SCHOOL OF ENGINEERING

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Faculty Teaching General Engineering Courses

Professors: Mark R. Cutkosky, Charbel Farhat, Roger T. Howe, Larry Leifer, Drew Nelson, Brad Osgood, Channing R. Robertson, Stephen M. Rock, Bernard Roth, Sheri Sheppard, Robert Sinclair, Simon Wong

Associate Professors: Samuel S. Chiu, Christopher Edwards, Ashish Goel, Sanjay Lall, Paul McIntyre, Reginald Mitchell, Olav Solgaard, Benjamin Van Roy

Assistant Professors: Eric Darve, Sarah Heilshorn, Adrian Lew, Nicolas A. Melosh, Gunter Niemeyer, Beth Pruitt, Clifford L. Wang, Thomas A. Weber

Professors (Teaching): Thomas H. Byers, Robert E. McGinn

Associate Professor (Teaching): Mehran Sahami

Lecturers: Jerry Cain, Vadim Khayms, Patrick Young, Julie Zelenski

Consulting Professors: Abbas Emami-Naeini, Thomas Kosnik

Consulting Associate Professors: Randy Komisar, Paul Mitiguy

Consulting Assistant Professors: William Behrman

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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, Materials Science and Engineering, and Mechanical Engineering. These departments and one interdisciplinary program, the Institute for Computational and Mathematical Engineering, 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 on Polymer Interfaces and Macromolecular Assemblies, Collaboratory for Research on Global Projects, Center for Position, Navigation, and Time, and the NIH Biotechnology Graduate Training Grant in Chemical Engineering. Energy Resources Engineering (formerly Petroleum Engineering) is offered through the School of Earth Sciences.

The School of Engineering's Institute of Design (http://dschool.stanford.edu) brings together students and faculty in engineering, business, education, medicine, and the humanities to learn design thinking and work together to solve big problems in a human-centered way.

The Woods Institute for the Environment (http://environment.stanford.edu) brings together faculty, staff, and students from the schools, institutes and centers at Stanford to conduct interdisciplinary research, education, and outreach to promote an environmentally sound and sustainable world.

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, Electrical Engineering, Environmental 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

Any students admitted to the University may declare an engineering major if they elect to do so; no additional courses or examinations are required for admission to the School of Engineering.

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 by means of a petition process. Inquiries may be addressed to the Office of Student Affairs in 201 Terman. For more information, see the transfer credit section of the *Handbook for Undergraduate Engineering Programs* at http://ughb.stanford.edu.

DEGREE PROGRAM OPTIONS

For more information about the requirements for the following options, see the "Undergraduate Degrees and Programs" section of this bulletin. Five years are usually required for a dual or coterminal program or for a combination of these two multiple degree programs. For further information, see the School of Engineering's student affairs office, Terman 201, or department contacts listed in the *Handbook for Undergraduate Engineering Programs,* available in hard copy or at http://ughb.stanford.edu.

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 3 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 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 University Registrar's Office or its web site for details about when courses begin to count toward the master's degree requirements and when graduate tuition is 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/shared/publications.htm#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, Architectural Design, Atmosphere/Energy, Biomechanical Engineering, Biomedical Computation, Computer Systems Engineering, Engineering Physics, and Product Design. In addition, students may elect a B.S. in an Individually Designed Major in Engineering.

The departments of Chemical Engineering, Civil and Environmental Engineering, Computer Science, Electrical Engineering, and Mechanical Engineering offer qualified majors opportunities to do independent study and research at an advanced level with a faculty mentor in order to receive a Bachelor of Science with honors.

Petroleum Engineering—Petroleum Engineering is offered by the Department of Energy Resource Engineering in the School of Earth Sciences. Consult the "Energy Resource Engineering" section of this bulletin for requirements. School of Engineering majors who anticipate summer jobs or career positions associated with the oil industry should consider enrolling in ENGR 120, Fundamentals of Petroleum Engineering.

Programs in Manufacturing—Programs in manufacturing are available at the undergraduate, master's, and doctorate 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 in Engineering (IDMENs).

SCHOOL OF ENGINEERING MAJORS

The School of Engineering offers two types of B.S. degrees: Bachelor of Science in Engineering and Bachelor of Science for Individually Designed Majors in Engineering (IDMENs). There are eight Engineering B.S. majors that have been proposed by cognizant faculty groups and pre-approved by the Undergraduate Council: Aeronautics and Astronautics; Architectural Design; Atmosphere/Energy; Biomechanical Engineering; Biomedical Computation; Computer Systems Engineering; Engineering Physics; and Product Design. The B.S. for an Individually Designed Major in Engineering has also been approved by the council.

AERONAUTICS AND ASTRONAUTICS (AA)

Mathematics (24 units):	
MATH 53 *or* CME 102/ENGR 155A	5
MATH electives (see Basic Requirement 1)	
Science (18 units):	
PHYSICS 41. Mechanics	4
PHYSICS 43. Electricity and Magnetism	4
One additional Physics course	3
Science electives (see Basic Requirement 2)	9
Technology in Society (one course required; see Basic Requirement 4)	3-5
Engineering Fundamentals (three courses minimum; see Basic Requirement 3):	
ENGR 14. Statics	3

ENGR 30. Engineering Thermodynamics 3
ENGR 70A or X. 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. Strength of Materials 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 Elective(s)[2] 3

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 Two of the following areas:
Fluids (AA 200A, 210A, 214A, 283; ME 131B)
Structures (AA 240A, 240B, 256)
Dynamics and Controls (AA 242A, 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.

ARCHITECTURAL DESIGN (AD)

Mathematics and Science (36 units minimum):
MATH 19, 20, and 21, *or* 41 and 42 (required) 10
One course in Statistics (required) 3-5
PHYSICS 21 *or* 41. Mechanics (required) 3-4
Recommended:
EARTHSYS 101, 102; GES 1; CEE 64, 70, 101D; CME 100;
PHYSICS 23 or 43; *or* from School of Engineering approved list[1]
Technology in Society (one course required; see Basic Requirement 4) 3-5
Engineering Fundamentals (three courses minimum; see Basic Requirement 3):
ENGR 14. Applied Mechanics: Statics 3
ENGR 60. Engineering Economy 3
Fundamentals Elective 3-5
Engineering Depth:
CEE 100. Managing Sustainable Building Projects (WIM) 4
CEE 101A. Mechanics of Materials 4
CEE 110. Building Information Modeling 4
CEE 31 or 31Q. Accessing Architecture Through Drawing 4
CEE 130. Architectural Design: 3D Modeling, Methodology, and Process 4
CEE 136. Green Architecture 4
CEE 137B. Intermediate Architecture Studio (or one of the 137 series) 5
CEE 156. Building Systems 4
ARTHIST 3. Introduction to the History of Architecture 5
Engineering Depth Electives (with at least 3 units from SoE courses):
the number of units of Depth Electives must be such that courses in Engineering Fundamentals and Engineering Depth total at least 60 units.[2]

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 School of Engineering approved list of math and science courses available in the *Handbook for Undergraduate Engineering Programs at* http://ughb.stanford.edu

2 Engineering depth electives: At least one of the following courses: CEE 111, 115, 131A or 138A; and others from CEE 80N, 101B, 101C, 122A,B, 135A, 139, 154, 172A, 176A, 180, 181, 182, 183; ENGR 50; ME 101, 110A, 115, 120, , 222; ARTSTUDI 60, 70, 140, 145, 148, 271; ARTHIST 142, 143A; FILMPROD 114; DRAMA 137.

