SCHOOL OF ENGINEERING

Courses offered by the School of Engineering are listed under the subject code ENGR on the Stanford Bulletin's ExploreCourses web site.

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 interdisciplinary research centers and programs within the school as well as several interschool activities, including the Army High Performance Computing Research Center, Biomedical Informatics Training Program, Center for Integrated Systems, Center for Work, Technology, and Organization, Collaboratory for Research on Global Projects, National Center for Physics-Based Simulation in Biology, Center for Position, Navigation, and Time, the Energy Modeling Forum, the NIH Biotechnology Graduate Training Grant in Chemical Engineering, and the Stanford Technology Ventures Program. Energy Resources Engineering (formerly Petroleum Engineering) is offered through the School of Earth, Energy, and Environmental Sciences.

The School of Engineering’s Hasso Plattner Institute of Design (also known as “the d.school,” 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.

The Global Engineering Program (https://engineering.stanford.edu/students/global-engineering-programs) offers a portfolio of international opportunities for Stanford undergraduate and graduate students majoring within the School of Engineering. Opportunities range from service learning programs to internships to study tours. These opportunities enhance engineering education by providing students with an opportunity to learn about technology and engineering globally, to build professional networks, and to gain real world experience in a culturally diverse and international environment. For more information and application deadlines, please see gep.stanford.edu

Instruction in Engineering is offered primarily during 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 in the School of Engineering

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 the definitive reference for all undergraduate engineering programs. It 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. Because it is revised in the summer, and updates are made to the web site on a continuing basis, the handbook reflects the most up-to-date information on School of Engineering programs for the academic year.

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
- 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 Handbook for Undergraduate Engineering Programs 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 135 Huang Engineering Center.

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

Freshman

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 "AP Credit (http://exploredegrees.stanford.edu/undergraduatedegreesandprograms/#aptext)" section of this bulletin
Curricula for majors in these departments have the following requirements and scope.

The B.S. for an Individually Designed Major in Engineering has also been proposed by the School of Engineering Center. For more information, see the transfer credit section of the Handbook for Undergraduate Engineering Programs at http://ughb.stanford.edu.

Transfer credit is given for courses taken elsewhere whenever the courses are equivalent or substantially similar to courses offered at Stanford. 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 135 Huang Engineering Center. For more information, see the transfer credit section of the Handbook for Undergraduate Engineering Programs at http://ughb.stanford.edu.

**Degree Program Options**

In addition to the B.S. degrees offered by departments, the School of Engineering offers two other types of B.S. degrees:

- Bachelor of Science in Engineering (see subplan majors listed below)
- Bachelor of Science for Individually Designed Majors in Engineering (IDMEN)

There are six Engineering B.S. subplans that have been proposed by cognizant faculty groups and approved by the Undergraduate Council:

- Architectural Design
- Atmosphere/Energy
- Biomedical Engineering
- Biomedical Computation
- Engineering Physics
- Product Design

The B.S. for an Individually Designed Major in Engineering has also been approved by the council.

Curricula for majors are offered by the departments of:

- Aeronautics and Astronautics
- Bioengineering
- Chemical Engineering
- Civil and Environmental Engineering
- Computer Science
- Electrical Engineering
- Management Science and Engineering
- Materials Science and Engineering
- Mechanical Engineering

Curricula for majors in these departments have the following components:

- 36-45 units of mathematics and science (see Basic Requirement 1 and 2 at the end of this section)
- Engineering fundamentals (two-three courses minimum, depending on individual program requirements; see Basic Requirement 3)
- Technology in Society (TIS) (one course minimum, see Basic Requirement 4)
- Engineering depth (courses such that the total number 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)

Consult the 2017-18 Handbook for Undergraduate Engineering Programs (http://ughb.stanford.edu) for additional information.

**Dual and Coterminal 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. Five years are usually required for a dual or coterminal program or for a combination of these two multiple degree programs. For further information, inquire with the School of Engineering’s student affairs office, 135 Huang Engineering Center, or with department contacts listed in the Handbook for Undergraduate Engineering Programs, available at http://ughb.stanford.edu.

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 (3 full-time quarters after completing 180 units)
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 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
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.

**Procedure for Applying for Admission to Coterminal Degree Programs**

Stanford undergraduates apply to the pertinent graduate department using the University coterminal application. Application deadlines and admissions criteria 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 interested in coterminal degree programs in Engineering should refer to our departments’ sections of this bulletin for more detailed information.
information. The University requirements for the coterminal master's degree are described in the "Coterminal Master's Degrees (http://exploredegrees.stanford.edu/cotermdegrees/#text)" section of this bulletin.

Graduate Programs in the School of Engineering

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.

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 under "Degree Program Options" in the "Undergraduate Programs in the School of Engineering (http://www.stanford.edu/dept/Registrar/bulletin/5144.htm)" section of this bulletin.

Fellowships and Assistantships

Departments and divisions of the School of Engineering award graduate fellowships, research assistantships, and teaching assistantships each year.

Curricula in the School of Engineering

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 choose 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 programs of the school offer graduate curricula as follows:

Aeronautics and Astronautics
- Aeroelasticity and Flow Simulation
- Aircraft Design, Performance, and Control
- Applied Aerodynamics
- Autonomy
- Computational Aero-Acoustics
- Computational Fluid Dynamics
- Computational Mechanics and Dynamical Systems
- Control of Robots, including Space and Deep-Underwater Robots
- Conventional and Composite Materials and Structures
- Decision Making under Uncertainty
- Direct and Large-Eddy Simulation of Turbulence
- High-Lift Aerodynamics
- Hybrid Propulsion
- Hypersonic and Supersonic Flow
- Micro and Nano Systems and Materials
- Multidisciplinary Design Optimization
- Navigation Systems (especially GPS)
- Optimal Control, Estimation, System Identification
- Sensors for Harsh Environments
- Space Debris Characterization
- Space Environment Effects on Spacecraft
- Space Plasmas
- Spacecraft Design and Satellite Engineering
- Turbulent Flow and Combustion

Bioengineering
- Biomedical Computation
- Biomedical Devices
- Biomedical Imaging
- Cell and Molecular Engineering
- Regenerative Medicine

Chemical Engineering
- Applied Statistical Mechanics
- Biocatalysis
- Biochemical Engineering
- Bioengineering
- Biophysics
- Computational Materials Science
- Colloid Science
- Dynamics of Complex Fluids
- Energy Conversion
- Functional Genomics
- Hydrodynamic Stability
- Kinetics and Catalysis
- Micro rheology
- Molecular Assemblies
- Nanoscience and Technology
- Newtonian and Non-Newtonian Fluid Mechanics
- Polymer Physics
- Protein Biotechnology
- Renewable Fuels
- Semiconductor Processing
- Soft Materials Science
- Solar Utilization
- Surface and Interface Science
- Transport Mechanics

Civil and Environmental Engineering
- Atmosphere/Energy
- Environmental Engineering
- Environmental and Water Studies
- Geomechanics
- Structural Engineering
- Sustainable Design and Construction

Computational and Mathematical Engineering
- Applied and Computational Mathematics
- Computational Biology
- Computational Fluid Dynamics
- Computational Geometry and Topology
- Computational Geosciences
- Computational Medicine
- Data Science
- Discrete Mathematics and Algorithms
- Numerical Analysis
• Optimization
• Partial Differential Equations
• Stochastic Processes
• Uncertainty Quantification
• Financial Mathematics

**Computer Science**
See http://forum.stanford.edu/research/areas.php for a comprehensive list.

• Algorithmic Game Theory
• Algorithms
• Artificial Intelligence
• Autonomous Agents
• Biomedical Computation
• Compilers
• Complexity Theory
• Computational and Cognitive Neuroscience
• Computational Biology
• Computational Geometry and Topology
• Computational Logic
• Computational Photography
• Computational Physics
• Computational Social Science
• Computer Architecture
• Computer Graphics
• Computer Security
• Computer Science Education
• Computer Sound
• Computer Vision
• Crowdsourcing
• Cryptography
• Database Systems
• Data Center Computing
• Data Mining
• Design and Analysis of Algorithms
• Distributed and Parallel Computation
• Distributed Systems
• Electronic Commerce
• Formal Verification
• General Game Playing
• Haptic Display of Virtual Environments
• Human-Computer Interaction
• Image Processing
• Information and Communication Technologies for Development
• Information Management
• Learning Theory
• Machine Learning
• Mathematical Theory of Computation
• Mobile Computing
• Multi-Agent Systems
• Nanotechnology-enabled Systems
• Natural Language and Speech Processing
• Networking and Internet Architecture
• Operating Systems
• Parallel Computing
• Probabilistic Models and Methods
• Programming Systems/Languages
• Robotics
• Robust System Design
• Scientific Computing and Numerical Analysis
• Sensor Networks
• Social and Information Networks
• Social Computing
• Ubiquitous and Pervasive Computing
• Visualization
• Web Application Infrastructure

