerequisite: minimal math skills. GER:2b

3-5 units, Aut, Spr (Young)

CS 106A. Programming Methodology—Introduction to the engineering of computer applications emphasizing modern software engineering principles: object-oriented design, decomposition, encapsulation, abstraction, and testing. Uses the Java programming language. Emphasis is on good programming style and the built-in facilities of the Java language. No prior programming experience required. GER:2b

3-5 units, Aut, Spr (Parlante), Win (Roberts)

CS 106B. Programming Abstractions—Abstraction and its relation to programming. Software engineering principles of data abstraction and modularity. Object-oriented programming, fundamental data structures (such as stacks, queues, sets) and data-directed design. Recursion and recursive data structures (linked lists, trees). Brief introduction to time and space complexity analysis. Uses the programming language C++ covering basic facilities provided by the language. Prerequisite: 106A or consent of instructor. GER:2b

3-5 units, Aut, Win (Zelenski), Spr (Staff)

CS 106X. Programming Methodology and Abstractions (Accelerated)—Intensive; 106A,B in one quarter. Students who complete 106A should enroll in 106B; 106X may be taken after 106A only with consent of instructor. Uses the C++ programming language. How programming concepts are expressed in C++. Abstraction and its relation to programming. Software engineering principles of data abstraction and modularity. Object-oriented programming, fundamental data structures (such as stacks, queues, sets) and data-directed design. Recursion and recursive data structures (linked lists, trees). Introduction to time and space complexity analysis. Prerequisite: substantial programming experience that allows ready understanding of concepts presented in 106A. GER:2b

3-5 units, Aut (Sahami), Win (Cain)

CS 107. Programming Paradigms—Advanced memory management features of C and C++; the differences between imperative and object-oriented paradigms. The functional paradigm (using LISP) and concurrent programming (using C and C++). Brief survey of other modern languages such as Python and C++. GER:2b

3-5 units, Aut, Spr (Cain)

CS 108. Object-Oriented Systems Design—Software design and construction in context of large OOP libraries. Taught in Java. Topics: review of OOP, the structure of Graphical User Interface (GUI) OOP libraries, GUI application design and construction, OOP software engineering strategies, approaches to programming in teams. Prerequisite: 107. GER:2b

3-4 units, Win, Spr (Parlante)

CS 121. Introduction to Artificial Intelligence—(Only one of 121/221 counts towards any CS degree program.) Introduction to the key concepts, representations, and techniques used in building practical computational systems (agents) that appear to display artificial intelligence (AI), through the use of sophisticated adaptive information processing algorithms. Topics: history of AI, reactive systems, heuristic search, planning, constraint satisfaction, knowledge representation and uncertain reasoning, machine learning, classification, applications to language, and vision. Prerequisites: 103B or 103X and basic facility with differential calculus, vector algebra, and probability theory. GER:2b

3 units, Win (Latombe)

CS 137. Introduction to Scientific Computing—(Same as CME 108.) Fundamentals of numerical computation for mathematical, computational and physical sciences and engineering. Numerical solution of systems of algebraic equations, least squares, quadrature, minimization of a function, banded matrices, non-linear equations, numerical solution of ordinary and partial differential equations. Truncation error, numerical stability for time dependent problems, stiffness, boundary value problems. Prerequisites: CS 106A or familiarity with MATLAB. For students who have taken MATH 51,52,53; not appropriate for students who have taken CME 102, 104 (formerly ENGR 155A,B). GER:2b

3-4 units, Win (Moin)

CS 138. Matlab and Maple for Science and Engineering Applications—Introduction to use of Matlab and Maple in engineering applications. Emphasis is on the use of software to solve real problems. How the algorithms work, primarily so user may understand their possible limitations. How to use packages to solve a variety of introductory but important problems in: linear systems, eigenvalue problems, ordinary differential equations, elementary statistics, elementary signal processing (Fourier transforms, wavelets), computer algebra, graphical interfaces. Applications for the engineering and physical sciences. Prerequisites: undergraduate linear algebra and a willingness to program. GER:2b

3-4 units (Staff) not given 2004-05

CS 140. Operating Systems and Systems Programming—The fundamentals of operating systems design and implementation. Basic structure; synchronization and communication mechanisms; implementation of processes, process management, scheduling, and protection; memory organization and management, including virtual memory; I/O device management, secondary storage, and file systems. Prerequisite: 108. GER:2b

3-4 units, Aut, Win (Rosenblum)

CS 143. Compilers—Principles and practices for design and implementation of compilers and interpreters. Topics: lexical analysis; parsing theory (LL, LR, and LALR parsing); symbol tables; type systems; scoping, semantic analysis; intermediate representations, runtime environments; and code generation. Students construct a compiler for a simple object-oriented language during course programming projects. Prerequisites: 103B or X, 107. GER:2b

3-4 units, Aut (Aiken), Spr (Johnson)

CS 145. Introduction to Databases—Database design and the use of database management systems for applications. The relational model, relational algebra, and SQL, the standard language for creating, querying, and modifying relational and object-relational databases. XML data including the query languages XPath and XQuery. UML database design, and relational design principles based on functional dependencies and normal forms. Other issues include indexes, views, transactions, authorization, integrity constraints, and triggers. Advanced topics from data warehousing, data mining, web data management, Datalog, data stream processing, temporal databases, middleware, or peer-to-peer systems. Prerequisites: 103B or X, 107. GER:2b

3-4 units, Aut (Ullman)

CS 147. Introduction to Human-Computer Interaction Design—Usability and affordances, direct manipulation, systematic design methods, user conceptual models and interface metaphors, design languages and genres, human cognitive and physical ergonomics, information and interactivity structures, design tools and environments. Structured around a set of case studies in which notable interface designs and/or projects are analyzed as illustrative of underlying principles. Discussions of cases and interface analysis and design exercises.

3-4 units, Aut (Winograd)

CS 148. Introductory Computer Graphics—For undergraduates; M.S. students or students interested in continuing in graphics should take 248. Only one of 148 or 248 counts towards any CS degree program. Two- and three-dimensional computer graphics. Topics: input and display devices, scan conversion of geometric primitives, two- and three-dimensional transformations and clipping, windowing techniques, curves and curved surfaces, three-dimensional viewing and perspective, hidden surface removal, illumination and color models, OpenGL, and 3-D modeling tools. Emphasis is on practical skills in using graphics libraries and tools. Programming using C/C++ and OpenGL, with demos in SoftImage. Prerequisites: 107, MATH 103. GER:2b
3 units, Aut (Johnson)

CS 154. Introduction to Automata and Complexity Theory—Regular sets: finite automata, regular expressions, equivalences among notations, methods of proving a language not to be regular. Context-free languages: grammars, pushdown automata, normal forms for grammars, proving languages non-context-free. Turing machines: equivalent forms, undecidability. Nondeterministic Turing machines: properties, the class NP, complete problems for NP, Cook's theorem, reducibilities among problems. Prerequisites: 103B or X. GER:2b
3-4 units, Aut (Dill), Spr (Motwani)

CS 154N. Introduction to NP Completeness—Turing machines: equivalent forms, undecidability. Nondeterministic Turing machines: properties, the class NP, complete problems for NP, Cook's theorem, reducibilities among problems. Students participate in approximately the last half of 154. Prerequisite: a knowledge of formal languages and automata as in the first part of 154.
2 units, Aut (Dill), Spr (Motwani)

CS 155. Computer and Network Security—For seniors and first-year graduate students. Principles of computer systems security. Attack techniques and how to defend against them. Topics include: network attacks and defenses, operating system holes, application security (web, email, databases), viruses, social engineering attacks, privacy, and digital rights management. Course projects focus on building reliable code. Recommended: basic knowledge of Unix. Prerequisite: 140. GER:2b
3 units, Spr (Boneh, Mitchell)