ATMOSPHERE/ENERGY (A/E)

Mathematics (23 units minimum, including at least one course from each group):
Group A:
MATH 53. Ordinary Differential Equations with Linear Algebra 5
CME 102. Ordinary Differential Equations for Engineers 5
Group B:
CME 106. Introduction to Probability and Statistics for Engineers 4
STATS 60. Introduction to Statistical Methods: Pre-Calculus 5
STATS 110. Statistical Methods in Engineering and the Physical Sciences 4-5
GES 160. Statistical Methods for Earth and Environmental Sciences 3-4
Science (22 units minimum, including all of the following):
PHYSICS 41. Mechanics 4
PHYSICS 43. Electricity and Magnetism
or 45. Light and Heat 4
CHEM 31B. Chemical Principles II *or* CHEM 31X. Chemical Principles 4
CEE 70. Environmental Science and Technology 3
Technology in Society:
STS 110. Ethics and Public Policy (WIM) 3-5
Engineering Fundamentals (three courses minimum, including the following):
ENGR 30. Engineering Thermodynamics 3
Plus one of following two courses plus one elective (see Basic Requirement 3):
ENGR 60. Engineering Economy 3
ENGR 70A or 70X. Programming Methodology 3-5
Engineering Depth (42 units minimum):
Required:
CEE 64. Air Pollution: From Urban Smog to Global Change 3
CEE 173A. Energy Resources 5
At least 34 units from the following with at least 4 courses from each group:
Group A: Atmosphere
AA 100. Introduction to Aeronautics and Astronautics 3
BIOSCI 147. Controlling Climate Change in the 21st Century 3
CEE 63. Weather and Storms 3
CEE 101B. Mechanics of Fluids
or ME 70. Introductory Fluids Engineering 4
CEE 161S. The Atmosphere and Global Environmental Change 3
CEE 161T. Aerosols, Clouds, and Climate Change 3
CEE 171. Environmental Planning Methods 3
CEE 172. Air Quality Management 3
CEE 172A. Indoor Air Quality (given alternate years) 2-3
CEE 178. Introduction to Human Exposure Analysis 3
EARTHSYS 111. Biology and Global Change 3
GES 90. Introduction to Geochemistry 3-4
Group B: Energy
CEE 115. Goals and Methods for the Sustainable Design of Buildings 3-4
CEE 136. Green Architecture 4
CEE 156. Building Systems 4
CEE 176A. Energy Efficient Buildings 3-4
CEE 176B. Electric Power: Renewables and Efficiency 3-4
CEE 176F. Energy Systems Field Trips (given alternate years) 4
EARTHSYS 45N. Powering the Rim: Energy Issues for the Pacific 3
EARTHSYS 101. Energy and the Environment 3
EARTHSYS 102. Renewable Energy Sources and Greener Energy Processes 3
ENERGY. 104 Technology in the Greenhouse 3
GES 145. Energy Flow and Policy: The Pacific Rim 3

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

BIOMECHANICAL ENGINEERING (BME)

Mathematics (21 units minimum; see Basic Requirement 1)
Science (22 units minimum)[1]
CHEM 31X or A,B (required) 4-8
BIOSCI 44X. Biology Labs (WIM) 4
Biological Sciences or Human Biology core 10
Additional units from School of Engineering approved list
Technology in Society (one course required; see Basic Requirement 4) 3-5
Engineering Topics (Engineering Science and Design):
Engineering Fundamentals (minimum three courses; see Basic Requirement 3):
ENGR 14. Applied Mechanics: Statics 3
ENGR 25. Biotechnology 3
Fundamentals Elective 3-5
Engineering Depth:
ENGR 15. Dynamics 3
ENGR 30. Engineering Thermodynamics 3
ME 70. Introductory Fluids Engineering 4
ME 80. Strength of Materials and Lab 4
ME 389. Bioengineering and Biodesign Forum 1
Options to complete the ME depth sequence (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 Engineering Design 4
ME 113. Mechanical Engineering Design 4
ME 131A. Heat Transfer 3-4
ME 131B. Fluid Mechanics 4
ME 140. Advanced Thermal Systems 5
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 (3 courses, minimum 9 units):
ME 281. Biomechanics of Movement 3
ME 284A. Cardiovascular Bioengineering 3
ME 284B. Cardiovascular Bioengineering 3
ME 280. Skeleton Development & Evolution 3
ME 294. Medical Device Design 3
Additional courses, as needed or desired:
BIOSCI 44Y. Core Experimental Lab 4
BIOSCI 112. Human Physiology 4
BIOSCI 118. Genetic Analysis of Biological Processes 5
BIOSCI 129A or B. Cellular Dynamics I or II 4
BIOSCI 136. Evolutionary Paleobiology 4
HUMBIO 160. Human Behavioral Biology 6

School of Engineering

SURG 101. Introduction to Surgery 5

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 Science must include both Chemistry and Physics with a depth in at least one, two courses of HUMBIO core or BIOSCI core, and CHEM 31A and B or X, *or* ENGR 31.

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 41. Mechanics 4
CHEM 31X *or* A,B. Chemical Principles 4
CHEM 33. Structure and Reactivity 4
BIOSCI 41. Evolution, Genetics, Biochemistry
or HUMBIO 2A. Genetics, Evolution, and Ecology 5
BIOSCI 42. Cell Biology, Dev. Biology, and Neurobiology
or HUMBIO 3A. Cell and Developmental Biology 5
BIOSCI 43. Plant Biology, Evolution, and Ecology
or HUMBIO 4A. The Human Organism 5
Engineering Fundamentals (two different courses required):
CS 106. Programming Abstractions (X or A,B) 5
for the second required course, see concentrations
Technology in Society (one course required; see Basic Requirement 4) 3-5
Engineering
CS 107. Programming Paradigms 5
One of CS 270, 273A, 274, 275, 278, 279 3
Research: 6 units of biomedical computation research in any department[2,3] 6
Engineering Depth Concentration (choose one of the following concentrations):[7]
Cellular/Molecular Concentration (10 courses):
Mathematics: one of the following courses: 5
MATH 51. Advanced Calculus
STATS 141. Biostatistics
CME 100. Vector Calculus for Engineers
Engineering Fundamentals[4] 3-5
Biology: (four courses)
BIOSCI 129A. Cell Dynamics I 4
BIOSCI 129B. Cell Dynamics II 4
BIOSCI 188. Biochemistry
or CHEM 135. Physical Chemistry
or CHEM 171. Physical Chemistry 3
BIOSCI 203. Advanced Genetics
or BIOSCI 118. Genetic Analysis of Biological Processes 4
Simulation Electives (two courses)[5,6] 6
Informatics Electives (two courses)[5,6] 6
Simulation, Informatics, or Cell/Mol Elective (one course)[5,6] 3
Informatics Concentration:
Mathematics:
STATS 141. Biostatistics 4
Engineering Fundamental[4] 3-5
Informatics Core (three courses)
CS 145. Databases 4
CS 161. Design and Analysis of Algorithms 4
CS 121/221. Artificial Intelligence 3
Informatics Electives (three courses)[5,6] 9
Cellular Electives (two courses)[5,6] 6
Organs Electives (two courses)[5,6] 6
Organs/Organisms Concentration:
Mathematics (one of the following courses):
MATH 51. Advanced Calculus 5
STATS 141. Biostatistics 5
CME 100. Vector Calculus for Engineers 5
Engineering Fundamental[4] 3
Biology (three courses)
BIOSCI 112. Human Physiology 4
BIOSCI 188. Biochemistry
or BIOE/RAD 220. Introduction to Imaging 3
Organs Elective[5,6] 3-5
Simulation Electives (two courses)[5,6] 6
Informatics Electives (two courses)[5,6] 6
Simulation, Informatics, or Organs Elective (one course)[5,6] 3
Simulation Concentration:
Mathematics:
MATH 51 *or* CME 100. Advanced Calculus I 5
MATH 52 *or* CME 102/ENGR 155A. Advanced Calculus II 5
MATH 53 *or* CME 104/ENGR 155B. Advanced Calculus III 5
Science:
PHYSICS 43 *or* 45 4
Engineering Fundamentals:
See requirement in Simulation Core
Simulation Core:
Two courses chosen from ENGR 14,15; ME 80 6
Simulation Elective (two courses)[5,6] 6
Cellular Elective (one course)[5,6] 3
Organs Elective (one course)[5,6] 3

These requirements are subject to change; see http://bmc.stanford.edu/ for the most up-to date program description. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs.*

1 MS&E 120, EE 178, and CME 106 are acceptable substitutes for STATS 116.
2 Research projects require pre-approval of BMC Coordinators
3 Research units taken as CS 191W or in conjunction with ENGR199W fulfill the Writing in the Major (WIM) requirement. CS 272, which does not have to be taken in conjunction with research, also fulfills the WIM requirement.
4 One course required 3-5 units. See Fundamentals list in *Handbook for Undergraduate Engineering Programs*.
5 The list of electives is continually updated to include all applicable courses. For the current list of electives, see http://bmc.stanford.edu.
6 A course may only be counted towards one elective or core requirement; it may not be double-counted.
7 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.