**Electrical Engineering**

• Biomedical Devices and Bioimaging
• Communication Systems: Wireless, Optical, Wireline
• Control, Learning, and Optimization
• Electronic and Magnetic Devices
• Energy: Solar Cells, Smart Grid, Load Control
• Environmental and Remote Sensing: Sensor Nets, Radar Systems, Space
• Fields and Waves
• Graphics, HCI, Computer Vision, Photography
• Information Theory and Coding: Image and Data Compression, Denoising
• Integrated Circuit Design: MEMS, Sensors, Analog RF
• Network Systems and Science: Nest Gen Internet, Wireless Networks
• Nano and Quantum Science
• Photonic Devices
• Systems Software: OS, Compilers, Languages
• Systems Hardware: Architecture, VLSI, Embedded Systems
• VLSI Design

**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

Bachelor of Science in the School of Engineering
Departments within the School of Engineering offer programs leading to the Bachelor of Science degree in the following fields:

• Aeronautics and Astronautics
• Bioengineering
• Chemical Engineering
• Civil Engineering
• Computer Science
• Electrical Engineering
• Environmental Systems Engineering
• Management Science and Engineering
• Materials Science and Engineering
• Mechanical Engineering

The School of Engineering itself offers interdisciplinary programs leading to the Bachelor of Science degree in Engineering with specializations in:

• Architectural Design
• Atmosphere/Energy
• Biomechanical Engineering
• Biomedical Computation
• Engineering Physics
• Product Design

In addition, students may elect a Bachelor of Science in an Individually Designed Major in Engineering.

Bachelor of Arts and Science (B.A.S.) in the School of Engineering
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 (http://exploredegrees.stanford.edu/undergraduatedegrees#bachelors)" section of this bulletin.

Independent Study, Research, and Honors
The departments of Aeronautics and Astronautics, Bioengineering, Chemical Engineering, Civil and Environmental Engineering, Computer Science, Electrical Engineering, Materials Science and Engineering, and Mechanical Engineering, as well as the faculty overseeing the Architectural Design, Atmosphere/Energy, Biomechanical Engineering, Biomedical Computation, and Engineering Physics majors, offer qualified students 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. An honors option is also available to students pursuing an independently designed major, with the guidance and approval of their adviser.

Petroleum Engineering
Petroleum Engineering is offered by the Department of Energy Resource Engineering in the School of Earth, Energy, and Environmental Sciences. Consult the "Energy Resources Engineering (http://exploredegrees.stanford.edu/schoolofearthsciences/energyresourcesengineering)" 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.

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).

Basic Requirements

Basic Requirement 1 (Mathematics)
Engineering students need a solid foundation in the calculus of continuous functions, linear algebra, an introduction to discrete mathematics, and an understanding of statistics and probability theory. Students are encouraged to select courses on 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 physics, chemistry, geology, and biology 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 two to three courses from the following list (the number depends upon the individual requirements of each major program):

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 10</td>
<td>Introduction to Engineering Analysis</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 14</td>
<td>Intro to Solid Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 15</td>
<td>Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 20</td>
<td>Introduction to Chemical Engineering</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 21</td>
<td>Engineering of Systems</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 25B</td>
<td>Biotechnology</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 25E</td>
<td>Energy: Chemical Transformations for Production, Storage, and Use (same as CHEMENG 25E)</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 40</td>
<td>Introductory Electronics</td>
<td>5</td>
</tr>
<tr>
<td>ENGR 40A</td>
<td>Introductory Electronics</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 40M</td>
<td>An Intro to Making: What is EE</td>
<td>3-5</td>
</tr>
<tr>
<td>ENGR 50</td>
<td>Introduction to Materials Science, Nanotechnology Emphasis</td>
<td>1,2</td>
</tr>
<tr>
<td>ENGR 50E</td>
<td>Introduction to Materials Science, Energy Emphasis</td>
<td>1</td>
</tr>
<tr>
<td>ENGR 50M</td>
<td>Introduction to Materials Science, Biomaterials Emphasis</td>
<td>1</td>
</tr>
<tr>
<td>ENGR 60</td>
<td>Engineering Economics and Sustainability</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 62</td>
<td>Introduction to Optimization (same as MS&amp;E 111)</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 70A/CS 106A</td>
<td>Programming Methodology</td>
<td>5</td>
</tr>
<tr>
<td>ENGR 70B/CS 106B</td>
<td>Programming Abstractions</td>
<td>5</td>
</tr>
<tr>
<td>ENGR 70X/CS 106X</td>
<td>Programming Abstractions (Accelerated)</td>
<td>5</td>
</tr>
<tr>
<td>ENGR 80</td>
<td>Introduction to Bioengineering (Engineering Living Matter) (same as BIEE 80)</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 90</td>
<td>Environmental Science and Technology (same as CEE 70)</td>
<td>3</td>
</tr>
</tbody>
</table>

1 Only one course from each numbered series can be used in the Engineering Fundamentals category within a major program.
2 ENGR 40M Making Stuff: What is EE and ENGR 50 Introduction to Materials Science, Nanotechnology Emphasis 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 (Engineering Topics)
In order to satisfy ABET (Accreditation Board for Engineering and Technology) requirements, a student majoring in Chemical, Civil, or Mechanical Engineering must complete one and a half years of engineering topics, consisting of a minimum of 68 units of Engineering Fundamentals and Engineering Depth appropriate to the student’s field of study. In most cases, students meet this requirement by completing the major program core and elective requirements. A student may need to take additional courses in Depth in order to fulfill the minimum requirement. Appropriate courses assigned to fulfill each major’s program are listed online at http://ughb.stanford.edu in the Handbook for Undergraduate Engineering Programs.

Experimentation
Chemical Engineering, Civil Engineering, and Mechanical Engineering must include experimental experience appropriate to the discipline. Lab courses taken in the sciences, as well as experimental work taken in courses within the School of Engineering, will fulfill this requirement.

Overseas Studies Courses in Engineering
For course descriptions and additional offerings, see the listings in the Stanford Bulletin’s ExploreCourses web site (http://explorecourses.stanford.edu) or the Bing Overseas Studies web site (http://bosp.stanford.edu). Students should consult their department or program’s student services office for applicability of Overseas Studies courses to a major or minor program.

Aeronautics and Astronautics (AA)
Mission of the Undergraduate Program in Aeronautics and Astronautics
The mission of the undergraduate program in Aeronautics and Astronautics Engineering is to provide students with the fundamental principles and techniques necessary for success and leadership in the conception, design, implementation, and operation of aerospace and related engineering systems. Courses in the major introduce students to engineering principles. Students learn to apply this fundamental knowledge to conduct laboratory experiments, and aerospace system design problems. Courses in the major include engineering fundamentals, mathematics, and the sciences, as well as in-depth courses in aeronautics and astronautics, dynamics, mechanics of materials, autonomous systems, computational engineering, embedded programming, fluids engineering, and heat transfer. The major prepares students for careers in aircraft and spacecraft engineering, autonomy, robotics, unmanned aerial vehicles, drones, space exploration, air and space-based telecommunication industries, computational engineering, teaching, research, military service, and other related technology-intensive fields.

Completion of the undergraduate program in Aeronautics and Astronautics leads to the conferral of the Bachelor of Science in Aeronautics and Astronautics.

Requirements

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 19</td>
<td>Calculus (required )</td>
<td>3</td>
</tr>
<tr>
<td>MATH 20</td>
<td>Calculus (required )</td>
<td>3</td>
</tr>
<tr>
<td>MATH 21</td>
<td>Calculus (required )</td>
<td>4</td>
</tr>
<tr>
<td>CME 100/ENGR 154</td>
<td>Vector Calculus for Engineers (required)</td>
<td>3</td>
</tr>
<tr>
<td>or MATH 51</td>
<td>Linear Algebra and Differential Calculus of Several Variables</td>
<td>5</td>
</tr>
</tbody>
</table>
Aero/Astro Focus Electives
15 units minimum

AA 102 Introduction to Applied Aerodynamics 1
AA 103 Air and Space Propulsion 1
AA 111 Introduction to Aerospace Computational Engineering 1

Aero/Astro Capstone Requirement
7 units minimum

AA 123A Air Capstone I, satisfies the Writing in the Major requirement, (WIM) 1
AA 123B Air Capstone II 1
AA 124A Space Capstone I, satisfies the Writing in Major requirement, (WIM) 1
AA 124B Space Capstone II 1

Aero/Astro Suggested Courses (not required)

AA 135 Introduction to Space Policy 1
AA 151 Lightweight Structures 1
AA 156 Mechanics and Composites 1
AA 173 Flight Mechanics and Controls 1
AA 175 Embedded Programming 1
AA 272C Global Positioning Systems 3
AA 279A Space Mechanics 3
AA 199 Independent Study in Aero/Astro 1-5