CS 157. Logic and Automated Reasoning—Introduction to logic for computer scientists. An elementary exposition from a computational point of view, of propositional logic, predicate logic, axiomatic theories, and theories with equality and induction. Interpretations, models, validity, proof. Automated deduction: polarity, skolemization, unification, resolution, equality. Strategies. Applications. Prerequisite: 103B or X. GER:2b
3-4 units, Aut (Manna), Spr (Genesereth)

CS 157L. Logic and Automated Reasoning Laboratory
1 unit, Aut (Manna)

CS 161. Design and Analysis of Algorithms—Efficient algorithms for sorting, searching, and selection. Algorithm analysis: worst and average case analysis. Recurrences and asymptotics. Data structures: balanced trees, heaps, hash tables. Algorithm design techniques: divide-and-conquer, dynamic programming, greedy algorithms, amortized analysis. Algorithms for fundamental graph problems such as depth-first search, connected components, topological sort, and shortest paths. Possible additional topics: network flow, string searching, parallel computation. Prerequisite: 103B or X; STATS 116. GER:2b
3-4 units, Aut (Plotkin), Win (Roughgarden)

CS 162. Introduction to Combinatorics and its Applications—(Enroll in MATH 108.)
3 units, Aut (Thiem)

CS 191. Senior Project—Restricted to Computer Science and Computer Systems Engineering students. Group or individual projects under faculty direction. Register using instructor's section number. A project can be either a significant software application or publishable research. Software application projects include substantial programming and modern user-interface technologies and are comparable in scale to shareware programs or commercial applications. Research projects may result in a paper publishable in an academic journal or presentable at a conference. Required public presentation of final application or research results.
1-6 units, Aut, Win, Spr, Sum (Staff)

CS 191W. Writing Intensive Senior Project—Restricted to Computer Science and Computer Systems Engineering students. Writing-intensive version of CS191. Register using the section number of an Academic Council member. WIM
3-6 units, Aut, Win, Spr (Staff)

CS 192. Programming Service Project—Restricted to Computer Science students. Appropriate academic credit (without financial support) is given for volunteer computer programming work of public benefit and educational value.
1-4 units, Aut, Win, Spr, Sum (Staff)

CS 193C. Client-Side Internet Technologies—JavaScript, document object model, Flash, HTML, cascading style sheets, and XML. Prerequisite: programming experience at the level of CS 106A. GER:2b
3 units, Win (Young)

CS 193D. C++ and Object-Oriented Programming—C++ programming language and object-oriented programming paradigm. The major features of C++ 3.0 and the object design principles which apply generally in Object Oriented Languages. Intensive programming assignments. Prerequisites: knowledge of C and basic programming methodology as developed in 106B or 106X. GER:2b
3 units (Staff) not given 2004-05

CS 193E. Object-Oriented User Interface Programming—Hands-on project using the Cocoa frameworks for the Mac OS X platform. The essentials of designing and implementing graphical applications using Cocoa tools and APIs. Topics include: object-oriented event-driven programming; Objective-C language; development tools such as Interface Builder, ProjectBuilder, and debugging and profiling tools; APIs for the foundation and application kits; and the Quartz graphic system. Requirements: C language and programming experience at the level of 106B/X. Recommended: UNIX, object-oriented programming, and graphical toolkits. GER:2b
3 units, Win (Staff)

CS 193I. Internet Technologies—Programmer-oriented survey of the authoring, distributing, and browsing technologies. The role, use, and implementation of current Internet tools. Topics: TCP/IP; namespace, connections, and protocols. Client/server structures. Web/HTTP/HTML techniques for text, images, links, and forms. Server side programming, CGI scripts. Security and privacy issues. Programming projects on client- and server-side may be in Perl or Java. Languages are introduced as needed. Emphasis is on understanding, exploiting, and extending Internet technologies. Prerequisites: programming fundamentals at the level of 106B or 106X, and the ability to build and debug programs in a Unix environment. GER:2b
3 units, Spr (Staff)

CS 193N. C# and the .NET Platform—Programming in the object-oriented language C#. Software development for the .NET platform including: Windows forms, graphics using GDI+, building custom controls, data access with ADO.NET, developing software for the Internet. Intensive programming assignments. Prerequisite: Object-oriented programming experience. GER:2b
3 units, Spr (Plummer)

CS 194. Software Project—Design, specification, coding, and testing of a significant team programming project under faculty supervision. Documentation includes a proposal, specification, and explanation of design. Demonstration of a prototype and the final product. Prerequisite: 108. GER:2b,WIM
3 units, Win (Young), Spr (Plummer)

CS 196. Microcomputer Consulting—Overview of computer consulting, focusing on Macintosh and Intel-compatible systems. Topics: operating systems, networks, troubleshooting, and consulting methodology. Biweekly lectures emphasize on-campus computing environments. Students work as consultants in campus computer clusters and in residences. Prerequisite: 1C.
2 units, Aut, Spr (Ly)

CS 198. Teaching Computer Science—Students lead a small discussion section of 106A while learning the fundamentals of teaching a programming language at the introductory level. Two workshops and one meeting weekly focus on teaching skills, techniques, and course specifics. Application and interview required; email cs198@cs for information. Prerequisite: 106B or 106X.
4 units, Aut (Johnson, Delaye, Berglund),
Win, Spr (Johnson, Berglund)

CS 199. Independent Work—Special study under faculty direction, usually leading to a written report. Letter grade given; if this is not appropriate, enroll in 199P. Register using the section number associated with the instructor.
1-6 units, Aut, Win, Spr, Sum (Staff)

CS 199P. Independent Work
1-6 units, Aut, Win, Spr, Sum (Staff)

UNDERGRADUATE AND GRADUATE

CS 200. Undergraduate Colloquium—Strongly recommended for junior-year CS majors as a way to build contacts with faculty. Weekly presentations by faculty and people from industry informally describing their views of computer science as a field and their experience as computer scientists. (AU)
1 unit, Aut (Young)

CS 201. Computers, Ethics, and Social Responsibility—Primarily for majors entering computer-related fields. Analysis of the ethical and social issues related to the development and use of computer technology. Background in ethical theory, and social, political, and legal considerations. Scenarios in problem areas: privacy, reliability and risks of complex systems, and the responsibility of professionals for the applications and consequences of their work. Prerequisite: 106B or X. GER:2b,WIM
3-4 units, Spr (Roberts)

CS 202. Law for Computer Science Professionals—Essential legal topics for the computer science professional including: intellectual property law as it relates to computer science including copyright registration, patents, and trade secrets; contract issues such as non-disclosure/non-compete agreements, license agreements, and works-made-for-hire; dispute resolution; and principles of business formation and ownership. Emphasis is on topics of current interest such as open source and the free software movement, peer-to-peer sharing, encryption, data mining, and spam. GER:2b
1 unit, Aut (Hansen)

CS 203. Understanding and Participating in Cyberlaw and Policy Making—The growing body of technology-oriented law and policy that regulates what computer scientists and developers can research, the tools they can use, the devices they build, and the publication of their work. How these processes work, and how developers can make their voices heard. How law and policy is made in the courts, Congress, and agencies, and how organizations and companies participate in the process. Cyber law including privacy, free speech, and intellectual property. Case studies of how technologists are participating in current debates. GER:2b
3 units, Aut (Gelman)

CS 204. Computers and Law—Laws of computer-mediated activity and the development of computational solutions enabling users to understand, utilize, exploit, and obey these laws. Publishing, licensing, and distribution of web content and software, business contracts and processes, and web services. Formalization and translation of laws and regulations, business rules, and contracts, integration of overlapping systems of authority, and monitoring of transactions. Existing technology, including XML-based languages, transactional and other logic systems, partial programs, and planning techniques.
2-3 units, Spr (Genesereth)