COMPUTER SYSTEMS ENGINEERING (CSE)

Mathematics (23 units minimum):
MATH 41, 42, 51. Calculus 15
MATH 52 or 53. Multivariable Math 5
STATS 116. Theory of Probability
or MS&E 120. Probabilistic Analysis
or CME 106. Probability and Statistics for Engineers 3-5
Science (12 units):
PHYSICS 41. Mechanics 4
PHYSICS 43. Electricity and Magnetism 4
PHYSICS 45. Light and Heat 4
Technology in Society (one course required; see Basic Requirement 4) 3-5
Engineering Fundamentals (13 units minimum; see Basic Requirement 3):
ENGR 40. Electronics 5
ENGR 70B or 70X. Programming Methodology and Abstractions
(same as CS 106 B or X) 5
Fundamentals Elective (may not be ENGR 70A, B, or X) 3-5
Writing in the Major (one course):
CS 191W, 194, 201, 294W 3-6
Computer Systems Engineering Core (32 units minimum):
CS 103X. Discrete Structures
or CS 103A and B. Discrete Mathematics and Structures 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 3 or 4
Senior Project (CS 191, 191W, 194, 294, or 294W)[1] 3
Plus two of the following:[2]
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 4
or CS 143. Compilers
EE 109. Digital Systems Design Lab 4
EE 271. VLSI Systems 3
Plus three to four of the following:[3]
CS 140 or 143 (if not counted above) 4
CS 240E. Embedded Wireless Systems 4
CS 244A. Introduction to Networking 4
CS 244E. Low-Power Wireless Networking 3
EE 273. Digital Systems Engineering 3
EE 282. Computer Systems Architecture 3
Robotics and Mechatronics Specialization
CS 205A. Math for Robotics, Vision, Graphics 3
CS 223A. Introduction to Robotics 3
ME 210. Introduction to Mechatronics 4
ENGR 105. Feedback Control Design 3
Plus two to three of the following:[3]
AA 278. Optimal Control and Hybrid Systems 3
CS 223B. Introduction to Computer Vision 3
CS 225A. Experimental Robotics 3
CS 225B. Robot Programming Lab 4
CS 277. Experimental Haptics 3
ENGR 205. Introduction to Control Design 3
ENGR 206. Control System Design 4
ENGR 207A. Modern Control Design I 3
ENGR 207B. Modern Control Design II 3

Networking Specialization	
CS 140. Operating Systems	4
CS 244A. Introduction to Networking	4
Plus four to five of the following:[3]	
CS 240. Advanced Topics in Operating Systems	3
CS 240E. Embedded Wireless Systems	3
CS 240X. Advanced Operating Systems II	3
CS 244B. Distributed Systems	3
CS 244E. Low-Power Wireless Networking	3
CS 249A. Object-Oriented Programming	3
CS 249B. Advanced Object-Oriented Programming	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 sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 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 (R. Plummer or P. Young). A signed approval form and brief description of the proposed project, should be filed the quarter before work on the project is begun. Further details can be found in the *Handbook for Undergraduate Engineering Programs* at http://ughb.stanford.edu.

2 Students pursuing the Robotics and Mechatronics or Networking specializations must take EE 102A and B.

3 Students who take CS 103X instead of 103A,B must complete the higher number of courses.

ENGINEERING PHYSICS (EPHYS)

Mathematics (21 units minimum):	
MATH 51, 52. Multivariable Calculus	
or CME 100, 104. Vector Calculus, Linear Algebra, PDE	10
MATH 53 or CME 102. Ordinary Differential Equations	5
MATH 131. Partial Differential Equations	3
One math elective such as EE 261, PHYSICS 112, *or* CME 106	3-4
Science:	
PHYSICS 41. Mechanics	4
PHYSICS 43/44. Electricity and Magnetism	5
PHYSICS 45/46. Light and Heat	5
PHYSICS 70. Foundations of Modern Physics	4
or	
PHYSICS 61. Mechanics and Special Relativity	4
PHYSICS 63/64. Electricity, Magnetism, and Waves	5
PHYSICS 65/67. Thermodynamics and Modern Physics	6
Technology in Society (one course required; see Basic Requirement 4):	3-5
Engineering Fundamentals	
(three courses minimum; CS 106X or B recommended)	9-11
Engineering Depth (core):	
Intermediate Mechanics:	
ENGR 15. Dynamics	3
or PHYSICS 110. Intermediate Mechanics	4
Intermediate Electricity and Magnetism:	
EE 141,142. Eng. Electromagnetics, Electromagnetic Waves	7
or PHYSICS 120, 121. Intermediate Electricity and Magnetism	8
Numerical Methods:	
APPPHYS 215. Numerical Methods for Physicists and Engineers	3
or CME 108/CS 137. Introduction to Scientific Computing	3-4
or PHYSICS 113. Computational Physics	4
Electronics Lab:	
ENGR 40. Introductory Electronics	5
or EE 122. Analog Circuits Laboratory	3
or PHYSICS 105. Analog Electronics	3
or APPPHYS 207. Laboratory Electronics	3
Writing Lab:	
EE 108A/ENGR 102E. Digital Systems I	4-5
or ENGR 102M/ME 203. Manufacturing and Design	4-5
or MATSCI 161. Nanocharacterization Laboratory	4
or PHYSICS 107. Experimental Techniques and Data Analysis	4
Quantum Mechanics:	
EE 222, 223. Applied Quantum Mechanics	6
or PHYSICS 130, 131. Quantum Mechanics	8
Thermodynamics and Statistical Mechanics:	
PHYSICS 170, 171. Thermodynamics, Kinetic Theory, and Statistical Mechanics	8
Design Course (choose one of the following):	
CS 108. Object-Oriented Systems Design	3-4
EE 133. Analog Communications Design Laboratory	3
EE 144. Wireless Electromagnetic Design Laboratory	3
ME 203. Manufacturing and Design	3-4
ME 210. Introduction to Mechatronics	4
PHYSICS 108. Project Laboratory	3
Three courses from one specialty area:	9-12
Solid State Physics:	
APPPHYS 272. Solid State Physics I	3
APPPHYS 273. Solid State Physics II	3
EE 116. Semiconductor Device Physics	3
EE 216. Principles and Models of Semiconductor Devices	3
MATSCI 199. Electronic and Optical Properties of Solids	4
PHYSICS 172. Physics of Solids I	3
PHYSICS 173. Magnetism and Long Range Order in Solids	3
Photonics:	
EE 216. Principles and Models of Semiconductor Devices	3
EE 231. Introduction to Lasers	3
EE 232. Laser Dynamics	3
EE 234. Photonics Laboratory	3
EE 243. Semiconductor Optoelectronic Devices	3
EE 268. Introduction to Modern Optics	3
MATSCI 199. Electronic and Optical Properties of Solids	4
Materials Science:	
MATSCI 151. Microstructure and Mechanical Properties	4
MATSCI 152. Electronic Materials Engineering	3
MATSCI 155. Nanomaterials Synthesis	4
MATSCI 160. Nanomaterials Laboratory	4
MATSCI 161. Nanocharacterization Laboratory	4
MATSCI 162. X-Ray Diffraction Laboratory	4
MATSCI 163. Mechanical Behavior Laboratory	4
MATSCI 190. Organic Materials	4
MATSCI 194. Phase Equilibria	4
PHYSICS 172. Physics of Solids I	
or MATSCI 199. Electronic and Optical Properties of Materials	3
Electromechanical System Design:	
ME 80. Strength of Materials	4
ME 112. Mechanical Engineering Design	4
ME 210. Introduction to Mechatronics	4
Energy Systems:	
ME 131A. Heat Transfer	3-4
ME 131B. Fluid Mechanics: Compressible Flow and Turbomachinery	4
ME 140. Advanced Thermal Systems	4

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

PRODUCT DESIGN (PD)

Mathematics (20 units minimum):	
Recommended: one course in Statistics	
Science (22 units minimum):	
15 units must be from School of Engineering approved list[1]	
One year of PHYSICS 40 series (required)	
Behavioral Science[1] (7 units minimum)	
PSYCH 1. Introduction to Psychology (required)	5
PSYCH elective from courses numbered 20-95[2]	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 (three courses minimum):	13-15
ENGR 40 (required), 70A *or* X (required), plus one course from ENGR 10, 15, 20, 25, 30, 50, 60, 62	
Product Design Engineering Depth (48 units):	
ARTSTUDI 60. Design I: Fundamental Visual Language	3
ARTSTUDI 160. Design II: The Bridge	3
Two additional Art Studio courses (ARTSTUDI 70 recommended)	6
ENGR 14. Applied Mechanics	3
ENGR 102M. Technical/Professional Writing for ME Majors[3]	1
ME 80. Strength of Materials	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	4

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 School of Engineering approved science list available at http://ughb.stanford.edu.

2 One quarter abroad may substitute for the PSYCH elective.

3 Must be taken concurrently to fulfill the Writing in the Major requirement.

INDIVIDUALLY DESIGNED MAJORS IN ENGINEERING (IDMENS)

The B.S. degree for IDMENs is 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. IDMEN 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 in Individually Designed Major in Engineering: (approved title)."

Students must submit written proposals to the IDMEN 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 IDMEN major, but the IDMEN proposal itself may not exceed 107 units. The student's curriculum must include at least three Engineering Fundamentals courses (choosing from ENGR 10, 14, 15, 20, 25, 30, 40, 50/50M, 60, 62, 70A, 70B, 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 specify how the 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 IDMEN 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 IDMEN 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 IDMEN proposal.