Aero/Astro Suggested Courses (not required)

MS&E 178 The Spirit of Entrepreneurship 2

Science
20 units minimum

PHYS 41 Mechanics (required) 4
PHYS 43 Electricity and Magnetism (required) 4
PHYS 45 Light and Heat (required) 4
CHEM 31X Chemical Principles Accelerated ( or CHEM 31A and CHEM 31B, or AP Chemistry) (required) 5
ENGR 80 Introduction to Bioengineering (Engineering Living Matter) (recommended) 4

School of Engineering approved Science Electives: See Undergraduate Handbook, Figure 4-2

Technology in Society (one course required)
School of Engineering approved Technology in Society courses: See Undergraduate Handbook, Figure 4-3. The course must be on the School of Engineering approved list the year you take it.
ENGR 131 Ethical Issues in Engineering (recommended) 4

Engineering Fundamentals (three courses required)
11 units minimum

ENGR 21 Engineering of Systems (required) 3
ENGR 70A/CS 106A Programming Methodology (required) 5
ENGR 10 Introduction to Engineering Analysis (recommended) 4
ENGR 40M An Intro to Making: What is EE (recommended) 3-5

Fundamentals Elective; see list of Approved Courses in Undergraduate Engineering Handbook website at ughb.stanford.edu, Figure 4-4

Aero/Astro Depth Requirements
27 units minimum

ENGR 14 Intro to Solid Mechanics (required) 3
ENGR 15 Dynamics (required) 3
ENGR 105 Feedback Control Design (required) 3
ME 30 Engineering Thermodynamics (required) 3
AA 100 Introduction to Aeronautics and Astronautics (required) 3

AA 101 Introduction to Aero Fluid Mechanics, required 1
AA 131 Space Flight, required 1
AA 141 Atmospheric Flight (required) 3
AA 171 Autonomous Systems, required 1
AA 190 Directed Research and Writing in Aero/Astro 3-5

Architectural Design (AD)
Completion of the undergraduate program in Architectural Design leads to the conferral of the Bachelor of Science in Engineering. The subplan "Architectural Design" appears on the transcript and on the diploma.

Mission of the Undergraduate Program in Architectural Design
The mission of the undergraduate program in Architectural Design is to develop students' ability to integrate engineering and architecture in ways that blend innovative architectural design with cutting-edge engineering technologies. Courses in the program combine hands-on architectural design studios with a wide variety of other courses. Students can choose
from a broad mix of elective courses concerning energy conservation, sustainability, building systems, and structures, as well as design foundation and fine arts courses. In addition to preparing students for advanced studies in architecture and construction management, the program's math and science requirements prepare students well for graduate work in other fields such as civil and environmental engineering, law, and business.

Requirements

Mathematics and Science (36 units minimum) ¹

Mathematics

MATH 19 Calculus 3
MATH 20 Calculus 3
MATH 21 Calculus 4
Or 10 units AP Calculus or MATH 41 & MATH 42
CME 100 Vector Calculus for Engineers (Recommended) 5
One course in Statistics (required) 3-5

Science

PHYSICS 41 Mechanics 4
Recommended:
EARTHSYS 101 Energy and the Environment
EARTHSYS 102 Fundamentals of Renewable Power
CEE 64 Air Pollution and Global Warming: History, Science, and Solutions
CEE 70 Environmental Science and Technology
PHYSICS 23 Electricity, Magnetism, and Optics or PHYSICS 43 Electricity and Magnetism

Or from School of Engineering approved list

Technology in Society

One course required; course chosen must be on the SoE Approved Courses list at ughb.stanford.edu the year taken. 3-5

Engineering Fundamentals

Two courses minimum, see Basic Requirement 3 6-8
ENGR 14 Intro to Solid Mechanics 3

AD Depth Core ²

CEE 31 Accessing Architecture Through Drawing 5
or CEE 31Q Accessing Architecture Through Drawing
CEE 100 Managing Sustainable Building Projects (or CEE 32D or CEE 32G) 4
CEE 120A Building Information Modeling Workshop 2-4
CEE 130 Architectural Design: 3-D Modeling, Methodology, and Process 5
CEE 137B Advanced Architecture Studio 6
ARTHIST 3 Introduction to World Architecture 5

Depth Options 12

See Note 2 for course options

Depth Electives

Elective units must be such that courses in ENGR Fundamentals, Core, Depth Options, and Depth Electives total at least 63 units. One of the following must be taken:

CEE 131C How Buildings are Made – Materiality and Construction Methods 4
CEE 131D Urban Design Studio 5
CEE 32D Construction: The Writing of Architecture
CEE 32G Architecture Since 1900
CEE 32H Responsive Structures
CEE 32V Architectural Design Lecture Series Course

CEE 32T Making and Remaking the Architect: Edward Durell Stone and Stanford
CEE 32U California Modernism: The Web of Apprenticeship
CEE 32W Making Meaning: A Purposeful Life in Design
CEE 133F Principles of Freehand Drawing
CEE 139 Design Portfolio Methods

Total Units 82-90

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (http://ughb.stanford.edu).

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 options: Choose at least 12 units from the following courses: CEE 101A, CEE 101B, CEE 101C, CEE 156, CEE 172, CEE 172A, CEE 176A, CEE 180, CEE 181, CEE 182, CEE 183, CEE 226, CEE 241, OR CEE 242. Students should investigate any prerequisites for the listed courses and carefully plan course sequences with the AD director.

Electives:

- ENGR 50, ENGR 103, ENGR 131
- ME 101, ME 110, ME 115A/B/C, ME 120, ME 203
- ARTSTUDI 138X, ARTSTUDI 140, ARTSTUDI 145, ARTSTUDI 151, ARTSTUDI 153, ARTSTUDI 160, ARTSTUDI 162, ARTSTUDI 163, ARTSTUDI 164, ARTSTUDI 168, ARTSTUDI 170, ARTSTUDI 171, ARTSTUDI 181
- ARTHIST 107A, ARTHIST 142, ARTHIST 143A, ARTHIST 188A
- FILMPROD 114
- TAPS 137
- SINY 122, URBANST 110, URBANST 113, URBANST 163, URBANST 171

Architectural Design Honors Program

The AD program offers eligible students the opportunity to engage in guided original research, or project design, over the course of an academic year. For interested students the following outlines the process:

1. The student must submit a letter applying for the honors option endorsed by the student’s primary adviser and honors adviser and submitted to the student services office in CEE. Applications must be received in the fourth quarter prior to graduation. It is strongly suggested that students meet with the Architectural Design Program Director well in advance of submitting an application.

2. The student must maintain a GPA of at least 3.5.

3. The student must complete an honors thesis or project. The timing and deadlines are to be decided by the program or honors adviser. At least one member of the evaluation committee must be a member of the Academic Council in the School of Engineering.

4. The student must present the work in an appropriate forum, e.g., in the same session as honors theses are presented in the department of the advisor. All honors programs require some public presentation of the thesis or project.

Atmosphere/Energy (A/E)

Completion of the undergraduate program in Atmosphere/Energy leads to the conferral of the Bachelor of Science in Engineering. The subplan “Atmosphere/Energy” appears on the transcript and on the diploma.

Mission of the Undergraduate Program in Atmosphere/Energy

Atmosphere and energy are strongly linked: fossil-fuel energy use contributes to air pollution, global warming, and weather modification;
and changes in the atmosphere feed back to renewable energy resources, including wind, solar, hydroelectric, and wave resources. The mission of the undergraduate program in Atmosphere/Energy (A/E) is to provide students with the fundamental background necessary to understand large- and local-scale climate, air pollution, and energy problems and solve them through clean, renewable, and efficient energy systems.

To accomplish this goal, students learn in detail the causes and proposed solutions to the problems, and learn to evaluate whether the proposed solutions are truly beneficial. A/E students take courses in renewable energy resources, indoor and outdoor air pollution, energy efficient buildings, climate change, renewable energy and clean-vehicle technologies, weather and storm systems, energy technologies in developing countries, electric grids, and air quality management. The curriculum is flexible. Depending upon their area of interest, students may take in-depth courses in energy or atmosphere and focus either on science, technology, or policy. The major is designed to provide students with excellent preparation for careers in industry, government, and research; and for study in graduate school.