CS 205. Mathematical Methods for Robotics, Vision, and Graphics—Overview of continuous mathematics background necessary for research in robotics, vision, and graphics. Possible topics: linear algebra; the conjugate gradient method; ordinary and partial differential equations; vector and tensor calculus; calculus of variations. Prerequisites: 106B or X; MATH 51 and 113; or equivalents.
3 units, Aut (Fedkiw)

CS 206. Technical Foundations of Electronic Commerce—Topics include: searching hyperlinked structures; data mining; online auctions and other trading mechanisms; safe exchange; copyright protection and security; online payment mechanisms; web software infrastructure; personalization and user tracking; integration of catalogs and other trading information. Prerequisites: basic concepts covered in 103 and 107, or equivalent courses; ability to follow simple combinatorial, probabilistic, and algorithmic arguments.
3 units (Staff) not given 2004-05

CS 211. Logic Design—(Enroll in EE 275.)
3 units (Staff) not given 2004-05

CS 212. Computer Architecture and Organization—(Enroll in EE 282.)
3 units, Aut (Kozyrakis)

CS 221. Artificial Intelligence: Principles and Techniques—(Only one of 121 or 221 counts towards any CS degree program.) Broad technical introduction to core concepts and techniques in artificial intelligence. Topics: search, planning, constraint satisfaction, knowledge representation, probabilistic models, machine learning, neural networks, vision, robotics, and natural language understanding. Prerequisites: 103B or 103X or PHIL 160A, 106B, or 106X, and exposure to basic concepts in probability. Recommended: 107 and facility with basic differential calculus.
3-4 units, Aut (Ng)

CS 222. Knowledge Representation—Declarative knowledge representation methods in artificial intelligence. Topics: time and action, defaults, compositional modeling, object-oriented representation, inheritance, ontologies, knowledge on the web, knowledge servers, multiple views, qualitative modeling. Prerequisite: familiarity with logic. Recommended: exposure to artificial intelligence as in 121/221.
3 units, Win (Fikes)

CS 223A. Introduction to Robotics—Topics: robotics foundations in kinematics, dynamics, control, motion planning, trajectory generation, programming and design. Recommended: knowledge of matrix algebra.
3 units, Win (Khatib)

CS 223B. Introduction to Computer Vision—Fundamental issues and techniques of computer vision. Image formation, edge detection and image segmentation, stereo, motion, shape representation, recognition. Project or final.
3 units, Win (Thrun)

CS 224M. Multi-Agent Systems—For advanced undergraduates, M.S. students, and beginning Ph.D. students. Topics: logics of knowledge and belief, other logics of mental state, theories of belief change, multi-agent probabilities, essentials of game theory, social choice and mechanism design, multi-agent learning, communication. Applications are discussed where appropriate, but the emphasis is on conceptual matters and theoretical foundations. Prerequisities: knowledge of basic probability theory and first-order logic.
3 units, Win (Shoham)

CS 224N. Natural Language Processing—(Same as LINGUIST 237.) Algorithms for processing linguistic information and the underlying computational properties of natural languages. Morphological, syntactic, and semantic processing from a linguistic and an algorithmic perspective. Focus is on modern quantitative techniques in NLP: using large corpora, statistical models for acquisition, representative systems. Prerequisites: LINGUIST 138/238 or CS 121/221, and programming experience. Recommended: basic familiarity with logic and probability.
3-4 units, Spr (Manning)

CS 224S. Speech Recognition and Synthesis—(Same as LINGUIST 236.) Introduction to automatic speech recognition and speech synthesis/ text-to-speech. Focus is on key algorithms including noisy channel model, hidden Markov models (HMMs), Viterbi decoding, N-gram language modeling, unit selection synthesis, and roles of linguistic knowledge. Prerequisite: programming experience. Recommended: familiarity with probability.
2-4 units, Win (Jurafsky)

CS 225A. Experimental Robotics—Hands-on experience with robotic systems. Topics: kinematic and dynamic control of motion, compliant motion and force control, sensor-based collision avoidance, motion planning, dynamic skills, and robot-human interfaces. Limited enrollment. Prerequisite: 223A.
3 units, Spr (Khatib)

CS 225B. Robot Programming Laboratory—Hands-on introduction to the techniques of robot programming for robotics and non-robotics students. Students program mobile robots to exhibit increasingly complex behavior (simple dead reckoning and reactivity, goal-directed motion, localization, complex tasks). Topics: motor control and sensor characteristics; sensor fusion, model construction, and robust estimation; control regimes (subsumption, potential fields); active perception; reactive planning architectures;sensor-based control including vision-guided navigation. Student programmed robot contest. Programming is in C++ on Unix or Windows machines, done in teams. Prerequisites: programming skills at the level of 106B, 106X, 205, or equivalent.
3-4 units (Konolige) not given 2004-05

CS 226. Statistical Techniques in Robotics—For students seeking to develop robust robot software and those interested in real-world applications of statistical theory. Probabalistic state estimation, Bayes filters, Kalman filters, information filters, and particle filters. Simultaneous localization and mapping techniques, and multi-robot sensor fusion. Markov techniques for making decisions under uncertainty, and probabilistic control algorithms and exploration.
3 units, Spr (Thrun)

CS 227. Reasoning Methods in Artificial Intelligence—Technical presentation of algorithmic techniques for problem solving in AI. Combines formal algorithmic analysis with a description of recent applications. Topics: propositional satisfiability, constraint satisfaction, planning and scheduling, diagnosis and repair. Focus is on recent results. Prerequisites: familiarity with the basic notions in data structures and design and with techniques in the design and analysis of algorithms. Recommended: previous or concurrent course in AI.
3 units, Spr (Nayak)

CS 228. Probabilistic Models in Artificial Intelligence—Probabilistic modeling languages suitable for representing complex domains, algorithms for reasoning and decision making using these representations, and learning these representations from data. Focus is on graphical modeling languages such as Bayesian belief networks, extensions to temporal modeling using hidden Markov models and dynamic Bayesian networks, and extensions to decision making using influence diagrams and Markov decision processes. Recent applications to domains (speech recognition, medical diagnosis, data mining, statistical text modeling, and robot motion planning). Prerequisites: understanding of basic concepts in probability theory and in design and analysis.
3 units, Aut (Koller)

CS 229. Machine Learning—Topics: statistical pattern recognition, linear and non-linear regression, non-parametric methods, exponential family, GLIMs, support vector machines, kernel methods, model/feature selection, learning theory, VC dimension, clustering, density estimation, EM, dimensionality reduction, ICA, PCA, reinforcement learning and adaptive control, Markov decision processes, approximate dynamic programming, and policy search. Prerequisites: linear algebra, and basic probability and statistics.
3 units, Aut (Ng)

CS 237. Advanced Numerical Analysis—Three quarter graduate sequence designed to acquaint students in mathematical and physical sciences and engineering with the theory of numerical analysis. Examples from applications.