The proposal must be signed by two faculty members who 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 an appraisal of the academic value and viability of the proposed major.

Students proposing IDMENs 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 IDMEN 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* 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, Computer Science, Electrical Engineering, Management Science and Engineering, Materials Science and Engineering, and Mechanical Engineering have the following components: 36-45 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 72). ABET accredited majors must meet a minimum number of Engineering Science and Engineering Design units; (see Basic Requirement 5). Curricular requirements for departmental majors are being revised at the time of publication. Consult the 2007-08 *Handbook for Undergraduate Engineering Programs* 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 *Handbook for Undergraduate Engineering Programs*.

CHEMICAL ENGINEERING (CHE)

Mathematics:	
MATH 41, 42.	10
CME 100. Vector Calculus for Engineers	5
or MATH 51 and 52. Calculus	10
CME 102. Ordinary Differential Equations for Engineers	
or MATH 53. Ordinary Differential Equations	5
CME 104. Linear Algebra & Partial Differential Equations for Engineers	5
or CME 106. Intro to Probability and Statistics for Engineers	4
Science:	
CHEM 31X. Chemical Principles	4
or CHEM 31A,B. Chemical Principles I,II	8
CHEM 33. Structure and Reactivity	4
CHEM 35. Organic Monofunctional Compounds	4
CHEM 36. Chemical Separations	3
PHYSICS 41. Mechanics	4
PHYSICS 43. Electricity and Magnetism	4
Technology in Society (one course required; see Basic Requirement 4)	3-5
Engineering Fundamentals (three courses minimum; see Basic Requirement 3):	
ENGR 20/CHEMENG 20. Introduction to Chemical Engineering	3
ENGR 25/CHEMENG 25. Biotechnology	3
Fundamentals Elective	3-5
Chemical Engineering Depth (minimum 68 Engineering Science and Design units; see Basic Requirement 5):	
CHEMENG 10. The Chemical Engineering Profession	1
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 130. Separation Process	3
CHEMENG 150. Biochemical Engineering	3
CHEMENG 170. Kinetics and Reactor Design	3
CHEMENG 180. Chemical Engineering Plant Design	3
CHEMENG 185A. Chemical Engineering Laboratory A (WIM)	4
CHEMENG 185B. Chemical Engineering Laboratory B (WIM)	4
CHEMENG 188. Biochemistry I	3
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 courses (140 or 160 required):	
CHEMENG 140. Microelectronics Processing Technology	3
CHEMENG 160. Polymer Science and Engineering	3
CHEMENG 174. Environmental Microbiology I	3
CHEMENG 189. Biochemistry II	3

Unit count is higher if program includes one or more of the following: MATH 20 series, MATH 50 series (in lieu of the CME math courses), or CHEM 31A,B (in lieu of CHEM 31X). The above requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*. 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)	3-5
Engineering Fundamentals (three courses minimum; see Basic Requirement 3)	
ENGR 14. Applied Mechanics: Statics	3
ENGR 60. Engineering Economy	3
Fundamentals Elective	3-5
Engineering Depth: (minimum of 68 Engineering Science and Design units; see Basic Requirement 5):	
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	1-7

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 Mathematics must include CME 102/ENGR 155A and a Statistics class. Science must include PHYSICS 41, and GES 1. For students in the Environmental and Water Studies track, CHEM 31B or X, and CHEM 33 are required. For students in the Structures and Construction track, CHEM 31A, CHEM 31X or ENGR 31 is required.

2 Environmental and Water Studies: ENGR 30; CEE 101D, 160, 161A, 166A, 166B, 171, 172, 177, 179A; and either CEE 169, 179B, or 179C. Remaining specialty units from: CEE 63, 64, 164, 169, 173A, 173B, 176A, 176B, 178, 179C, 199.

3 Structures and Construction: ENGR 50; CEE 102, 156, 180, 181, 182, 183. Remaining specialty units from: ENGR 15, ENGR 155B, CME 104; CEE 101D, 111, 122A,B, 140, 143, 147, 151, 154, 160, 161A, 171, 176A,B, 195A/B, 196, 199, 203, and one of 130, 131, 132, 134, 134A, 136, or 137A.

COMPUTER SCIENCE (CS)

Mathematics (23 units minimum):	
CS 103X. Discrete Structures (Accelerated)	
or CS 103A and B. Discrete Mathematics and Structures	4-6
MATH 41, 42. Calculus[1]	10
STATS 116. Theory of Probability	
or MS&E 120. Probabilistic Analysis	
or CME 106. Probability and Statistics for Engineers	3-5
Plus two electives[2]	
Science (11 unit minimum):	
PHYSICS 41. Mechanics	4
PHYSICS 43. Electricity and Magnetism	4
Science Elective[3]	3
Technology in Society (one course; see Basic Requirement 4)	3-5
Engineering Fundamentals (13 units; see Basic Requirement 3)	
CS 106 B or X. Programming Methodology and Abstractions	5
ENGR 40. Electronics	5
Fundamentals Elective (may not be 70A, B, or X)	3-5
Writing in the Major (one course):	
CS 191W, 194, 201, 294W	
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	3-4
Two systems electives[4]	7-8
Applications (two courses):	
CS 121 or 221. Introduction to Artificial Intelligence	3-4
One applications elective[5]	3-4
Project (one course):	
CS 191, 191W, 194, 294, 294W[6]	3
Restricted Electives (two or three courses)[7]	6-12

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 MATH 19, 20, and 21 may be taken instead of MATH 41 and 42 as long as at least 23 math units are taken.

2 The math electives list consists of: MATH 51, 103, 108, 109, 110, 113; CS 156, 157, 205A; PHIL 151; CME 100, 102, 104. Completion of MATH 52 and 53 counts as one math elective. Restrictions: MATH 51 and 103, or MATH 51 and CME 100, or MATH 103 and 113, or CS 157 and PHIL 151, may not 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 55; AP Chemistry also meets this requirement. Either of the PHYSICS sequences 61/63 or 21/23 may be substituted for 41/43 as long as at least 11 science units are taken.

4 The two systems courses must be chosen from the following set: CS 140, 143, 155, 240D, 242, and 244A. The systems electives must include a course with a large software project, currently satisfied by either CS 140 or 143.

5 The applications elective must be chosen from the following: CS 145, 147, 148, 223A, 223B, 248, 262.

6 Independent study projects (CS 191 or 191W) require faculty sponsorship and must be approved by the adviser, faculty sponsor, and the CS program adviser (R. Plummer or P. Young). A signed approval form, along with a brief description of the proposed project, should be filed the quarter before work on the project is begun. Further details can be found in the *Handbook for Undergraduate Engineering Programs*.

7 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 140, 143, 144 or 244A, 145, 147, 148 or 248, 155, 156, 157, 205A, 205B, 222, 223A, 223B, 224M, 224N, 224S, 225A, 225B, 226, 227, 228, 229, 240, 242, 243, 244B, 245, 247, 249A, 249B, , 255, 256, 257, 258, 261, 262, 270, 271, 272, 273A, 274, 276, 277, 295; CME 108; EE 282.

ELECTRICAL ENGINEERING (EE)

Mathematics:	
MATH 41, 42	10
MATH 51 and 52, *or* CME 100/ ENGR 154 and CME 104/ENGR 155B	10
MATH 53 *or* CME 102/ENGR 155A	5
EE 178, STATS 116, MATH 151, *or* CME 106/ENGR 155C	3-5
Science:	
PHYSICS (41, 43) or (61, 63)	8
Math or Science electives[1]:	7-9
Technology in Society (one course; see Basic Requirement 4)	3-5
Technical Writing: ENGR 102E (WIM corequisite for EE 108A)	1
EE 100. The Electrical Engineering Profession	1
Engineering Fundamentals: (three courses minimum; see Basic Requirement 3)	
CS 106X *or* CS 106B	5
At least two additional courses, at least one of which is not in EE or CS	6-10
Engineering Depth (minimum 68 Engineering Science and Design units; see Basic Requirement 5):	
Circuits: EE 101A,B	8
Signals Processing and Linear Systems: EE 102A,B	8
Digital Systems: EE 108A (Laboratory, WIM), 108B	8
Physics in Electrical Engineering: EE 41 *or* EE 141	4-5
Specialty courses[2]	9-12
One course in Design[3]	
Electrical Engineering electives[4]	9-20

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 A minimum of 12 science units must be taken. A minimum of 45 math and science units combined must be taken.