Requirements

Mathematics and Science (45 units minimum):

Mathematics
23 units minimum, including at least one course from each group:

Group A
- MATH 53: Ordinary Differential Equations with Linear Algebra
- CME 102: Ordinary Differential Equations for Engineers

Group B
- CME 106: Introduction to Probability and Statistics for Engineers
- STATS 60: Introduction to Statistical Methods: Precalculus
- STATS 101: Data Science 101
- STATS 110: Statistical Methods in Engineering and the Physical Sciences

Science
20 units minimum, including all of the following:

- PHYSICS 41: Mechanics
- PHYSICS 43: Electricity and Magnetism
- or PHYSICS 45: Light and Heat
- CHEM 31B: Chemical Principles II
- or CHEM 31X: Chemical Principles Accelerated
- CEE 70: Environmental Science and Technology

Technology in Society (1 course)
3-5 units

One 3-5 unit course required; must be on School of Engineering Approved List the year taken.

Writing in the Major (WIM)

One 3-5 unit course required. Choose a TiS course that fulfills a WIM:

- BIOE 131: Ethics in Bioengineering
- COMM 120W: Digital Media in Society
- OR one of these WIM courses:
  - CEE 100: Managing Sustainable Building Projects
  - EARTHSYS 200: Environmental Communication in Action: The SAGE Project

Engineering Fundamentals

Two courses minimum (recommend 3), including at least one of the following:

- ENGR 25E: Energy: Chemical Transformations for Production, Storage, and Use
- ENGR 50E: Introduction to Materials Science, Energy Emphasis

Plus at least one of the following:

- ENGR 10: Introduction to Engineering Analysis
- ENGR 70A: Programming Methodology

A third Fundamental is optional but recommended (3-4 units)

Engineering Depth

Required: 6-8 units

- CEE 64: Air Pollution and Global Warming: History, Science, and Solutions (cannot also fulfill science requirement)
- CEE 107A: Understanding Energy
- or CEE 107S: Energy Resources: Fuels and Tools

34-36 units from the following with at least four courses from each group:

Group A: Atmosphere
- AA 100: Introduction to Aeronautics and Astronautics
- CEE 63: Weather and Storms
- CEE 101B: Mechanics of Fluids
- or ME 70: Introductory Fluids Engineering
- CEE 161C: Natural Ventilation of Buildings
- CEE 161I: Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation
- CEE 162I: Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation
- CEE 172: Air Quality Management
- CEE 178: Introduction to Human Exposure Analysis
- EARTHSYS 41N: The Global Warming Paradox
- EARTHSYS 111: Biology and Global Change
- EARTHSYS 142: Remote Sensing of Land
- or EARTHSYS 1Fundamentals of Geographic Information Science (GIS)
- EARTHSYS 188: Social and Environmental Tradeoffs in Climate Decision-Making
- ME 131B: Fluid Mechanics: Compressible Flow and Turbomachinery
- MS&E 92Q: International Environmental Policy
- PHYSICS 199: The Physics of Energy and Climate Change
- EARTH 2: Climate and Society
- EARTHSYS 196: Implementing Climate Solutions at Scale

Group B: Energy

- APPHYS 79Q: Energy Options for the 21st Century
- AA 116Q: Electric Automobiles and Aircraft
- or EE 155: Green Electronics
- CEE 156: Building Systems
- CEE 176A: Energy Efficient Buildings
- CEE 176B: Electric Power: Renewables and Efficiency
- CEE 176C: Energy Storage Integration - Vehicles, Renewables, and the Grid
- CEE 177S: Design for a Sustainable World
- EARTHSYS 46C: Environmental Impact of Energy Systems: What are the Risks?
- EARTHSYS 101: Energy and the Environment
- EARTHSYS 102: Fundamentals of Renewable Power

- ECON 17N: Energy, the Environment, and the Economy (OR OSPKYOTO 45 OR SIW 144)
- EE 151: Sustainable Energy Systems
- ENERGY 104: Sustainable Energy for 9 Billion
- ENGR 50E: Introduction to Materials Science, Energy Emphasis
- MATSCI 156: Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution
The Stanford Bioengineering major enables students to combine engineering and the life sciences in ways that advance scientific discovery, healthcare and medicine, manufacturing, environmental quality, culture, education, and policy. Students who major in BioE earn a fundamental engineering degree for which the raw materials, underlying basic sciences, fundamental toolkit, and future frontiers are all defined by the unique properties of living systems.

Students will complete engineering fundamentals courses, including an introduction to bioengineering and computer programming. A series of core BIOE classes beginning in the second year leads to a student-selected depth area and a senior capstone design project. The department also organizes a summer Research Experience for Undergraduates (REU) (http://bioengineering.stanford.edu/student-resources/reu) program. BIOE graduates are well prepared to pursue careers and lead projects in research, medicine, business, law, and policy.

Requirements
Mathematics

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 19</td>
<td>Calculus</td>
<td>10</td>
</tr>
<tr>
<td>&amp; MATH 20</td>
<td>and Calculus</td>
<td>10</td>
</tr>
<tr>
<td>&amp; MATH 21</td>
<td>and Calculus</td>
<td>10</td>
</tr>
</tbody>
</table>

Select one of the following sequences:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 100</td>
<td>Vector Calculus for Engineers</td>
<td>10</td>
</tr>
<tr>
<td>&amp; CME 102</td>
<td>and Ordinary Differential Equations for Engineers (Recommended)</td>
<td></td>
</tr>
<tr>
<td>MATH 51</td>
<td>Linear Algebra and Differential Calculus of Several Variables</td>
<td>10</td>
</tr>
<tr>
<td>&amp; MATH 53</td>
<td>and Ordinary Differential Equations with Linear Algebra</td>
<td></td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 106</td>
<td>Introduction to Probability and Statistics for Engineers (Recommended)</td>
<td>4-5</td>
</tr>
<tr>
<td>or STATS 110</td>
<td>Statistical Methods in Engineering and the Physical Sciences</td>
<td></td>
</tr>
<tr>
<td>or STATS 141</td>
<td>Biostatistics</td>
<td></td>
</tr>
</tbody>
</table>

Science

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 31X</td>
<td>Chemical Principles Accelerated</td>
<td>5-10</td>
</tr>
</tbody>
</table>
or CHEM 31A | Chemical Principles I | |
& CHEM 31B | and Chemical Principles II | |
| CHEM 33 | Structure and Reactivity of Organic Molecules | 5 |
| BIO 82 | Genetics | 4 |
| BIO 84 | Physiology | 4 |
| PHYSICS 41 | Mechanics | 4 |
| PHYSICS 43 | Electricity and Magnetism | 4 |

Technology in Society

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOE 131</td>
<td>Ethics in Bioengineering (WIM)</td>
<td>3</td>
</tr>
</tbody>
</table>

Engineering Fundamentals

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 70A</td>
<td>Programming Methodology (same as CS 106A)</td>
<td>5</td>
</tr>
<tr>
<td>ENGR 80</td>
<td>Introduction to Bioengineering (Engineering Living Matter)</td>
<td>4</td>
</tr>
</tbody>
</table>

Fundamentals Elective; see UGHB Fig. 3-4 for approved course list; may not use ENGR 70B or ENGR 70X

Bioengineering Core

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOE 42</td>
<td>Physical Biology</td>
<td>4</td>
</tr>
<tr>
<td>BIOE 44</td>
<td>Fundamentals for Engineering Biology Lab</td>
<td>4</td>
</tr>
<tr>
<td>BIOE 101</td>
<td>Systems Biology</td>
<td>3</td>
</tr>
<tr>
<td>BIOE 103</td>
<td>Systems Physiology and Design</td>
<td>4</td>
</tr>
<tr>
<td>BIOE 123</td>
<td>Biomedical System Prototyping Lab</td>
<td>4</td>
</tr>
<tr>
<td>BIOE 141A</td>
<td>Senior Capstone Design I</td>
<td>4</td>
</tr>
<tr>
<td>BIOE 141B</td>
<td>Senior Capstone Design II</td>
<td>4</td>
</tr>
</tbody>
</table>
Bioengineering Depth Electives