CS 237A. Numerical Linear Algebra—(Same as CME 302.) First in a three quarter graduate sequence. Solution of systems of linear equations: direct methods, error analysis, structured matrices; iterative methods and least squares. Parallel techniques. Prerequisites: CS 137, MATH 103 or 113.
3 units, Aut (Golub)

CS 237B. Numerical Solution of Partial Differential Equations I—Linear multistep methods and Runge-Kutta methods for ordinary differential equations: zero-stability, A-stability, and convergence. Elliptic partial differential equations: finite difference, finite element, and spectral methods. Parabolic partial differential equations: stability, convergence, explicit and implicit time integration. Prerequisites: 205 or 237A; MATH 130, 131; or equivalents.
3 units (Staff) not given 2004-05

CS 237C. Numerical Solution of Partial Differential Equations—(Same as CME 306.) Hyperbolic partial differential equations: stability, convergence and qualitative properties. Nonlinear hyperbolic equations and systems. Combined solution methods from elliptic, parabolic, and hyperbolic problems. Examples include: Burgers equation, Euler equations for compressible flow, Navier Stokes equations for incompressible flow. Prerequisites: CS 205, or 237A,B; MATH 130, 131; or equivalents.
3 units, Spr (Fedkiw)

CS 238. Parallel Methods in Numerical Analysis—(Same as CME 342.) Emphasis is on techniques for obtaining maximum parallelism in numerical algorithms, especially those occurring when solving matrix problems and partial differential equations, and the subsequent mapping onto the computer. Implementation issues on parallel computers. Topics: parallel architecture, programming models, matrix computations, FFT, fast multiple methods, domain decomposition, and graph partitioning. Prerequisite: CS 237A or CME 200 (formerly ME 300A), or consent of instructor. Recommended: familiarity with differential equations, and advanced programming language such as C or C++.
3 units, Spr (Alonso)

CS 240. Advanced Topics in Operating Systems—OS topics and recent developments in OS research. Classic and new papers. Topics: virtual memory management, synchronization and communication, file systems, protection and security, operating system extension techniques, fault tolerance, and the history and experience of systems programming. Prerequisite: 140 or equivalent.
3 units, Win, Spr (Engler)

CS 241. Internet Technologies and Systems—Architecture, design, and implementation of Internet-scale services and applications. Scalability, high availability, fault tolerance, and robustness for Internet services. Cluster-based runtime systems for Internet workloads, implementation and deployment challenges, economics of deploying and operating a service. Extending Internet services to mobile, wireless, and post-PC computing devices. Service-centric view of the Internet, including composition of services and mass customization. Research agenda for Internet-scale services. Programming assignments building and deploying Internet service prototypes. Prerequisites: 193I or equivalent experience; 240 and 244A.
3 units, Spr (Fox)

CS 242. Programming Languages—Basic elements and programming paradigms: functional, imperative, and object-oriented. Formal semantic methods. Modern type systems, higher-order functions and closure, exceptions and continuations. Runtime support for different language features. Emphasis is on separating the different elements of programming languages and styles. First half uses Lisp and ML to illustrate concepts; second half a selection of object-oriented languages. Prerequisite: 107, or experience with Lisp, C, and some object-oriented language.
3 units, Aut (Mitchell)

CS 243. Advanced Compiling Techniques—The theoretical and practical aspects of building modem compilers. Topics: intermediate representations, basic blocks and flow-graphs, data flow analysis, register allocation, global code optimizations, and interprocedural analysis. Prerequisite: 143 or equivalent.
3-4 units, Win (Staff)

CS 244A. Introduction to Computer Networks—Packet switching; the Internet architecture; routing; router architecture; flow control algorithms; retransmission algorithms; congestion control, TCP/IP; detecting and recovering from errors; switching; Ethernet (wired and wireless) and local area networks; physical layers; clocking and synchronization. Assignments introduce network programming, including sockets, designing a router and implementing a transport layer. EE284 is an alternate class, with less emphasis on programming. Students should not take both EE284 and CS244A. Prerequisite: 140 or equivalent.
3-4 units, Win (McKeown)

CS 244B. Distributed Systems—Distributed operating systems and applications issues, emphasizing high-level protocols and distributed state sharing as the key technologies. Topics: distributed shared memory, object-oriented distributed system design, distributed directory services, atomic transactions and time synchronization, file access, process scheduling, process migration and remote procedure call focusing on distribution, scale, robustness in the face of failure, and security. Prerequisites: 244A, 249.
3 units, Spr (Cheriton)

CS 244C. Distributed Systems Project—Companion project option for students taking 244B. Corequisite: 244B.
3-6 units, Spr (Cheriton)

CS 245. Database Systems Principles—File organization and access, buffer management, performance analysis, and storage management. Database system architecture, query optimization, transaction management, recovery, concurrency control. Reliability, protection, and integrity. Design and management issues. Prerequisites: 145, 161.
3 units, Win (Garcia-Molina)

CS 246. Information Integration—How to solve the problem of accessing structured data on the Internet which is complicated by conceptual heterogeneity among the data sources including differences in structure and vocabulary. Topics: notations and models for structured data such as XML and RDF; information integration techniques; standard schemas and vocabularies; data structuring technology; and applications such as corporate logistics, e-commerce, civil engineering, and health care. Large-scale datawebs and prospects for building a fully integrated semantic web, essentially a web for databases. Prerequisites: 145, 157.
3 units (Genesereth) not given 2004-05

CS 247A. Human-Computer Interaction: Interaction Design Studio—Intended as preparation for project-based courses such as 377 or 447. Systematic presentation and experience with methods used in interaction design including needs analysis, user observation, idea sketching, concept generation, scenario building, storyboards, user character stereotypes, usability analysis, and market strategies. Prerequisite: 147 or ME 101.
3-4 units, Win (Klemmer)

CS 247B. Contextual and Organizational Issues in Human-Computer Interaction—(Same as MS&E 430.) Focus is on the contextual issues associated with designing and using computer interfaces and technology, providing insights into, experience with, and ways of understanding issues in work and consumer settings that influence the design of computer interfaces. Student team projects develop skills in: observing individuals and groups of people in context, using models of work and other activity to extend their design capabilities, identifying constraints and tradeoffs on designs within the context of use, and observing and working with people in interdisciplinary design groups. Enrollment limited. Prerequisite: 247A; those whose program of study is closely related to HCI admitted, space permitting.
3-4 units, Spr (Hinds)

CS 248. Introduction to Computer Graphics—(Only one of 148 or 248 counts towards any CS degree program.) The fundamentals of input and display devices, scan conversion of geometric primitives, 2D and 3D geometric transformations, clipping and windowing, scene modeling and animation, algorithms for visible surface determination, introduction to local and global shading models, color, and real-time rendering methods. Written assignments and programming projects. Prerequisites: 107, MATH 103 or equivalent.
3-5 units, Aut (Levoy)

CS 249. Object-Oriented Programming from a Modeling and Simulation Perspective—Topics: large-scale software development approaches, encapsulation, use of inheritance and dynamic dispatch, design of interfaces and interface/implementation separation, exception handling, design patterns, minimalizing dependencies and value-oriented programming. The role of programming conventions, style, and restrictions in surviving object-oriented programming for class libraries, frameworks, and programming-in-the-large; general techniques for object-oriented programming. Prerequisites: C; basic programming methodology as in 106B or X; 107; C++ (may be taken concurrently). Recommended: 193D.
3 units, Aut (Cheriton)

CS 255. Introduction to Cryptography—For advanced undergraduates and graduate students. Basic theory and practice of cryptographic techniques used in computer security. Topics: encryption (single and double key), digital signatures, pseudo-random bit generation, authentication, electronic commerce (anonymous cash, micropayments), key management, PKI, zero-knowledge protocols. Prerequisite: basic probability theory.
3 units, Win (Boneh)

CS 256. Formal Methods for Reactive Systems—Formal methods for specification, verification, and development of concurrent and reactive programs. Reactive systems: syntax and semantics, fairness requirements. Specification language: temporal formulas (state, future, and past) and omega-automata. Hierarchy of program properties: safety, guarantee, obligation, response, persistence, and reactivity. Invariant generation. Deductive verification of programs: verification diagrams and rules, completeness. Modularity. Parameterized programs. Algorithmic verification of finite-state programs (model checking). Prerequisite: 157 or PHIL 160A, or equivalent.
3 units, Win (Manna)

CS 256L. Formal Methods for Reactive Systems Laboratory
2 units, Win (Manna)

CS 258. Introduction to Programming Language Theory—Syntactic, operational, and semantic issues in the mathematical analysis of programming languages. Type systems and non-context-free syntax. Universal algebra and algebraic data types. Operational semantics given by rewrite rules; confluence and termination. Scott-semantics for languages with higher-type functions and recursion. Treatment of side-effects. Prerequisites: 154, 157 or PHIL 160A.
3 units, Win (Mitchell)

CS 259. Security Protocols—Hands-on experience in formal methods to verify and evaluate cryptographic protocols and secure systems. Common security protocols and their properties including secrecy, authentication, key establishment, and fairness. Topics: standard formal models and tools used in security protocol analysis; their advantages and limitations. Fully automated, finite-state, model-checking techniques.