2 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, 271 or 275, 273, 282; CS 107
- Computer Software: CS 107, 108, 194, or 244A; EE 284
- Controls: ENGR 105, 205, 206 207A, 207B, 209A, 209B; EE 263
- Circuits and Devices: EE 116, 122, 133, 212, 214, 215, 216, 271
- Fields and Waves: EE 134, 141, 144, 241, 242, 246, 247, 252, 256
- Communications and Signal Processing: EE 133, 168, 179, 261 263, (264 or 265), 276, 278, 279
- Solid State and Photonic Devices: EE 116, 134, 136, 141, 216, 222, 223, 228, 235, 268

3 The design course may be part of the specialty sequence. The following courses satisfy this requirement: EE 109, 133, 134, 144, 168, 256, 262, 265; CS 194, ENGR 206.

4 May include up to two additional Engineering Fundamentals. May include up to 10 units of EE 191. May include any CS 193 course.

ENVIRONMENTAL ENGINEERING (ENV)

Mathematics and Science (see Basic Requirement 1 and 2)	45 units[1]
Technology in Society[2] (one course;see Basic Requirement 4)	3-5
Engineering Fundamentals (three courses minimum; see Basic Requirement 3):	
ENGR 30. Engineering Thermodynamics	3
ENGR 60. Engineering Economy	3
Fundamentals Elective	3-5
Engineering Depth (minimum of 68 Engineering Science and Design units; see Basic Requirement 5):	
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: CEE 169, 179B, or 179C	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 sample programs in the Handbook for Undergraduate Engineering Programs.

1 Math must include CME 102/ENGR 155A and a Statistics course. Science must include PHYSICS 41; CHEM 31B or X, 33; and GES 1.

2 Should choose a class that specifically includes an ethics component, such as STS 101, 110, 115, or CS 201.

3 Breadth electives currently include CEE 63, 101C, 161S, 161T, 162, 164, 166D, 169, 172A, 173A, 175A, 176A, 176B, 178, 179C, and 199.

School of Engineering

MANAGEMENT SCIENCE AND ENGINEERING (MS&E)

Course	Units
Mathematics (32 units minimum[1]; see Basic Requirement 1):	
MATH 41. Calculus	5
MATH 42. Calculus	5
MATH 51. Linear Algebra and Differential Calculus of Several Variables	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 31B or X, and 33	8
PHYSICS 21, 22, 23, and 24	8
PHYSICS 41 and 43	8
Science Elective	3
Technology in Society (one course[2]; see Basic Requirement 4)	3-5
Engineering Fundamentals (three courses minimum; see Basic Requirement 3):	
CS 106A *or* X. Programming Methodology[3]	5
ENGR 25. Biotechnology	
or ENGR 40. Introduction to Electronics	3-5
Fundamentals Elective[4]	3-5
Engineering Depth (core):	22-29
CS 106B, unless 106X used as fundamental	3-5
ENGR 60. Engineering Economy[4]	3
MS&E 108. Senior Project	5
MS&E 111. Introduction to Optimization[4]	4
MS&E 130 *or* 134. Information[5]	3-4
MS&E 142 *or* 160. Investment Science or Production[6]	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 247S. Finance	3-4
Two of the following courses:	
ENGR 145. Technology Entrepreneurship[8]	4
FINANCE 323. International Financial Management	4
MS&E 107. Interactive Management Science	3
MS&E 160. Production and Operating Systems[6]	4
MS&E 223. Simulation	3
MS&E 250A. Engineering Risk Analysis	3
STATS 240. Statistical Methods in Finance	3-4
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	24-29
At least one of the following courses:	
ECON 50. Economic Analysis I	5
PSYCH 70. Introduction to Social Psychology	4
SOC 114. Economic Sociology	5
At least two of the following courses:	
ENGR 145. Technology Entrepreneurship[8]	4
MS&E 175. Innovation, Creativity, and Change	4
MS&E 181. Issues in Technology and Work[8]	4
At least four of the following courses (may also include omitted courses from above: ENGR 145, MS&E 175, or MS&E 181):	
Organizations and Technology:	
MS&E 134. Organizations and Info Systems[5]	4
CS 147. Intro Human-Computer Interaction	3-4
MS&E 169. Quality Engineering	4
MS&E 184. Technology and Work	3
Entrepreneurship and Innovation:	
MS&E 140. Industrial Accounting	3-4
MS&E 266. Management of New Product Development	3-4
MS&E 267. Innovations in Manufacturing	3-4
Policy and Strategy Concentration:	25-30
ECON 50. Economic Analysis I	5
ECON 51. Economic Analysis II	5
MS&E 190. Policy and Strategy Analysis	3
At least four of the following courses, including at least one course in policy and at least one course in strategy:	
Policy:	
MS&E 193. Technology and National Security[8]	3
MS&E 197. Ethics and Public Policy (WIM)[8]	5
MS&E 243. Energy and Environmental Policy Analysis	3
MS&E 248. Economics of Natural Resources	3-4
MS&E 292. Health Policy Modeling	3
Strategy:	
ENGR 145. Technology Entrepreneurship[8]	4
MS&E 175. Innovation, Creativity, and Change	3-4
MS&E 266. Mgmt. of New Product Development	3-4
MS&E 267. Innovations in Manufacturing	3-4
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
and three of the following 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 264. Manufacturing Systems Design	3
MS&E 265. Supply Chain Logistics	4
MS&E 266. Management of New Product Development	3-4
MS&E 267. Innovations in Manufacturing	3-4
MS&E 268. Operations Strategy	3

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

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 55, 70. AP credit for Chemistry, Mathematics, and Physics may be used.

2 Technology in Society course must be one of the following MS&E approved courses: COMM 120, COMM 169, CS 201, MS&E 181, MS&E 193 (WIM), STS 101/ENGR 130, STS 110/MS&E 197 (WIM), STS 115/ENGR 131, STS 160, STS 163, STS 170, STS 279.

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)

Course	Units
Mathematics (20 units minimum; see Basic Requirement 1):	
MATH 51 and 52, *or* CME 100/ENGR 154 and CME 104/ENGR 155B	10
MATH 53 *or* CME 102/ENGR 155A	5
Science (20 units minimum; see Basic Requirement 2):	
Must include a full year of physics or chemistry, with one quarter of study in the other subject.	
Technology in Society (one course; see Basic Requirement 4)	3-5
Engineering Fundamentals (three courses minimum; see Basic Requirement 3)	
ENGR 50. Intro to Materials Science, Nanotechnology[1]	4
or ENGR 50M. Intro to Materials Science, Biomaterials[1]	4
At least two additional courses	6-8
Engineering Depth:	
Choose four of the following lab courses:	
MATSCI 160. Nanomaterials Laboratory	4
MATSCI 161. Nanocharacterization Laboratory (WIM)	4
MATSCI 162. X-Ray Diffraction Laboratory	4
MATSCI 163. Mechanical Behavior Laboratory	4
MATSCI 164. Electronic and Photonic Materials and Devices Lab	4
Materials Science Fundamentals[2]	24
Science and Engineering Options[3]	10

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 If both ENGR 50 courses are taken, one may be used for the MATSCI depth fundamentals requirement.

2 MATSCI Fundamentals; 24 units (6 courses) from ENGR 50 or 50M (alternatively, MATSCI 70N), 151,152, 153,154, 155, 156, 157, 190, 192, 193, 194, 195, 196, 197, 198, 199.

3 MATSCI Options; 10 units from one of the following areas:

Bioengineering: BIOE 220, 222A, 222B, 280, 281, 284A, 284B; MATSCI 380, 381; ME 80, 81
Chemical Engineering: CHEM 171; CHEMENG 130, 140, 150, 150A, 160
Chemistry: CHEM 151, 153, 171, 173, 175
Electronics and Photonics: EE 101A, 101B, 102A, 116, 134, 136, 141
Energy Technology: EE 293A, 293B; MATSCI 302; ME 260
Materials Characterization Techniques: MATSCI 320, 321, 323, 324, 325, 326, 405
Mechanical Behavior and Design: AA 240A, 240B, 256; MATSCI 170, 358; ME 80, 81 (or CEE 101A), 203, 294

Physics: PHYSICS 70, 110, 120, 121,130, 131, 134 170, 171, 172, 173
Self-Defined Option: petition for a self-defined cohesive program, minimum of 10 units.