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOE 115</td>
<td>Computational Modeling of Microbial Communities</td>
</tr>
<tr>
<td>BIOE 122</td>
<td>Biosecurity and Bioterrorism Response</td>
</tr>
<tr>
<td>BIOE 140</td>
<td>Physical Biology of Macromolecules</td>
</tr>
<tr>
<td>BIOE 201C</td>
<td>Diagnostic Devices Lab</td>
</tr>
<tr>
<td>BIOE 211</td>
<td>Biophysics of Multi-cellular Systems and Amorphous Computing</td>
</tr>
<tr>
<td>BIOE 212</td>
<td>Introduction to Biomedical Informatics Research Methodology</td>
</tr>
<tr>
<td>BIOE 214</td>
<td>Representations and Algorithms for Computational Molecular Biology</td>
</tr>
<tr>
<td>BIOE 217</td>
<td>Translational Bioinformatics</td>
</tr>
<tr>
<td>BIOE 220</td>
<td>Introduction to Imaging and Image-based Human Anatomy</td>
</tr>
<tr>
<td>BIOE 221</td>
<td>Physics and Engineering of Radionuclide-based Medical Imaging</td>
</tr>
<tr>
<td>BIOE 222</td>
<td>Instrumentation and Applications for Multi-modality Molecular Imaging of Living Subjects</td>
</tr>
<tr>
<td>BIOE 223</td>
<td>Physics and Engineering of X-Ray Computed Tomography</td>
</tr>
<tr>
<td>BIOE 224</td>
<td>Probes and Applications for Multi-modality Molecular Imaging of Living Subjects</td>
</tr>
<tr>
<td>BIOE 225</td>
<td>Ultrasound Imaging and Therapeutic Applications</td>
</tr>
<tr>
<td>BIOE 227</td>
<td>Functional MRI Methods</td>
</tr>
<tr>
<td>BIOE 231</td>
<td>Protein Engineering</td>
</tr>
<tr>
<td>BIOE 244</td>
<td>Advanced Frameworks and Approaches for Engineering Integrated Genetic Systems</td>
</tr>
<tr>
<td>BIOE 253</td>
<td>Science and Technology Policy</td>
</tr>
<tr>
<td>BIOE 260</td>
<td>Tissue Engineering</td>
</tr>
<tr>
<td>BIOE 279</td>
<td>Computational Biology: Structure and Organization of Biomolecules and Cells</td>
</tr>
<tr>
<td>BIOE 281</td>
<td>Biomechanics of Movement</td>
</tr>
<tr>
<td>BIOE 287</td>
<td>Principles and Practice of Optogenetics for Optical Control of Biological Tissues</td>
</tr>
</tbody>
</table>

1. It is strongly recommended that CME 100 Vector Calculus for Engineers and CME 102 Ordinary Differential Equations for Engineers be taken rather than MATH 51 Linear Algebra and Differential Calculus of Several Variables and MATH 53 Ordinary Differential Equations with Linear Algebra. If you are taking the MATH 50 series, it is strongly recommended to take CME 192 Introduction to MATLAB. CME 106 Introduction to Probability and Statistics for Engineers utilizes MATLAB, a powerful technical computing program, and should be taken rather than STATS 110 Statistical Methods in Engineering and the Physical Sciences or STATS 141 Biostatistics. Although not required, CME 104 Linear Algebra and Partial Differential Equations for Engineers is recommended for some Bioengineering courses.

2. Science must include both Chemistry (CHEM 31A Chemical Principles I and CHEM 31B Chemical Principles II; or CHEM 31X Chemical Principles Accelerated) and calculus-based Physics (PHYSICS 41 Mechanics and PHYSICS 43 Electricity and Magnetism), with two quarters of course work in each, in addition to two courses of BIO core. CHEM 31A Chemical Principles I and CHEM 31B Chemical Principles II are considered one course even though given over two quarters.

Students pursuing a premed program need to take additional courses; see the UGHB, BioE Premed 4-Year Plan.

Honors Program

The School of Engineering offers a program leading to a Bachelor of Science in Bioengineering with Honors (BIOE-BSH). This program provides the opportunity for qualified BioE majors to conduct independent research at an advanced level with a faculty research adviser and documented in an honors thesis.

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

1. Declare the honors program in Axess (BIOE-BSH).
2. Maintain an overall grade point average (GPA) of at least 3.5 as calculated on the unofficial transcript.
3. Complete at least two quarters of research with a minimum of nine units of BIOE 191 Bioengineering Problems and Experimental Investigation or BIOE 191X Out-of-Department Advanced Research Laboratory in Bioengineering for a letter grade; up to three units may be used towards the bioengineering depth elective requirements.
4. Submit a completed thesis draft to the honors adviser and second reader by the third week of Spring Quarter. Further revisions and final endorsement are to be finished by the second Monday in May, when two signed bound copies plus one PC-compatible CD-ROM are to be submitted to the student services officer.
5. Attend the Bioengineering Honors Symposium at the end of Spring Quarter and give a poster or oral presentation, or present in another approved suitable forum.

For more information and application instructions, see the Bioengineering Honors Program (http://bioengineering.stanford.edu/academics/undergraduate-programs/bioengineering-honors-program) web site.

Biomechanical Engineering (BME)

Completion of the undergraduate program in Biomechanical Engineering leads to the conferral of the Bachelor of Science in Engineering. The subplan "Biomechanical Engineering" appears on the transcript and on the diploma.

Mission of the Undergraduate Program in Biomechanical Engineering

The mission of the undergraduate program in Biomechanical Engineering is to help students address health science challenges by applying engineering mechanics and design to the fields of biology and medicine. The program is interdisciplinary in nature, integrating engineering course work with biology and clinical medicine. Research and teaching in this discipline focus primarily on neuromuscular, musculoskeletal, cardiovascular, and cell and tissue biomechanics. This major prepares students for graduate studies in bioengineering, biomechanics, medicine or related areas.

Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mathematics</strong></td>
<td>21</td>
</tr>
<tr>
<td>21 units minimum; see Basic Requirement 1</td>
<td></td>
</tr>
<tr>
<td><strong>Science (22 units Minimum)</strong></td>
<td></td>
</tr>
<tr>
<td>CHEM 31X Chemical Principles Accelerated (or CHEM 31A+B)</td>
<td>5</td>
</tr>
<tr>
<td>CHEM 33 Structure and Reactivity of Organic Molecules</td>
<td>5</td>
</tr>
<tr>
<td>PHYSICS 41 Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>Biology or Human Biology A/B core courses</td>
<td>8-10</td>
</tr>
</tbody>
</table>
| BIO 45 Introduction to Laboratory Research in Cell and Molecular Biology   | 4     | (or BIO 44X if taken before 2016-17)
Technology in Society

One course required; course must be on School of Engineering Approved Courses list in the UGHB the year taken

Engineering Topics (Engineering Science and Design)

Engineering Fundamentals (minimum three courses; see Basic Requirement 3):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 14</td>
<td>Intro to Solid Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 25B</td>
<td>Biotechnology</td>
<td>3</td>
</tr>
</tbody>
</table>

or ENGR 80

Introduction to Biomechanical Engineering (Engineering Living Matter)

Fundamentals Elective 3-5

Engineering Depth

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 15</td>
<td>Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>ME 30</td>
<td>Engineering Thermodynamics</td>
<td>3</td>
</tr>
<tr>
<td>ME 70</td>
<td>Introductory Fluids Engineering</td>
<td>4</td>
</tr>
<tr>
<td>ME 80</td>
<td>Mechanics of Materials</td>
<td>4</td>
</tr>
<tr>
<td>ME 389</td>
<td>Biomechanical Research Symposium</td>
<td>1</td>
</tr>
</tbody>
</table>

Options to complete the ME depth sequence (3 courses, minimum 9 units):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 105</td>
<td>Feedback Control Design</td>
<td>3</td>
</tr>
<tr>
<td>ME 101</td>
<td>Visual Thinking</td>
<td>3</td>
</tr>
<tr>
<td>ME 112</td>
<td>Mechanical Systems Design</td>
<td>3</td>
</tr>
<tr>
<td>ME 131A</td>
<td>Heat Transfer</td>
<td>3</td>
</tr>
<tr>
<td>ME 131B</td>
<td>Fluid Mechanics: Compressible Flow and Turbomachinery</td>
<td>3</td>
</tr>
<tr>
<td>ME 161</td>
<td>Dynamic Systems, Vibrations and Control</td>
<td>3</td>
</tr>
<tr>
<td>ME 203</td>
<td>Design and Manufacturing</td>
<td>3</td>
</tr>
<tr>
<td>ME 210</td>
<td>Introduction to Mechatronics</td>
<td>3</td>
</tr>
<tr>
<td>ME 220</td>
<td>Introduction to Sensors</td>
<td>3</td>
</tr>
</tbody>
</table>

Options to complete the BME depth sequence (3 courses, minimum 9 units) and WIM:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOE 260</td>
<td>Tissue Engineering</td>
<td>3</td>
</tr>
<tr>
<td>BIOE/ME 285</td>
<td>Computational Modeling in the Cardiovascular System</td>
<td>3</td>
</tr>
<tr>
<td>ME 234</td>
<td>Introduction to Neuromechanics</td>
<td>3</td>
</tr>
<tr>
<td>ME 239</td>
<td>Mechanics of the Cell</td>
<td>3</td>
</tr>
<tr>
<td>ME 281</td>
<td>Biomechanics of Movement</td>
<td>3</td>
</tr>
<tr>
<td>ME 283</td>
<td>Introduction to Biomechanics and Mechanobiology</td>
<td>3</td>
</tr>
<tr>
<td>ME 287</td>
<td>Mechanics of Biological Tissues</td>
<td>3</td>
</tr>
<tr>
<td>ME 328</td>
<td>Medical Robotics (with permission of instructor)</td>
<td>3</td>
</tr>
<tr>
<td>ME 337</td>
<td>Mechanics of Growth</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Units 92-98

1 Science must include both Chemistry and Physics with one year of course work (3 courses) in at least one, two courses of HUMBIO core or BIO core, and CHEM 31A and CHEM 31B or CHEM 31X. CHEM 31A/B are considered one course even though given over two quarters.
2 If ME 389 is not offered, other options include BIOE 393, ME 571, or course by petition.
3 There are two options for fulfilling the WIM requirement. The first option is to complete ME 112. The second option is to perform engineering research over the summer or during the academic year and enroll in 3 units of ENGR 199W Writing of Original Research for Engineers, preferably during the time a student is performing research or the following quarter, to write a technical report on the research. This second option requires an agreement with the student's faculty research supervisor.