Constraint solving, process algebras, protocol logics, probabilistic model checking, and game theory. Students select a protocol or secure system to analyze, specify it in the chosen model, use a formal analysis tool to verify the properties, and present findings.

3 units (Mitchell) not given 2004-05

CS 261. Optimization and Algorithmic Paradigms—Algorithms for network optimization: max-flow, min-cost flow, matching, assignment, and min-cut problems. Introduction to linear programming. Use of LP duality for design and analysis of algorithms. Approximation algorithms for NP-complete problems such as Steiner Trees, Traveling Salesman, and scheduling problems. Randomized algorithms. Introduction to online algorithms.

3 units, Win (Plotkin)

CS 262. Computational Genomics—(Same as BIOMEDIN 262.) Applications of computer science to genomics, and concepts in genomics from a computer science point of view. Topics: dynamic programming, sequence alignments, hidden Markov models, Gibbs sampling, and probabilistic context-free grammars. Applications of these tools to sequence analysis: comparative genomics, DNA sequencing and assembly, genomic annotation of repeats, genes, and regulatory sequences, microarrays and gene expression, phylogeny and molecular evolution, and RNA structure. Prerequisites: 161 or familiarity with basic algorithmic concepts. Recommended: basic knowledge of genetics.

3 units, Win (Batzoglou)

CS 270. Introduction to Biomedical Informatics: Fundamental Methods—(Same as BIOMEDIN 210.) Issues in the modeling, design, and implementation of computational systems for use in biomedicine. Topics: basic knowledge representation, controlled terminologies in medicine and biological science, fundamental algorithms, information dissemination and retrieval, knowledge acquisition, and ontologies. Emphasis is on the principles of modeling data and knowledge in biomedicine and on translation of resulting models into useful automated systems. Recommended: understanding of the basic principles of object-oriented systems at the level of CS 107.

3 units, Aut (Musen)

CS 271. Introduction to Biomedical Systems—(Same as BIOMEDIN 211.) Focus is on information systems and decision-support technology. System requirements, data, standards, algorithms, and implementation issues. Prerequisite: BIOMEDIN 210.

1-3 units, Win (Das)

CS 272. Biomedical Informatics Project Course—(Same as BIOMEDIN 212.) Hands-on software building. Students conceive, design, specify, implement, evaluate, and report on a software project in the domain of biomedicine. Focus is on pragmatics of creating written proposals, providing status reports, and preparing final reports. Introductory-level aspects of software engineering such as version control, UML, and testing. Prerequisites: BIOMEDIN 210 or 214, or consent of instructor; CS 106.

3 units, Aut (Altman, Cheng, Klein)

CS 273. Algorithms for Structure and Motion in Biology—Algorithms motivated by challenges in predicting molecule properties in silico. Topics: geometric and kinematic models of biomolecules (proteins, ligands), conformation spaces, obtention of structure from experimental data, finding sequence and structural similarities, molecular surfaces and shape analysis, energy calculation, detection of steric clashes and proximity computation, conformation sampling, threading, and study folding and binding motions.

3 units, Spr (Batzoglou, Latombe)

CS 274. Representations and Algorithms for Computational Molecular Biology—(Same as BIOE 214, BIOMEDIN 214.) Topics: algorithms for alignment of biological sequences and structures, computing with strings, phylogenetic tree construction, hidden Markov models, computing with networks of genes, basic structural computations on proteins, protein structure prediction, protein threading techniques, homology modeling, molecular dynamics and energy minimization, statistical analysis of 3D biological data, integration of data sources, knowledge representation and controlled terminologies for molecular biology, graphical display of biological data, and genetic algorithms and programming applied to biological problems. Prerequisites: programming skills and matrix algebra.

4 units, Spr (Altman)

CS 275A. Musical Information: An Introduction—(Enroll in MUSIC 253.)

1-4 units, Win (Selfridge-Field)

CS 275B. Applications of Musical Information: Query, Analysis, and Style Simulation—(Enroll in MUSIC 254.)

1-4 units, Spr (Selfridge-Field)

CS 276A. Text Retrieval and Mining—Text information retrieval systems; efficient text indexing; Boolean, vector space, and probabilistic retrieval models; ranking and rank aggregation; evaluating IR systems. Text clustering and classification methods: Latent semantic indexing, taxonomy induction, cluster labeling; classification algorithms and their evaluation, text filtering and routing.

3 units, Aut (Manning, Raghavan)

CS 276B. Web Search and Mining—Advanced topics and project in information retrieval. Web search engines including crawling and indexing, link-based algorithms, and web metadata. Collaborative filtering and recommender systems. Text-centric XML indexing and ranked retrieval. User interfaces for IR. Students work in teams to implement a project of their choosing. Prerequisite: CS 276A.

3 units, Win (Manning, Raghavan)

CS 277. Experimental Haptics—Haptics as it relates to creating touch feedback in simulated or virtualized environments. Goal is to develop virtual reality haptic simulators and applications. Theoretical topics: psychophysical issues, performance and design of haptic interfaces, haptic rendering methods for 3-D virtual environments, and haptic simulation and rendering of rigid and deformable solids. Applied topics: introduction to C++Builder, Open GL and basic haptic library, implementation of haptic rendering algorithms, collision detection in 3-D environments, design of real-time models for soft tissue simulation. Guest speakers. Lab/programming exercises; a more open-ended final project. Enrollment limited to 20. Prerequisite: 145. Recommended: 223.

3 units, Spr (Salisbury)

CS 294. Research Project in Artificial Intelligence—Focus is on a major challenge problem in artificial intelligence. Students form teams to work under faculty supervision on a significant research and implementation project. Lectures on state-of-the-art AI methods and good software design practices for large projects. Prerequisites: course from 200-level AI series, and consent of instructor.

CS 294. DARPA Grand Challenge—Goal is to develop an entry into the DARPA Grand Challenge to build a ground vehicle that can drive autonomously from Los Angeles to Las Vegas. $2 million award to winner; success requires major advances in core problems in artificial intelligence including robotic perception and high-speed control. Focus is on team-based design, development, implementation, and evaluation of cutting-edge AI algorithms in the context of the Grand Challenge. Classes in basic AI algorithms, system design, and methodology. Limited enrollment.

3 units, Aut (Thrun)

CS 294W. Writing Intensive Research Project in Artificial Intelligence—Restricted to Computer Science and Computer Systems Engineering undergraduates. Register for only one of 294 or 294W. WIM

3 units, Aut (Thrun)

CS 295. Software Engineering—Software specification, testing, and verification. Emphasis is on current best practices and technology for developing reliable software at reasonable cost. Assignments focus on applying these techniques to realistic software systems. Prerequisites: 108. Recommended a project course such as 140, 143, or 145. GER:2b

3 units, Spr (Aiken)

CS 298. Seminar on Teaching Introductory Computer Science—Faculty, undergraduates, and graduate students interested in teaching discuss topics raised by teaching computer science at the introductory level. Prerequisite: consent of instructor.