MECHANICAL ENGINEERING (ME)

Mathematics (24 units minimum[1]; see Basic Requirement 1):
CME 102/ENGR 155A. Ordinary Differential Equations for Engineers
or MATH 53 Ordinary Differential Equations with Linear Algebra 5
CME 106/ENGR 155C. Intro to Probability and Statistics for Engineers
or STATS 110. Statistical Methods in Engineering
or STATS 116. Theory of Probability 3-5
Science (21 units minimum[1]; see Basic Requirement 2):
CHEM 31X *or* 31A,B (required)
Technology in Society (one course from approved ME list;[2]
see Basic Requirement 4) 3-5
Engineering Fundamentals: (three courses minimum; see Basic Requirement 3)
ENGR 40. Introductory Electronics (required) 5
ENGR 70A/B *or* X (same as CS 106A/B *or* X). Programming
Methodology and Abstractions (required) 3-5
Fundamentals Elective 3-5
Engineering Depth (minimum of 68 Engineering Science and Design units; see Basic Requirement 5):

ENGR 14. Applied Mechanics: Statics	3
ENGR 15. Dynamics	3
ENGR 30. Engineering Thermodynamics	3
ENGR 102M. Technical Writing (WIM corequisite for ME 203)	1
ME 70. Introductory Fluids Engineering	4
ME 80. Strength of Materials	4
ME 101. Visual Thinking	3
ME 103D. Engineering Drawing	1
ME 112. Mechanical Engineering Design	4
ME 113. Mechanical Engineering Design	4
ME 131A. Heat Transfer	4
ME 131B. Fluid Mechanics	4
ME 140. Advanced Thermal Systems	5
ME 161. Dynamic Systems	4
ME 203. Manufacturing and Design (WIM; take with ENGR 102M)	4

Options to complete the ME depth sequence (choose three courses):

ENGR 105. Feedback Control Design	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
ME 284A. Cardiovascular Bioengineering	3
ME 284B. Cardiovascular Bioengineering	3

These requirements are subject to change. The final requirements are published with sample programs in the *Handbook for Undergraduate Engineering Programs*.

1 Math and science must total 45 units. Math: 24 units required and must include a course in differential equations (CME 102/ENGR 155A or MATH 53) and Statistics (CME 106/ENGR 155C or STATS 110 or 116). Science: 21 units minimum and requires courses in Physics, Chemistry, or Biology, with at least a full year in either Physics or Chemistry.

2 ME majors must choose their TIS course from the following list: STS 101, 110, ME 190, POLISCI 114S, MS&E 193, PUBPOL 194 or CS 201.

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 math requirement are listed 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 at http://ughb.stanford.edu 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 chosen by the student rather than by the department:
ENGR 10. Introduction to Engineering Analysis
ENGR 14. Applied Mechanics: Statics and Deformables
ENGR 15. Dynamics
ENGR 20/CHEMENG 20. Introduction to Chemical Engineering
ENGR 25/CHEMENG 25. Biotechnology
ENGR 30. Engineering Thermodynamics
ENGR 40. Introductory Electronics[1]
ENGR 50/50M. Introductory Science of Materials[1]
ENGR 60. Engineering Economics
ENGR 62/MS&E 111. Introduction to Optimization
ENGR 70A,B/CS 106A,B *or ENGR 70X/CS 106X. 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 in the *Handbook for Undergraduate Engineering Programs*.

Basic Requirement 5 (Science and Design)—In order to satisfy ABET (Accreditation Board for Engineering and Technology) requirements, a student majoring in Chemical, Civil, Electrical, Environmental, or Mechanical Engineering must complete one and a half years of Engineering topics, consisting of a minimum of 68 units of Engineering Science and Engineering Design appropriate to the student's field of study. In most cases, students meet this requirement by completing the major program core and elective requirements in Fundamentals and Depth. For example, ENGR 40 is a 5-unit course; 3 of these 5 units are assigned to Engineering Science and the remaining 2 units are assigned to Engineering Design. A student may need to take additional courses in Depth in order to fulfill the minimum requirement. The science and design units assigned to each major's depth courses are listed online at http://ughb.stanford.edu/ 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:

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
Two courses from one of the upper-division elective areas below (min. 6 units) plus one course from a second area below (min. 3 units):	9-11
Aerospace Systems Synthesis/Design:	
AA 236A,B. Spacecraft Design	8
AA 241A,B. Aircraft Design	6
Dynamics and Controls:	
AA 242A. Classical Dynamics	3
AA 271A. 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. Fundamentals 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

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

CHEMICAL ENGINEERING (CHE)

The following core courses fulfill the minor requirements:

ENGR 20/CHEMENG 20. Introduction to Chemical Engineering	3
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 185. Chemical Engineering Lab	4
CHEM 171. Physical Chemistry	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, Environmental Engineering, and Architectural Design. The minimum prerequisite for a Civil Engineering minor focusing on construction engineering and management or structural engineering is MATH 42 (or 21); however, many courses of interest require PHYSICS 41 and/or MATH 51 as prerequisites. The minimum prerequisite for a Civil Engineering minor focusing on architectural design is MATH 41 (or 19) and a course in Statistics. Students should recognize that a minor in Civil Engineering is not an ABET-accredited degree program.

Since civil engineering is a broad field and undergraduates with 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 (Environment and Energy Building, Room 316). 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 Anne Kiremidjian (kiremidjian@stanford.edu) is the CEE undergraduate minor adviser in Structural Engineering and Construction. Professor Lynn Hildemann (hildemann@stanford.edu) is the CEE minor adviser in Environmental Engineering. Patti Walters (pwalters@stanford.edu), Program Director for Architectural Design, is the CEE undergraduate minor adviser in Architectural Design. Students must consult one of these advisers in developing their minor program, and obtain approval of the finalized study list from them.

COMPUTER SCIENCE (CS)

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

Introductory Programming (AP Credit may be used to fulfill this requirement):	
CS 106A,B. Programming Method/Abstractions	10
or CS 106X. Programming Method/Abstractions (Accelerated)	5
Core:	
CS 103A/B. Discrete Math/Structures	4-6
or CS 103X. Discrete Structures	
CS 107. Programming Paradigms	5
CS 108. Object-Oriented Systems Design	4
Electives (choose 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
Systems:	
CS 140. Operating Systems	4
CS 143. Compilers	4
CS 144. Networking	4
CS 145. Databases	4
CS 148. Graphics	3
Theory:	
CS 154. Automata and Complexity Theory	4
CS 157. Logic and Automated Reasoning	3
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 from any of the following three options, along with four graded EE courses of level 100 or higher (13-21 units), fulfill the minor requirements:

Option I:	
ENGR 40. Introductory Electronics	5
EE 101A. Circuits I	4
EE 101B. Circuits II	4
Four graded EE courses numbered 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 numbered 100 or higher	
Option III:	
ENGR 40. Introductory Electronics	5
EE 108A. Digital Systems I	4
EE 108B. Digital Systems II	4
Four graded EE courses numbered100 or higher	

ENVIRONMENTAL ENGINEERING (ENV)

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 atmosphere/energy. The minimum prerequisite for an Environmental Engineering minor is MATH 42 (or 21); however, many courses of interest require PHYSICS 41 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 (Environment and Energy Building, Room 316). 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 Lynn Hildemann (hildemann@stanford.edu) is the CEE undergraduate minor adviser in Environmental Engineering. Students must consult with Professor Hildemann in developing their minor program, and obtain approval of the finalized study list from her.

MANAGEMENT SCIENCE AND ENGINEERING (MS&E)

The following courses fulfill the minor requirements:

Background requirement:	
MATH 51. Calculus	
Minor requirements:	
ENGR 60. Engineering Economy (prerequisite: MATH 41)	3
MS&E 111. Introduction to Optimization	4
MS&E 120. Probabilistic Analysis (prerequisite: MATH 51)	5
MS&E 121. Introduction to Stochastic Modeling	4
MS&E 130 *or* 134. Information	3-4
MS&E 142 *or* 160. Investment Science or Production	3-4
MS&E 180. Organizations: Theory and Management	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 (choose one of the following):	
ENGR 50. Introductory Science of Materials, Nanotechnology Emphasis	4
ENGR 50M. Introductory Science of Materials, Biomaterials Emphasis	4
Materials Science Fundamentals and Depth (choose 6 of the following):	24
MATSCI 151. Microstructure and Mechanical Properties	4
MATSCI 152. Electronic Materials Engineering	4
MATSCI 153. Nanostructure and Characterization	4
MATSCI 154. Solid State Thermodynamics	4
MATSCI 155. Nanomaterials Synthesis	4
MATSCI 156. Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	4
MATSCI 157. Quantum Mechanics for Materials Scientists	4
MATSCI 160. Nanomaterials Laboratory	4
MATSCI 161. Nanocharacterization Laboratory	4
MATSCI 162. X-Ray Diffraction Laboratory	4
MATSCI 163. Mechanical Behavior Laboratory	4
MATSCI 164. Electronic and Photonic Materials and Devices Laboratory	4
MATSCI 190. Organic Materials	4
MATSCI 192. Materials Chemistry	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 analytic and design activities. Prerequisites: MATH 41, 42, and PHYSICS 41.