4 Students satisfy the Bio core by taking two of the following: BIO 82 Genetics, BIO 83 Biochemistry & Molecular Biology, BIO 84 Physiology or BIO 86 Cell Biology. Details for Humbio core and total science unit requirement are not available at this time, but will be published soon.

Honors Program

The School of Engineering offers a program leading to a Bachelor of Science in Engineering: Biomechanical Engineering with Honors. This program provides an opportunity for qualified BME majors to conduct independent study and research related to biomechanical engineering at an advanced level with a faculty mentor.

Honors Criteria:

- GPA of 3.5 or higher in the major
- Arrangement with an ME faculty member (or a faculty member from another department who is approved by the BME Undergraduate Program Director) who agrees to serve as the honors adviser, plus a second faculty member who reads and approves the thesis. The honors adviser must be a member of the Academic Council in the School of Engineering.
- Applications are subject to the review and final approval by the BME Undergraduate Program Director. Applicants and thesis advisers receive written notification when a decision has been made. Submit application documents to the student services office, Building 530, room 125.
- An application consists of
  - One page written statement describing the research topic
  - Unofficial Stanford transcript
  - Signature of thesis adviser and thesis reader agreeing to serve on the committee
  - Deadline: No later than the second week of the Autumn Quarter of the senior year
- In order to graduate with honors:
  - Declare ENGR-BSH (honors) program in Axess
  - Maintain 3.5 GPA
  - Submit a completed thesis draft to the adviser and reader by April 1
  - Present the thesis synopsis at the Mechanical Engineering Poster Session held in April
  - Further revisions and a final endorsement by the adviser and reader are to be completed by May 15 when two bound copies are to be submitted to the Mechanical Engineering student services office.

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).

Biomedical Computation (BMC)

Completion of the undergraduate program in Biomedical Computation leads to the conferral of the Bachelor of Science in Engineering. The subplan "Biomedical Computation" appears on the transcript and on the diploma.

Mission of the Undergraduate Program in Biomedical Computation

Quantitative and computational methods are central to the advancement of biology and medicine in the 21st century. These methods span the analysis of biomedical data, the construction of computational models for biological systems, and the design of computer systems that help biologists and physicians create and administer treatments to patients. The Biomedical Computation major prepares students to work at the cutting edge of this interface between computer science, biology, and medicine. Students begin their journey by acquiring foundational knowledge in the underlying biological and computational disciplines. They learn techniques in informatics and simulation and
their numerous applications in understanding and analyzing biology at all levels, from individual molecules in cells to entire organs, organisms, and populations. Students then focus their efforts in a depth area of their choosing, and participate in a substantial research project with a Stanford faculty member. Upon graduation, students are prepared to enter a range of disciplines in either academia or industry.

### Requirements

<table>
<thead>
<tr>
<th>Mathematics</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 unit minimum, see Basic Requirement 1</td>
<td></td>
</tr>
<tr>
<td>MATH 19 Calculus (or AP Calculus)</td>
<td>3</td>
</tr>
<tr>
<td>MATH 20 Calculus (or AP Calculus)</td>
<td>3</td>
</tr>
<tr>
<td>MATH 21 Calculus (or AP Calculus)</td>
<td>4</td>
</tr>
<tr>
<td>CS 103 Mathematical Foundations of Computing</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 109 Introduction to Probability for Computer Scientists</td>
<td>3-5</td>
</tr>
<tr>
<td><strong>Science</strong></td>
<td></td>
</tr>
<tr>
<td>17 units minimum, see Basic Requirement 2</td>
<td></td>
</tr>
<tr>
<td>PHYSICS 41 Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 31X Chemical Principles Accelerated</td>
<td>5</td>
</tr>
<tr>
<td>CHEM 33 Structure and Reactivity of Organic Molecules</td>
<td>5</td>
</tr>
<tr>
<td>BIO 82 Genetics (or HUMBIO 2A)</td>
<td>4</td>
</tr>
<tr>
<td>BIO 83 Biochemistry &amp; Molecular Biology (or BIO 84 or HUMBIO 3A)</td>
<td>4</td>
</tr>
<tr>
<td>BIO 86 Cell Biology (or HUMBIO 4A)</td>
<td>4</td>
</tr>
<tr>
<td><strong>Engineering Fundamentals</strong></td>
<td></td>
</tr>
<tr>
<td>CS 106B Programming Abstractions</td>
<td>3-5</td>
</tr>
<tr>
<td>or CS 106X Programming Abstractions (Accelerated)</td>
<td></td>
</tr>
<tr>
<td>For the second required course, see concentrations</td>
<td></td>
</tr>
<tr>
<td><strong>Technology in Society</strong></td>
<td></td>
</tr>
<tr>
<td>One course required, see Basic Requirement 4; course used must be on the School of Engineering Approved Courses list in the UGHB the year taken.</td>
<td></td>
</tr>
<tr>
<td><strong>Engineering</strong></td>
<td></td>
</tr>
<tr>
<td>CS 107 Computer Organization and Systems</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 161 Design and Analysis of Algorithms</td>
<td>3-5</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td></td>
</tr>
<tr>
<td>CS 270 Modeling Biomedical Systems: Ontology, Terminology, Problem Solving</td>
<td>3</td>
</tr>
<tr>
<td>CS 273A The Human Genome Source Code</td>
<td></td>
</tr>
<tr>
<td>CS 274 Representations and Algorithms for Computational Molecular Biology</td>
<td></td>
</tr>
<tr>
<td>CS 275 Translational Bioinformatics</td>
<td></td>
</tr>
<tr>
<td>CS 279 Computational Biology: Structure and Organization of Biomolecules and Cells</td>
<td></td>
</tr>
<tr>
<td>Research: 6 units of biomedical computation research in any department</td>
<td>6</td>
</tr>
<tr>
<td>Engineering Depth Concentration (select one of the following concentrations):</td>
<td></td>
</tr>
<tr>
<td><strong>Cellular/Molecular Concentration</strong></td>
<td></td>
</tr>
<tr>
<td>Mathematics: Select one of the following:</td>
<td></td>
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<tr>
<td>CME 100 Vector Calculus for Engineers</td>
<td></td>
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<tr>
<td>STATS 141 Biostatistics</td>
<td></td>
</tr>
<tr>
<td>MATH 51 Linear Algebra and Differential Calculus of Several Variables</td>
<td></td>
</tr>
<tr>
<td>One additional Engineering Fundamental</td>
<td>4</td>
</tr>
<tr>
<td>BIO 104 Advanced Molecular Biology</td>
<td></td>
</tr>
<tr>
<td>CHEM 141 The Chemical Principles of Life I (or CHEM 171)</td>
<td>4</td>
</tr>
<tr>
<td>Cell/Mol Electives (two courses)</td>
<td>5-6</td>
</tr>
<tr>
<td>Informatics Electives (two courses)</td>
<td>5-6</td>
</tr>
<tr>
<td>Simulation Electives (two courses)</td>
<td>5-6</td>
</tr>
<tr>
<td>Simulation, Informatics, or Cell/Mol Elective (one course)</td>
<td>5-6</td>
</tr>
</tbody>
</table>

### Informatics Concentration

Mathematics: Select one of the following:

- STATS 141 Biostatistics
- STATS 203 Introduction to Regression Models and Analysis of Variance
- STATS 205 Introduction to Nonparametric Statistics
- STATS 215 Statistical Models in Biology

One additional Engineering Fundamental

Informatics Core (three courses):

- CS 145 Introduction to Databases
- or CS 147 Introduction to Human-Computer Interaction Design
- or CS 221 Artificial Intelligence: Principles and Techniques
- or CS 228 Probabilistic Graphical Models: Principles and Techniques
- or CS 229 Machine Learning

One additional course from the previous two lines

Informatics Electives (three courses)

Cellular Electives (two courses)

Organs Electives (two courses) | 6-10

### Organs/Organisms Concentration

Mathematics (select one of the following):

- CME 100 Vector Calculus for Engineers
- STATS 141 Biostatistics
- MATH 51 Linear Algebra and Differential Calculus of Several Variables