1-3 units, Aut (Roberts)

PRIMARILY FOR GRADUATE STUDENTS

CS 300. Departmental Lecture Series—For first-year Computer Science Ph.D. students. Presentations by members of the department faculty, each describing informally his or her current research interests and views of computer science as a whole. (AU)

1 unit, Aut (Motwani)

CS 315A. Parallel Computer Architecture and Programming—The principles and tradeoffs in the design of parallel architectures. Emphasis is on naming, latency, bandwidth, and synchronization in parallel machines. Case studies on shared memory, message passing, data flow, and data parallel machines illustrate techniques. Architectural studies and lectures on techniques for programming parallel computers. Programming assignments on one or more commercial multiprocessors. Prerequisites: EE 282, and reasonable programming experience.

3 units, Spr (Olukotun)

CS 316A. Logic Synthesis of VLSI Circuits—(Enroll in EE 318.)

3 units, Win (DeMicheli)

CS 316B. Computer-Aided System Design Laboratory—(Enroll in EE 319.)

3 units, Spr (DeMicheli)

CS 319. Topics in Digital Systems—Advanced material is often taught for the first time as a topics course, perhaps by a faculty member visiting from another institution. Students may therefore enroll repeatedly in a course with this number. See *Time Schedule* for current topics.

3 units, by arrangement (Staff)

CS 323. Common Sense Reasoning in Logic—Formalizing common sense knowledge and reasoning using situation calculus with nonmonotonic logics, especially circumscription. Variations of situation calculus. Formalizing context. Formalizing facts about knowledge. Prerequisite: basic knowledge of logic such as 157, or PHIL 160A.

3 units (McCarthy) not given 2004-05

CS 324. Computer Science and Game Theory—Interactions among game theory, complexity, and algorithms. Topics vary but may include: complexity of finding a Nash equilibrium and other solution concepts in game theory (non-cooperative and coalitional); algorithms for finding such solution concepts; bounded rationality or the impact on solution concepts of assuming computational limitations and players; and specialized topics such as algorithmic issues in combinatorial auctions.

3 units (Shoham) not given 2004-05

CS 326A. Motion Planning—For students interested in computer graphics, geometrical computing, robotics, and/or artificial intelligence. Computing object motions is central to many application domains (e.g., design, manufacturing, robotics, animated graphics, medical surgery, drug design). Basic path planning methods generate collision-free paths among static obstacles. Extensions include uncertainty, mobile obstacles, manipulating movable objects, and maneuvering with kinematic constraints. Configuration space is a unifying concept, geometric arrangements are a basic combinatorial structure. Theoretical methods with applications in various domains: assembly planning, radiosurgery, graphic animation of human figures.

3 units (Latombe) not given 2004-05

CS 327A. Advanced Robotics—Emerging areas of human-centered robotics and interactive haptic simulation of virtual environments. Topics: redundancy; task-oriented dynamics and control, whole-body control-task and posture decomposition, cooperative robots, haptics and simulation, haptically augmented teleoperation, human-friendly robot design. Prerequisites: 223A or equivalent.

3 units, Spr (Khatib)

CS 329. Topics in Artificial Intelligence—Advanced material is often taught for the first time as a topics course, perhaps by a faculty member visiting from another institution. Students may therefore enroll repeatedly in a course with this number.

3 units, by arrangement (Staff)

CS 336. Advanced Methods in Matrix Computation—(Same as CME 324.) Eigenvalue problems: perturbation theory, Lanczos method, Jacobi method. Parallel implementation. Singular value problems. Generalized eigenvalue problems. Polynomial equations. Prerequisite: CS 237A.

3 units, Spr (Golub)

CS 337. Numerical Methods for Initial Boundary Value Problems—(Same as CME 326.) Initial boundary value problems are solved in different areas of engineering and science modeling phenomena, such as wave propagation and vibration, and fluid flow. Numerical techniques for such simulations in the context of applications. Emphasis is on stability and convergence theory for methods for hyperbolic and parabolic initial boundary value problems, and the development of efficient methods for these problems.

3 units, Win (Gustaffson)

CS 339. Topics in Numerical Analysis—Advanced material is often taught for the first time as a topics course, perhaps by a faculty member visiting from another institution. Students may enroll repeatedly in a course with this number. See *Time Schedule* for current topics.

3 units, by arrangement (Staff)

CS 340. Level Set Methods—Introduction to modeling surfaces with implicit functions. Focus is on the mathematical and computational techniques required to treat dynamic implicit surfaces. Level set methods can be used for a variety of applications including multiphase flow (such as bubbles and drops), image processing, computer vision, and graphics.

3 units, Win (Fedkiw)

CS 343. Advanced Topics in Compilers—Topics change every quarter. May be repeated for credit. Prerequisite: 243.

3 units (Lam) not given 2004-05

CS 344. Projects in Computer Networks—Hands-on experience designing the hardware and software that makes up the Internet infrastructure. Small teams complete three design projects such as: implementing a working Ethernet switch in Verilog (using the NetFPGA platform developed for this class) and then debugging the switch in an operational network; or extending an Ethernet switch to be an Internet router. Projects also include software components such as developing and implementing routing protocols on the Virtual Network System (developed for and used in CS 244A). Enrollment limited to 20. Prerequisites: CS 244A/EE 284, and experience with Verilog and hardware design.

3 units, Spr (McKeown)

CS 345. Topics in Data Warehousing—Content varies. May be repeated for credit with instructor consent. Prerequisite: 145. Recommended: 245.

3 units, Aut (Babcock)

CS 346. Database System Implementation—A major database system implementation project realizes the principles and techniques covered in earlier courses. Students independently build a complete database management system, from file structures through query processing, with a personally designed feature or extension. Lectures on project details and advanced techniques in database system implementation, focusing on query processing and optimization. Guest speakers from industry on commercial DBMS implementation techniques. Prerequisites: 145, 245, programming experience in C++.

3-5 units, Spr (Widom)

CS 347. Transaction Processing and Distributed Databases—The principles and system organization of distributed databases. Data fragmentation and distribution, distributed database design, query processing and optimization, distributed concurrency control, reliability and commit protocols, and replicated data management. Distributed algorithms for data management: clocks, deadlock detection, and mutual exclusion. Heterogeneous and federated distributed database systems. Overview of commercial systems and research prototypes. Prerequisites: 145, 245.
3 units, Spr (Garcia-Molina)

CS 348A. Computer Graphics: Geometric Modeling—The mathematical tools needed for the geometrical aspects of computer graphics and especially for modeling smooth shapes. Fundamentals: homogeneous coordinates, transformations, and perspective. Theory of parametric and implicit curve and surface models: polar forms, Bezier arcs and de Casteljau subdivision, continuity constraints, B-splines, tensor product, and triangular patch surfaces. Subdivision surfaces and multiresolution representations of geometry. Representations of solids and conversions among them. Mesh generation, simplification, and compression. Prerequisites: linear algebra and discrete algorithms.
3-4 units, Win (Guibas)

CS 348B. Computer Graphics: Image Synthesis Techniques—Intermediate level, emphasizing the sampling, shading, and display aspects of computer graphics. Topics: local and global illumination methods including radiosity and distributed ray tracing, texture generation and rendering, volume rendering, strategies for anti-aliasing and photo-realism, human vision and color science as they relate to computer displays, and high-performance architectures for graphics. Written assignments and programming projects. Prerequisite: 248 or equivalent. Recommended: exposure to Fourier analysis or digital signal processing.
3-4 units, Spr (Hanrahan)

CS 349. Topics in Programming Systems—Advanced material is often taught for the first time as a topics course, perhaps by a faculty member visiting from another institution. Students may enroll repeatedly in a course with this number. See *Time Schedule* for topics currently being offered.