ENGR 14. Applied Mechanics: Statics	3
ENGR 15. Dynamics	3
ENGR 30. Thermodynamics	3
ME 70. Introductory Fluids Engineering	4
ME 101. Visual Thinking	3
Plus two of the following:	
ME 80. Strength of Materials	4
ME 131A. Heat Transfer	4
ME 161. Dynamic Systems	4
ME 203. Manufacturing and Design	4

Thermosciences Minor Prerequisites: MATH 41, 42, 43, and PHYSICS 41.

ENGR 14. Applied Mechanics: Statics	3
ENGR 30. Thermodynamics	3
ME 70. Introductory Fluids Engineering	4
ME 131A. Heat Transfer	4
ME 131B. Fluid Mechanics	4
ME 140. Advanced Thermal Systems	5

Mechanical Design: This minor aims to expose students to design activities supported by analysis. Prerequisites: MATH 41, 42, and PHYSICS 41.

ENGR 14. Applied Mechanics: Statics	3
ENGR 15. Dynamics	3
ME 80. Strength of Materials	4
ME 101. Visual Thinking	3
ME 112. Mechanical Engineering Design	4
ME 203. Manufacturing and Design	4
Plus one of the following:	
ME 113. Engineering Design	4
ME 210. Introduction to Mechatronics	4
ME 220. Introduction to Sensors	4

GRADUATE PROGRAMS

ADMISSION

Application for admission with graduate standing in the school should be made to the graduate admissions committee in the appropriate department or program. 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. Stanford undergraduates may also apply as coterminal students; details can be found in the "Degree Program Options" section above.

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

Industrial firms, government laboratories, and other organizations may participate in the Honors Cooperative Program (HCP), a program that permits qualified engineers, scientists, and technology professionals admitted to Stanford graduate degree programs to register for Stanford courses and obtain the degree on a part-time basis in 55 areas of concentration. In 23 of these areas of concentration, the master's degree can be obtained entirely online.

Through this program, many graduate courses offered by the School of Engineering on campus are made available through the Stanford Center for Professional Development (SCPD). SCPD delivers more than 250 courses a year on television and online. For HCP employees who are not part of a graduate degree program at Stanford, courses and certificates are also available through a non-degree option and a non-credit professional education program. Non-credit short courses 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. Doctoral programs related to manufacturing are available in a number of departments and involve research projects ranging from reliable manufacturing methods for nanofabricated devices to models of production scheduling and supply chain management.

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 nanoscience, and a student interested in an aspect of nanotechnology 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

BIOENGINEERING

Biomedical Computation
Biomedical Devices
Biomedical Imaging
Cardiovascular Engineering
Cell and Molecular Engineering
Mechanobiology
Musculoskeletal Engineering
Neuroscience Engineering
Regenerative Medicine

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

Atmosphere/Energy
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

COMPUTATIONAL AND MATHEMATICAL ENGINEERING

Applied and Computational Mathematics
Computational Fluid Dynamics
Computational Geometry and Topology
Discrete Mathematics and Algorithms
Numerical Analysis
Optimization
Partial Differential Equations
Stochastic Processes

COMPUTER SCIENCE

Algorithmic Game Theory
Analysis of Algorithms
Artificial Intelligence
Automated Deduction
Autonomous Agents
Biomedical Computation
Compilers
Complexity Theory
Computational Biology
Computational Geometry
Computational Logic
Computational Physics
Computer Architecture
Computer Graphics
Computer Logic
Computer Security
Computer Vision
Cryptography
Database Systems
Design Automation
Digital Libraries
Distributed and Parallel Computation
Electronic Commerce
Enterprise Management

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 and Speech Processing
Networks, Internet Infrastructure, and Distributed Systems
Operating Systems
Parallel Computing
Programming Systems/Languages
Reasoning Under Uncertainty
Robotics
Robust System Design
Scientific Computing and Numerical Analysis
Sensor Networks
Ubiquitous and Pervasive Computing

ELECTRICAL ENGINEERING

Computer Hardware
Computer Software Systems
Control and Systems Engineering
Communication Systems
Dynamic Systems and Optimization
Electronic Circuits
Electronic Devices, Sensors, and Technology
Fields, Waves, and Radioscience
Image Systems
Lasers, Optoelectronics, and Quantum Electronics
Network 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
Electrical and Optical Behavior of Solids
Electron Microscopy
Fracture and Fatigue
Imperfections in Crystals
Kinetics
Magnetic Behavior of Solids
Magnetic Storage Materials
Nanomaterials
Photovoltaics
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

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. The presentation of a thesis is not a school requirement. Further information is found in departmental listings.

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 intended for students who want additional graduate training beyond that offered in an M.S. program. The program of study must satisfy the student's department and must include at least 90 units beyond the B.S. degree. 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 available 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. 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.

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 see 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.

4 units, not given this year

ENGR 14. Applied Mechanics: Statics—The mechanics of particles, rigid bodies, trusses, frames, and machines in static equilibrium emphasizing the use of free-body diagrams and the principle of virtual work. Frictional effects and internal forces in structural members. Lab in Autumn; no lab in Spring. Prerequisite: PHYSICS 41 or consent of instructor. GER:DB-EngrAppSci

3 units, Aut (Farhat, C), Spr (Mitiguy, P)

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:DB-EngrAppSci

3 units, Aut (Niemeyer, G), Spr (Lew, A)

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

3 units, Spr (Robertson, C)

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

3 units, Spr (Wang, C)

ENGR 30. Engineering Thermodynamics—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 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 45 (formerly 51) or equivalent high school physics. GER:DB-EngrAppSci

3 units, Aut (Edwards, C), Win (Mitchell, R)

ENGR 31. Chemical Principles with Application to Nanoscale Science and 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: DB-NatSci

4 units, Aut (McIntyre, P)

ENGR 40. Introductory Electronics—Electrical quantities and their measurement, including operation of the oscilloscope. Function of electronic components including resistor, capacitor, and inductor. Analog circuits including the operational amplifier and tuned circuits. Digital logic circuits and their functions. Lab assignments. Enrollment limited to 200. Lab. Prerequisite: PHYSICS 43. GER:DB-EngrAppSci

5 units, Aut (Howe, R), Spr (Wong, S)

ENGR 50. Introduction to Materials Science, Nanotechnology Emphasis—The structure, bonding, and atomic arrangements in materials leading to their properties and applications. Topics include electronic and mechanical behavior, emphasizing nanotechnology, solid state devices, and advanced structural and composite materials. GER:DB-EngrAppSci

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

ENGR 50M. Introduction to Materials Science, Biomaterials Emphasis—Topics include: the relationship between atomic structure and macroscopic properties of man-made and natural materials; mechanical and thermodynamic behavior of surgical implants including alloys, ceramics, and polymers; and materials selection for biotechnology applications such as contact lenses, artificial joints, and cardiovascular stents. GER:DB-EngrAppSci

4 units, Aut (Heilshorn, S)

ENGR 60. Engineering Economy—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: sophomore or higher class standing; knowledge of elementary probability. GER:DB-EngrAppSci

3 units, Aut (Chiu, S), Win (Weber, T), Sum (Weber, T)

ENGR 62. Introduction to Optimization—(Same as MS&E 111.) 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:DB-EngrAppSci

4 units, Aut (Goel, A), Spr (Van Roy, B)

ENGR 70A. Programming Methodology—(Same as CS 106A.) 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:DB-EngrAppSci

3-5 units, Aut (Sahami, M), Win, Spr (Young, P), Sum (Staff)

ENGR 70B. Programming Abstractions—(Same as CS 106B.) 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, graphs). Introduction to time and space complexity analysis. Uses the programming language C++ covering its basic facilities. Prerequisite: 106A or equivalent. GER:DB-EngrAppSci
3-5 units, Win (Zelenski, J), Spr (Staff), Sum (Staff)

ENGR 70X. Programming Abstractions (Accelerated)—(Same as CS 106X.) Intensive version of 106B for students with a strong programming background interested in a rigorous treatment of the topics at an accelerated pace. Additional advanced material and more challenging projects. Prerequisite: excellence in 106A or equivalent, or consent of instructor. GER:DB-EngrAppSci
3-5 units, Aut (Zelenski, J), Win (Cain, G)

ENGR 100. Teaching Public Speaking—The theory and practice of teaching public speaking and presentation development. Lectures/discussions on developing an instructional plan, using audiovisual equipment for instruction, devising 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, Spr (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. Prerequisite: freshman English. Corequisite for WIM: EE 108A.
1 unit, Aut, Win (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.
1 unit, Aut, Win (Staff)

ENGR 103. Public Speaking—Priority to Engineering students. 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 (Staff)

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 a variety of fields. Some use of computer aided design with MATLAB. Prerequisite: EE 102, ME 161, or equivalent. GER:DB-EngrAppSci
3 units, Win (Rock, S), Sum (Emami-Naeini, A)