One additional Engineering Fundamental

Biology (two courses):

- BIO 112 Human Physiology
- CHEM 141 The Chemical Principles of Life I (or BIOE 220)

Two additional Organs Electives

Simulation Electives (two courses)

Informatics Electives (two courses)

Simulation, Informatics, or Organs Elective (one course)

### Simulation Concentration

Mathematics:

- CME 100 Vector Calculus for Engineers
- or MATH 51 Linear Algebra and Differential Calculus of Several Variables

ME 30 Engineering Thermodynamics (Fulfills 2nd Engineering Fundamental) | 3

Simulation Core:

- CME 102 Ordinary Differential Equations for Engineers
- or MATH 53 Ordinary Differential Equations with Linear Algebra
- ENGR 80 Introduction to Bioengineering (Engineering Living Matter) | 4
- BIOE 101 Systems Biology | 3
- BIOE 103 Systems Physiology and Design | 4
- Simulation Electives (two courses) | 5-6
- Cellular Elective (one course) | 5-6
- Organs Elective (one course) | 5-6
- Simulation, Cellular, or Organs Elective (two courses) | 5-6

**Total Units**: 88-104
Honors Program

The Biomedical Computation program offers an honors option for qualified students, resulting in a B.S. with Honors degree in Engineering (ENGR-BSH, Biomedical Computation). An honors project is meant to be a substantial research project during the later part of a student’s undergraduate career, culminating in a final written and oral presentation describing the student’s project and its significance. There is no limit to the number of majors who can graduate with honors; any BMC major who is interested and meets the qualifications is considered.

1. Students apply by submitting a 1-2 page proposal describing the problem the student has chosen to investigate, its significance, and the student’s research plan. This plan must be endorsed by the student’s research and academic advisers, one of whom must be a member of the Academic Council. In making its decision, the department evaluates the overall scope and significance of the student’s proposed work.

2. Students must maintain a 3.5 GPA.

3. Students must complete three quarters of research. All three quarters must be on the same project with the same adviser. A Summer Quarter counts as one quarter of research.
   - Ideally, funding should not be obtained through summer research college sources, but rather through the UAR’s Student Grants Program (http://exploredegrees.stanford.edu/schoolofengineering/%20http://studentgrants.stanford.edu). In no case can the same work be double-paid by two sources.

4. Students must complete a substantial write-up of the research in the format of a publishable research paper. This research paper is expected to be approximately 15-20 pages and must be approved by the student’s research adviser and by a second reader.

5. As the culmination of the honors project, each student presents the results in a public forum. This can either be in the honors presentation venue of the home department of the student’s adviser, or in a suitable alternate venue.

For additional information and sample programs, see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).
ENGR 25E  Energy: Chemical Transformations for Production, Storage, and Use (same as CHEMENG 25E)

Chemical Engineering Depth

Minimum 68 Engineering Science and Design units; see Basic Requirement 5

CHEM 10  The Chemical Engineering Profession

CHEM 100  Chemical Process Modeling, Dynamics, and Control

CHEM 110  Equilibrium Thermodynamics

CHEM 120A  Fluid Mechanics

CHEM 120B  Energy and Mass Transport

CHEM 130  Separation Processes

CHEM 150  Biochemical Engineering

CHEM 170  Kinetics and Reactor Design

CHEM 180  Chemical Engineering Plant Design

CHEM 181  Biochemistry I

CHEM 185A  Chemical Engineering Laboratory A (WIM)

CHEM 185B  Chemical Engineering Laboratory B

CHEM 171  Physical Chemistry I

CHEM 173  Physical Chemistry II

CHEM 175  Physical Chemistry III

Select four of the following: 1,2,3

CHEMENG 140  Micro and Nanoscale Fabrication Engineering

CHEMENG 142  Basic Principles of Heterogeneous Catalysis with Applications in Energy Transformations

CHEMENG 160  Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life

CHEMENG 162  Polymers for Clean Energy and Water

CHEMENG 174  Environmental Microbiology I

CHEMENG 183  Biochemistry II

CHEMENG 196  Creating New Ventures in Engineering and Science-based Industries

Total Units 125-135

1 Unit count is higher if program includes one or more of the following: MATH 51 and MATH 52 in lieu of CME 100; or CHEM 31A and CHEM 31B in lieu of CHEM 31X.

2 Any two acceptable except combining 160 and 162.

3 Students may substitute two of the depth electives with two other science and engineering 3-unit lecture courses. See Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu) for additional details.

* For additional information and sample programs, see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu)

Civil Engineering (CE)

Completion of the undergraduate program in Civil Engineering leads to the conferral of the Bachelor of Science in Civil Engineering.

Mission of the Undergraduate Program in Civil Engineering

The mission of the undergraduate program in Civil Engineering is to provide students with the principles of engineering and the methodologies necessary for civil engineering practice. This pre-professional program balances the fundamentals common to many specialties in civil engineering and allows for concentration in structures and construction or environmental and water studies. Students in the major learn to apply knowledge of mathematics, science, and civil engineering to conduct experiments, design structures and systems to creatively solve engineering problems, and communicate their ideas effectively. The curriculum includes course work in structural, construction, and environmental engineering. The major prepares students for careers in consulting, industry and government, as well as for graduate studies in engineering.

Requirements

Mathematics and Science 45 units minimum; see Basic Requirements 1 and 2

Technology in Society

One course; course chosen must be on the SoE Approved Courses list at ughb.stanford.edu+ the year taken; see Basic Requirement 4

Engineering Fundamentals

Two courses required

ENGR 14  Intro to Solid Mechanics

ENGR 90/CEE 70  Environmental Science and Technology

Engineering Depth

Minimum of 68 Engineering Fundamentals plus Engineering Depth; see Basic Requirement 5

CEE 100  Managing Sustainable Building Projects

CEE 101A  Mechanics of Materials

CEE 101B  Mechanics of Fluids (or CEE 101N)

CEE 101C  Geotechnical Engineering

Specialty courses in either:

Environmental and Water Studies (see below)

Structures and Construction (see below)

Other School of Engineering Electives 3-0

Total Units 109-111

1 Mathematics must include CME 100 Vector Calculus for Engineers and CME 102 Ordinary Differential Equations for Engineers (or Math 51 Linear Algebra and Differential Calculus of Several Variables and MATH 53 Ordinary Differential Equations with Linear Algebra) and a Statistics course. Science must include Physics 41 Mechanics; either ENGR 31 Chemical Principles with Application to Nanoscale Science and Technology, CHEM 31A Chemical Principles I or CHEM 31X Chemical Principles; two additional quarters in either chemistry or physics, and GS 1A Introduction to Geology: The Physical Science of the Earth (or GS 1B or 1C); for students in the Environmental and Water Studies track, the additional chemistry or physics must include CHEM 33; for students in the Structures and Construction track, it must include PHYSICS 43 or 45. Please note that the only quarter GS 1A is offered for AY 2015-16 is Spring Quarter.

2 Chosen TiS class must specifically include an ethics component, as indicated in Figure 3-3 in the Engineering Undergraduate Handbook (http://web.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Handbooks)

3 CEE 100 meets the Writing in the Major (WIM) requirement

Environmental and Water Studies Focus

ME 30  Engineering Thermodynamics

CEE 101D  Computations in Civil and Environmental Engineering (or CEE 101S)

CEE 162E  Rivers, Streams, and Canals

CEE 166A  Watersheds and Wetlands

CEE 166B  Floods and Droughts, Dams and Aqueducts

CEE 171  Environmental Planning Methods

CEE 172  Air Quality Management

CEE 177  Aquatic Chemistry and Biology
CEE 122B Computer Integrated A/E/C 2
CEE 131A Professional Practice: Mixed Use Design in an Urban Setting (not given AY 2015-16) 3
CEE 131B Financial Management of Sustainable Urban Systems 3
CEE 141A Infrastructure Project Development 3
CEE 141B Infrastructure Project Delivery 3
CEE 151 Negotiation 3
CEE 155 Introduction to Sensing Networks for CEE 4
CEE 161C Natural Ventilation of Buildings 3
CEE 162E Rivers, Streams, and Canals 3-4
CEE 171 Environmental Planning Methods 3
CEE 176A Energy Efficient Buildings 3-4
CEE 176B Electric Power: Renewables and Efficiency 3-4
CEE 195 Fundamentals of Structural Geology 3
CEE 196 Engineering Geology and Global Change 3
CEE 199 Undergraduate Research in Civil and Environmental Engineering 1-4
CEE 203 Probabilistic Models in Civil Engineering 3-4
One of the following can also count as remaining specialty units. 3-4
CEE 120B Building Information Modeling Workshop 2-4
CEE 130 Architectural Design: 3-D Modeling, Methodology, and Process 3
CEE 131A Professional Practice: Mixed-Use Design in an Urban Setting 3
CEE 134B Intermediate Arch Studio 3

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).