CS 349. Advanced Topics in Object-Oriented Programming—Topics: software development processes and methodologies; invasive versus non-invasive implementations techniques; specialized memory management; audit; logging; value-type design; type structure of programs; concurrency models and their impact on encapsulation; large-scale software development disciplines and strategies; testing and design methodologies; role of specifications; semantics mechanisms; models; meta-programming and templates; design patterns; distributed object systems; and case studies of large-scale design.
3 units, Win (Cheriton)

CS 351. Topics in Complexity Theory and Lower Bounds—Focus is on one of basic machine models and complexity measures, their properties and relationships; complexity classes and their properties; reductions and complete problems; concrete representative problems from important complexity classes. Techniques for establishing limits on the possible efficiency of algorithms, and concrete lower bounds based on the following models of computation: decision trees, straight line programs, communication games, branching programs, PRAMs, boolean circuits. Approximation algorithms and the complexity of approximations. Pseudo-randomness and cryptography. Prerequisite: 154, or equivalent.
3 units (Motwani) not given 2004-05

CS 353. Algebraic Logic—Algebraic methods relevant to computer science. Lattice theory: partial orders, monoids, closure systems, topologies, fixpoint theorems. Universal algebra: HSP, free algebras, equational theories, Birkhoff's theorem, completeness of equational logic. Algebras for logic: Boolean, Heyting, cylindric. Categories: limits, adjunctions, algebraic theories, monads. Prerequisites: 157 or PHIL 160A, 161; or equivalents.
3 units (Pratt) not given 2004-05

CS 355. Advanced Topics in Cryptography—Topics: pseudo-random generation, zero knowledge protocols, elliptic curve systems, threshold cryptography, security analysis using random oracles, lower and upper bounds on factoring and discrete log. Prerequisite: 255.
3 units, Aut (Boneh)

CS 356. Automatic Formal Verification Techniques—Automatic methods for formally verifying hardware, protocol, and software system designs. Topics: state graph and automata models of system behavior; automata on infinite strings; linear and branching-time temporal logic; model-checking; modeling real-time systems. Analysis methods based on Boolean formulas, and other ways of coping with the state explosion problem; exploiting abstractions. Applications to circuits, algorithms, and protocols. Case studies use verification tools. Prerequisite: 154 or 254. Recommended: good understanding of basic automata and complexity theory.
3 units, Spr (Dill)

CS 357. Advanced Topics in Formal Methods—Topics vary annually. Possible topics include automata on infinite words, static analysis methods, verification of real-time and hybrid systems, and verification diagrams. May be repeated for credit. Prerequisite: 256.
3 units, Spr (Manna, Sipma)

CS 357C. Automata on Infinite Objects—Topics: automata on infinite words (Buchi, Muller, Rabin automata); automata on infinite trees; alternating automata on infinite words and trees; relationship with linear-time and branching time logics; relationship with monadic second-order logics; complexity and decidability issues; applications to verification and synthesis of reactive programs; applications to game theory.
3 units (Manna, Sipma) not given 2004-05

CS 359. Topics in the Theory of Computation—Advanced material is often taught for the first time as a topics course, perhaps by a faculty member visiting from another institution. Students may therefore enroll repeatedly in a course with this number. See Time Schedule for topics currently being offered.
3 units (Staff) not given 2004-05

CS 361A. Advanced Algorithms—Advanced data structures: union-find, self-adjusting data structures and amortized analysis, dynamic trees, Fibonacci heaps, universal hash function and sparse hash tables, persistent data structures. Advanced combinatorial algorithms: algebraic (matrix and polynomial) algorithms, number theoretic algorithms, group theoretic algorithms and graph isomorphism, online algorithms and competitive analysis, strings and pattern matching, heuristic and probabilistic analysis (TSP, satisfiability, cliques, colorings), local search algorithms. Prerequisite: 161 or 261, or equivalents.
3 units (Motwani) not given 2004-05

CS 361B. Advanced Algorithms—Topics: fundamental techniques used in the development of exact and approximate algorithms for combinational optimization problems, e.g., generalized flow, multicommodity flow, sparsest cuts, generalized Steiner trees, load balancing, and scheduling. Using linear programming, emphasis is on LP duality for design and analysis of approximation algorithms; interior point methods for LP. Techniques for development of strongly polynomial algorithms.
3 units (Plotkin) not given 2004-05

CS 364A. Algorithmic Game Theory—Topics on theoretical computer science and game theory, such as: auctions; congestion and potential games; cost sharing; existence and computation of equilibria; game theory in the Internet; mechanism design; network games; price of anarchy; pricing; and selfish routing. Minimal overlap with 224M and 324. Prerequisites: 154N and 161, or equivalent.
3 units, Aut (Roughgarden)

CS 364B. Topics in Algorithmic Game Theory—Further exploration of topics from 364A. Students work on a research problem related to the course. May be taken prior to 364A; may be repeated for credit. Prerequisites: 154N and 161, or equivalent.
3 units (Roughgarden) not given 2004-05

CS 365. Randomized Algorithms—Design and analysis of algorithms that use randomness to guide their computations. Basic tools, from probability theory and probabilistic analysis, that are recurrent in algorithmic applications. Randomized complexity theory and game-theoretic techniques. Algebraic techniques. Probability amplification and derandomization. Applications: sorting and searching, data structures, combinatorial optimization and graph algorithms, geometric algorithms and linear programming, approximation and counting problems, parallel and distributed algorithms, online algorithms, number-theoretic algorithms. Prerequisites: 161 or 261, STATS 116, or equivalents.
3 units, Aut (Motwani)

CS 368. Geometric Algorithms—Graduate-level introduction to the techniques in the design and analysis of efficient geometric algorithms including: convexity, triangulation, sweeping, partitioning, and point location. Voronoi and Delaunay diagrams. Arrangements and convex polytopes. Intersection and visibility problems. Geometric searching and optimization. Random sampling methods. Impact of numerical issues in geometric computation. Example applications to robotic motion planning, visibility preprocessing in graphics, model-based recognition in computer vision, and structural molecular biology. Prerequisite: 161.
3 units, Spr (Guibas)

CS 369. Topics in Analysis of Algorithms—Advanced material is often taught for the first time as a topics course, perhaps by a faculty member visiting from another institution. Students may enroll repeatedly in a course with this number. See *Time Schedule* for current topics.

CS 369. Combinatorial Optimization—Emphasis is on development of approximation algorithms. Possible topics: facility location, generalized Steiner tree and primal-dual algorithms, K-MST, but-at-bulk and access network design problems, and online scheduling and routing. Prerequisite: CS 261 or equivalent.
3 units, Spr (Plotkin)

CS 374. Algorithms in Biology—(Same as BIOMEDIN 374.) Algorithms and computational models applied to molecular biology and genetics. Topics vary annually. Possible topics include biological sequence comparison, annotation of genes and other functional elements, molecular evolution, genome rearrangements, microarrays and gene regulation, protein folding and classification, molecular docking, RNA secondary structure, DNA computing, and self-assembly. May be repeated for credit. Prerequisites: 161, 262 or 274, or BIOCHEM 218, or equivalents.
2-3 units, Aut (Batzoglou)

CS 376. Research Topics in Human-Computer Interaction—Seminal work on interaction techniques and the design, prototyping, and evaluation of user interfaces. Topics: computer-supported cooperative work; audio, speech, and multimodal interfaces; user interface toolkits; design methods; evaluation methods; ubiquitous and context-aware computing; tangible interfaces; haptic interaction; and mobile interfaces.
3 units, Aut (Klemmer)