ENGR 110. Perspectives in Assistive Technology—(Graduate students register for 210.) Seminar. The medical, social, psychological, and technical challenges in designing assistive technologies to improve the lives of people with disabilities. Guest speakers include professionals, clinicians, and device users. Additional unit for students who prepare a project background and preliminary design report for an assistive technology project to be undertaken in ME 113 or as independent study in Spring Quarter.
1-2 units, Win (Nelson, D)

ENGR 115. Design the Tech Challenge—(Graduate students register for 215.) Students work with Tech Museum of San Jose staff to design the Tech Challenge, a yearly engineering competition for 6-12th grade students. Brainstorming, field trips to the museum, prototyping, coaching, and presentations to the Tech Challenge advisory board. See at http://techchallenge.thetech.org. May be repeated for credit.
2 units, Win (Staff)

ENGR 120. Fundamentals of Petroleum Engineering—(Same as ENERGY 120.) Lectures, problems, field trip. 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. GER:DB-EngrAppSci
3 units, Aut (Horne, R)

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:DB-SocSci
4-5 units, Aut (McGinn, R)

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:DB-Hum
4 units, alternate years, not given this year

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, T)

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

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

ENGR 145. Technology Entrepreneurship—For juniors, seniors, and coterminal students of any major. The formation and growth of a high-impact enterprise including concepts essential to the entrepreneurial process, and the role of the individual and team in achieving success. Case studies, workshops, and a team project. GER:DB-SocSci
4 units, Aut (Gould, A; Kosnik, T), Win (Byers, T; Komisar, R; Kosnik, T)

ENGR 150. Social Innovation and Entrepreneurship—(Graduate students register for 250.) The art of innovation and entrepreneurship for social benefit. Project team develops, tests, and iteratively improves technology-based social innovation and business plan to deploy it. Feedback and coaching from domain experts, product designers, and successful social entrepreneurs. Limited enrollment; application required. See http://sie.stanford.edu.
1-6 units, Aut, Win, Spr (Behrman, W)

ENGR 154. Vector Calculus for Engineers—(Same as CME 100.) 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:DB-Math

5 units, Aut (Khayms, V; Darve, E)

ENGR 155A. Ordinary Differential Equations for Engineers—(Same as CME 102.) 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. MATLAB programming as a tool kit for computations. Problems from various engineering fields. Prerequisite: CME 100/ENGR 154 or MATH 51. GER:DB-Math

5 units, Win (Darve, E)

ENGR 155B. Linear Algebra and Partial Differential Equations for Engineers—(Same as CME 104.) 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 various engineering fields. Prerequisite: CME 102/ENGR 155A. GER:DB-Math

5 units, Spr (Khayms, V)

ENGR 155C. Introduction to Probability and Statistics for Engineers—(Same as CME 106.) 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/ENGR154 or MATH 51. GER:DB-Math

3-4 units, Win, Sum (Khayms, V)

ENGR 159Q. Japanese Companies and Japanese Society—(Same as MATSCI 159Q.) Stanford Introductory Seminar. 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. The Japanese research ethic. The home campus equivalent of a Kyoto SCTI course. GER:DB-SocSci

3 units, Spr (Sinclair, R)

ENGR 192. Engineering Public Service Project—Volunteer work on a public service project with a technical engineering component. Project requires a faculty sponsor and a community partner such as a nonprofit organization, school, or individual. Required report. See http://soe.stanford.edu/publicservice. May be repeated for credit. Prerequisite: consent of instructor.

1-2 units, Aut (Staff), Win (Sheppard, S), Spr (Staff), Sum (Sheppard, S)

ENGR 199. 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 section number corresponding to the particular faculty member. May be repeated for credit. Prerequisite: consent of instructor.

1-15 units, Aut, Win, Spr (Staff)

ENGR 199W. Writing of Original Research for Engineers—Technical writing in science and engineering. Students produce a substantial document describing their research, methods, and results. Prerequisite: completion of freshman writing requirements; prior or concurrent in 2 units of research in the major department; and consent of instructor. WIM for BioMedical Computation.

1-3 units, Aut, Win, Spr, Sum (Staff)

PRIMARILY FOR GRADUATE STUDENTS

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 (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 (Staff)

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: Matlab.

3 units, Aut (Rock, S)

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. Limited enrollment. Prerequisite: 105.

4 units, Spr (Niemeyer, G)

ENGR 207A. Linear Control Systems I—Introduction to control of discrete-time linear systems. State-space models. Controllability and observability. The linear quadratic regulator. Prerequisite: 105 or 205.

3 units, Aut (Lall, S)

ENGR 207B. Linear Control Systems II—Probabilistic methods for control and estimation. Statistical inference for discrete and continuous random variables. Linear estimation with Gaussian noise. The Kalman filter. Prerequisite: 207A or EE 263.

3 units, Win (Lall, S)

ENGR 207C. Linear Control Systems III—Introduction to stochastic control. Markov decision processes and stochastic dynamic programming. Separation of control and estimator design. Stochastic optimal control. Prerequisite: 207B.

3 units, not given this year (Lall, S)

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 (Staff)

ENGR 210. Perspectives in Assistive Technology—(Undergraduates register for 110; see 110.)

1-2 units, Win (Nelson, D)

ENGR 210A. Robust Control—Analysis and design techniques for multivariable feedback systems. Stability and robustness of feedback loops, passivity, and the small-gain theorem. Prerequisite: 207A or EE 263.

3 units, not given this year (Lall, S)

ENGR 210B. Advanced Topics in Computation for Control—Recent developments in computational techniques for feedback control systems. The use of convex optimization to solve problems in control. Prerequisites: Background in convex optimization, such as EE 364, and background in control, such as ENGR 207B.

3 units, not given this year (Lall, S)

ENGR 215. Design the Tech Challenge—(Undergraduates register for 115; see 115.)

2 units, Win (Staff)

ENGR 231. Transformative Design—Project-based. How interactive technologies can be designed to encourage behavioral transformation. Topics such as self-efficacy, social support, and mechanism of cultural change in domains such as weight-loss, energy conservation, or safe driving. Lab familiarizes students with hardware and software tools for interaction prototyping. Students teams create functional prototypes for self-selected problem domains.

3-5 units, Win (Roth, B; Ju, W; Jain, S)

ENGR 240. Introduction to Micro and Nano Electromechanical Systems (M/NEMS)—For first-year graduate students and seniors. The role of miniaturization technologies in materials, mechanical, biomedical engineering, and information technology. M/NEMS facbrication techniques, device applications, and the design tradeoffs in developing systems.

3 units, Aut (Pruitt, B)

ENGR 250. Social Innovation and Entrepreneurship—(Undergraduates register for 150; see 150.)

1-6 units, Aut, Win, Spr (Behrman, W)

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, not given this year

ENGR 290. Graduate Environment of Support—For course assistants (CAs) and tutors in the School of Engineering tutorial and learning program. Interactive training for effective academic assistance. Pedagogy, developing course material, tutoring, and advising. Sources include video, readings, projects, and role playing.

1 unit, Aut (Osgood, B; Lozano, N)

ENGR 298. Seminar in Fluid Mechanics—Interdepartmental. 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. May be repeated for credit.

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

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, Sum (Staff)

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, M; Leifer, L)

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.

3-5 units, **B:** *Win,* **C:** *Spr (Cutkosky, M; Leifer, L)*

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. May be repeated for credit. Prerequisite: consent of instructor. Corequisite: ENGR 310A,B,C.

1-5 units, Aut, Win, Spr, Sum (Leifer, L; Cutkosky, M)

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. May be repeated for credit.

1 unit, Win (Staff)

ENGR 311B. Design the Engineer—The nature of engineering work; how to integrate this work into students' future. Prerequisite: 311A or consent of instructor.

1 unit, Spr (Roth, B)

ENGR 341. Micro/Nano Systems Design and Fabrication Laboratory—Theory and fundamentals. Hands-on training in the Stanford Nanofabrication Facility. Prerequisite: ENGR 240 or equivalent.

3-5 units, Spr (Solgaard, O; Pruitt, B)

OVERSEAS STUDIES

These courses 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

OSPBER 40B. Introductory Electronics
5 units, Aut, Win (Howe, R), Spr (Wong, S)

OSPBER 50B. Introductory Science of Materials
4 units, Aut, Win, Spr (Staff)

FLORENCE

OSPFLOR 50F. Introductory Science of Materials
4 units, Aut Aut, Win, Spr (Staff)

KYOTO

OSPKYOTO 40K. Introductory Electronics
5 units, Spr (Wong, S)

PARIS

OSPPARIS 40P. Introductory Electronics
5 units, Aut, Spr (Wong, S)

OSPPARIS 50P. Introductory Science of Materials
4 units, Aut, Win (Staff)

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