CS 377. Topics in Human-Computer Interaction—Contents change each quarter. May be repeated for credit. See http://hci.stanford.edu/courses/ for specific offerings.
2-3 units, Aut, Win, Spr (Staff)

CS 377X. Spoken Dialogue Systems—(Enroll in LINGUIST 239S, SYMBSYS 121K/221K.)
2-4 units, Aut (Byrne, Cohen)

CS 378. Phenomenological Foundations of Cognition, Language, and Computation—Critical analysis of theoretical foundations of the cognitive approach to language, thought, and computation. Contrasts of the rationalistic assumptions of current linguistics and artificial intelligence with alternatives from phenomenology, theoretical biology, critical literary theory, and socially-oriented speech act theory. Emphasis is on the relevance of theoretical orientation to the design, implementation, and impact of computer systems as it affects human-computer interaction. GER:2b
3-4 units, Spr (Winograd)

CS 379. Interdisciplinary Topics—Advanced material that relates computer science to other disciplines is often taught for the first time as a topics course, perhaps by a faculty member visiting from another institution. Students may therefore enroll repeatedly in a course with this number. See *Time Schedule* for current topics.
1-3 units, by arrangement (Staff)

CS 390A,B,C. Curricular Practical Training—Educational opportunities in high technology research and development labs in the computing industry. Qualified computer science students engage in internship work and integrate that work into their academic program. Students register during the quarter they are employed and must complete a research report outlining work activity, problems investigated, results, and follow-on projects they expect to perform. 390 A,B,C may each be taken only once.
1 unit, Aut, Win, Spr, Sum (Motwani)

CS 393. Computer Laboratory—For CS graduate students. A substantial computer program is designed and implemented; written report required. Recommended as a preparation for dissertation research. Register using the section number associated with the instructor. Prerequisite: consent of instructor.
1-9 units, Aut, Win, Spr, Sum (Staff)

CS 395. Independent Database Project—For graduate students in Computer Science. Use of database management or file systems for a substantial application or implementation of components of database management system. Written analysis and evaluation required. Register using the section number associated with the instructor. Prerequisite: consent of instructor.
1-6 units, Aut, Win, Spr, Sum (Staff)

CS 399. Independent Project—Letter grade only.
1-9 units, Aut, Win, Spr, Sum (Staff)

CS 399P. Independent Project—Graded satisfactory/no credit.
1-9 units, Aut, Win, Spr, Sum (Staff)

EXPERIMENTAL

CS 428. Information Processing for Sensor Networks—Literature and issues in designing and analyzing sensor network information processing applications. Localization and tracking as canonical examples to expose constraints in scaling and deploying sensor networks. Topics include querying, data routing, in-network processing, distributed estimation, power management, and network self-organization. How these base capabilities support high-level information processing tasks.
2 units, Spr (Guibas)

CS 444A. Principles of Dependable Computer Systems—The design of software systems with high dependability requirements; emphasis is on large scale distributed systems and Internet services. Topics: high availability, fault tolerance, monitoring, detection, diagnosis, confinement, fast recovery, graceful service degradation, voting and distributed agreement algorithms, redundancy and replication. The limitations of reliable software, the impact of scale on availability, how to cope with human error, dependability evaluation metrics. Assignments apply these principles to real systems. Prerequisites: 240, 244B.
2-4 units, Aut (Fox)

CS 447. Interdisciplinary Interaction Design—(Same as ME 325.) Small teams develop technology prototypes combining product and interaction design. Focus is on software and hardware interfaces, interaction, design aesthetics, and underpinnings of successful design including a reflective, interactive design process, group dynamics of interdisciplinary teamwork, and working with users. Prerequisite: CS 247A.
3-4 units, Win (Kelley, Winograd)

CS 448. Topics in Computer Graphics—Topics may include exotic input and display technologies, graphics architectures, modeling shape and motion, experiments in digital television, interactive workplaces, introduction to hand-drawn cartoon animation. Readings and a project. May be repeated for credit. See http://graphics.stanford.edu/courses/ for specific offerings. Prerequisite: 248 or consent of instructor.
3-4 units, by arrangement (Staff)

CS 468. Topics in Geometric Algorithms—Recent offerings include: shape matching, proximity and nearest-neighbor problems, visibility and motion planning, collision detection, and computational topology. Readings from the literature and a presentation or a project may be required. May be repeated for credit. Prerequisite: 368, or consent of instructor.
2 units, Win (Guibas)

CS 471. E-Business Process Foundry—Project-based. Crossdisciplinary teams from Computer Science and Graduate School of Business produce prototypes of operating business processes that utilize web technologies. Small project teams make regular presentations and progress reports to the class and industry experts. Each team includes individuals with technical knowledge of databases, scripting languages, web services, and business knowledge of the non-virtual processes that provide real goods and services. Past teams have successfully implemented prototype systems in daily use by existing nonprofit organizations.
4 units (Fox, Patell) not given 2004-05

CS 499. Advanced Reading and Research—For CS graduate students. Register using the section number associated with the instructor. Prerequisite: consent of instructor.
1-15 units, Aut, Win, Spr, Sum (Staff)

GRADUATE SEMINARS

CS 510. Digital Systems Reliability Seminar—(Enroll in EE 385A.)
1-4 units, Aut, Win, Spr, Sum (McCluskey)

CS 525. Knowledge Acquisition for Expert Systems—(Same as BIOMEDIN 230.) Experimental approaches to the construction of expert-system knowledge bases. Topics: interviewing techniques, formal and informal approaches to modeling expert knowledge, and automated tools that facilitate knowledge acquisition. Enrollment limited to 20. Prerequisite: course in artificial intelligence.
2 units, Spr (Musen)

CS 528. Broad Area Colloquium for Artificial Intelligence, Geometry, Graphics, Robotics, and Vision—Weekly series of informal research talks on topics related to perceiving, modeling, manipulating, and displaying the physical world. The computational models and numerical methods underlying these topics. Brings together faculty and students in these five closely related areas.
1 unit, Aut, Win, Spr (Thrun)

CS 531. Numerical Analysis/Scientific Computing Seminar
1 unit, Aut, Win, Spr (Golub)

CS 540. Seminar on Computer Systems—(Enroll in EE 380.)
1 unit, Aut, Win, Spr (Allison)

CS 545. Database Research Seminar—Current research and industrial innovation in the area of database and information systems.
1 unit, Win (Wiederhold)

CS 545G. Genome Database Seminar—(Same as BIOMEDIN 345.) Principles and methodologies for databases that encode molecular biology information including DNA sequences, protein sequence and structure, gene expression, and metabolic and other functional genomics data. Representation and integration of data sources, and presentation for biomedical and pharmaceutical researchers. Issues: data structures and ontologies, cross-referencing, quality control and error detection, search processes, suitability of DBMSs, data provenance, and privacy protection for patient-derived information. Presentations by experts from commercial and research organizations. May be combined with a 395 project.
1 unit (Wiederhold) not given 2004-05

CS 547. Human-Computer Interaction Seminar—Weekly speakers on topics related to human-computer interaction design. (AU)
1 unit, Aut, Win, Spr (Winograd)

CS 548. Stanford Networking Research Center, and Internet and Distributed Systems Seminar—Recent research in distributed operating systems, computer communications, parallel machines, parallel programming, and distributed applications. Invited speakers from Stanford and elsewhere present topics and results of current interest. (AU)
1 unit, Spr (Fox)

CS 579. Frontiers in Interdisciplinary Biosciences—(Crosslisted in departments in the schools of H&S, Engineering, and Medicine; student register through their affiliated departments; otherwise register for CHEMENG 459.) See CHEMENG 459 or http://biox.stanford.edu/courses/459_announce.html.
1 unit, Aut, Win, Spr (Robertson)