Computer Science (CS)

Completion of the undergraduate program in Computer Science leads to the conferral of the Bachelor of Science in Computer Science.

Mission of the Undergraduate Program in Computer Science

The mission of the undergraduate program in Computer Science is to develop students' breadth of knowledge across the subject areas of computer science, including their ability to apply the defining processes of computer science theory, abstraction, design, and implementation to solve problems in the discipline. Students take a set of core courses. After learning the essential programming techniques and the mathematical foundations of computer science, students take courses in areas such as programming techniques, automata and complexity theory, systems programming, computer architecture, analysis of algorithms, artificial intelligence, and applications. The program prepares students for careers in government, law, the corporate sector, and for graduate study.

Requirements

Mathematics (26 units minimum)—
CS 103 Mathematical Foundations of Computing 5
CS 109 Introduction to Probability for Computer Scientists 5
MATH 19 Calculus 3
MATH 20 Calculus 3
MATH 21 Calculus 4
Plus two electives 2

Science (11 units minimum)—
PHYSICS 41 Mechanics 4
PHYSICS 43  Electricity and Magnetism  4
Science elective  3

Technology in Society (3-5 units)—
One course; course chosen must be on the SoE Approved Courses list at 〈ughb.stanford.edu〉 the year taken; see Basic Requirements in the School of Engineering section

Engineering Fundamentals (13 units minimum; see Basic Requirement 3 in the School of Engineering section)—
CS 106B  Programming Abstractions  5
or CS 106X  Programming Abstractions (Accelerated)
ENGR 40M  An Intro to Making: What is EE (or ENGR 40A and ENGR 40B)  3-5
Fundamentals Elective (May be an ENGR fundamentals or an additional CS Depth course. See Fig. 3-4 in the UGHB for approved ENGR fundamentals list. May not be any CS 106)

*Students who take ENGR 40A or 40M for fewer than 5 units are required to take 1-2 additional units of ENGR Fundamentals (13 units minimum), or 1-2 additional units of Depth (27 units minimum for track and elective courses).

Writing in the Major—
Select one of the following:
CS 181W  Computers, Ethics, and Public Policy
CS 191W  Writing Intensive Senior Project
CS 194W  Software Project
CS 210B  Software Project Experience with Corporate Partners
CS 294W  Writing Intensive Research Project in Computer Science

Computer Science Core (15 units)—
CS 107  Computer Organization and Systems  5
or CS 107E  Computer Systems from the Ground Up
CS 110  Principles of Computer Systems  5
CS 161  Design and Analysis of Algorithms  5

Senior Project (3 units)—
CS 191  Senior Project
CS 191W  Writing Intensive Senior Project
CS 194  Software Project
CS 194H  User Interface Design Project
CS 194W  Software Project
CS 210B  Software Project Experience with Corporate Partners
CS 294  6
or CS 294W  Writing Intensive Research Project in Computer Science

Computer Science Depth B.S.
Choose one of the following ten CS degree tracks (a track must consist of at least 25 units and 7 classes):

Artificial Intelligence Track—

CS 221  Artificial Intelligence: Principles and Techniques  4
Select two courses, each from a different area:
Area I, AI Methods:
CS 228  Probabilistic Graphical Models: Principles and Techniques

CS 229  Machine Learning
CS 234  Reinforcement Learning
CS 238  Decision Making under Uncertainty
Area II, Natural Language Processing:
CS 124  From Languages to Information
CS 224N  Natural Language Processing with Deep Learning
CS 224S  Spoken Language Processing
CS 224U  Natural Language Understanding
Area III, Vision:
CS 131  Computer Vision: Foundations and Applications
CS 231A  Computer Vision: From 3D Reconstruction to Recognition
CS 231N  Convolutional Neural Networks for Visual Recognition
Area IV, Robotics:
CS 223A  Introduction to Robotics
Select one additional course from the Areas above or from the following:
AI Methods:
CS 157  Logic and Automated Reasoning
STATS 315A  Modern Applied Statistics: Learning
STATS 315B  Modern Applied Statistics: Data Mining
Vision:
CS 231B
CS 231M
CS 331A
Comp Bio:
CS 262
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells
CS 371  Computational Biology in Four Dimensions
CS 374  Information and the Web:
CS 276  Information Retrieval and Web Search
CS 224W  Analysis of Networks
Other:
CS 227B  General Game Playing
CS 277
CS 379  Interdisciplinary Topics
Robotics and Control:
CS 327A  Advanced Robotic Manipulation
CS 329  Topics in Artificial Intelligence (with advisor approval)
ENGR 205  Introduction to Control Design Techniques
EE 209
MS&E 251  Stochastic Control
MS&E 351  Dynamic Programming and Stochastic Control
Track Electives: at least three additional courses selected from the Areas and lists above, general CS electives, or the following:
CS 238  Decision Making under Uncertainty
CS 275  Translational Bioinformatics
CS 326  Topics in Advanced Robotic Manipulation
CS 334A  Convex Optimization I
or EE 364A  Convex Optimization I
CS 428  Computation and cognition: the probabilistic approach
Biocomputation Track—

The Mathematics, Science, and Engineering Fundamentals requirements are non-standard for this track. See Handbook for Undergraduate Engineering Programs for details.

Select one of the following: 3-4

CS 221 Artificial Intelligence: Principles and Techniques 3-4
CS 228 Probabilistic Graphical Models: Principles and Techniques 3-4
CS 229 Machine Learning 3
CS 231A Computer Vision: From 3D Reconstruction to Recognition 3-4

Select one of the following:

CS 262 3
CS 270 Modeling Biomedical Systems: Ontology, Terminology, Problem Solving 3
CS 273A The Human Genome Source Code 3
CS 274 Representations and Algorithms for Computational Molecular Biology 3
CS 275 Translational Bioinformatics 3
CS 279 Computational Biology: Structure and Organization of Biomolecules and Cells 3

One additional course from the lists above or the following: 3-4

CS 124 From Languages to Information 3
CS 145 Introduction to Databases 3-4
CS 147 Introduction to Human-Computer Interaction Design 3
CS 148 Introduction to Computer Graphics and Imaging 3-4
CS 149 Interactive Computer Graphics 3-4
CS 142 Web Applications 3
CS 143 Compilers 3-4
CS 144 Introduction to Computer Networking 3-4
CS 145 Introduction to Databases 3-4
CS 264  Beyond Worst-Case Analysis  3
CS 265  Randomized Algorithms and Probabilistic Analysis  3
CS 266  
CS 267  Graph Algorithms  3
CS 269I  Incentives in Computer Science  3
CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving  3
CS 272  Introduction to Biomedical Informatics Research Methodology  3-5
CS 273A  The Human Genome Source Code  3
CS 273B  Deep Learning in Genomics and Biomedicine  3
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 275  Translational Bioinformatics  4
CS 276  Information Retrieval and Web Search  3
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 348B  Computer Graphics: Image Synthesis Techniques  3-4
CS 348C  Computer Graphics: Animation and Simulation  3
CS 371  Computational Biology in Four Dimensions  3
CS 374  
CME 108  Introduction to Scientific Computing  3
EE 180  Digital Systems Architecture  4
EE 263  Introduction to Linear Dynamical Systems  3
EE 282  Computer Systems Architecture  3
EE 364A  Convex Optimization I  3
BIOE 101  Systems Biology  3
MS&E 152  Introduction to Decision Analysis  3-4
MS&E 252  Decision Analysis I: Foundations of Decision Analysis  3-4
STATS 206  Applied Multivariate Analysis  3
STATS 315A  Modern Applied Statistics: Learning  2-3
STATS 315B  Modern Applied Statistics: Data Mining  2-3
BMI 231  
BMI 260  Genomics  3
GENE 211  Genomics  3
One course from the following:
BIOE 222A  
BIOE 222B  
CHEMENG 150  Biochemical Engineering  3
CHEMENG 174  Environmental Microbiology I  3
APPHYS 294  Cellular Biophysics  3
BIO 104  Advanced Molecular Biology  5
BIO 118  Genetic Analysis of Biological Processes  4
BIO 129A  
BIO 129B  
BIO 188  
BIO 189  
BIO 214  Advanced Cell Biology  4
BIO 217  
BIO 230  Molecular and Cellular Immunology  4
CHEM 135  
CHEM 171  Physical Chemistry I  4
BIOC 218  
BIOC 241  Biological Macromolecules  3-5
SBIO 228  
One course from the following:
BIOE 220  Introduction to Imaging and Image-based Human Anatomy  3
BIOE 222A  
BIOE 222B  
CHEMENG 150  Biochemical Engineering  3
CHEMENG 174  Environmental Microbiology I  3
CS 262  
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
CS 374  Statistical and Machine Learning Methods for Genomics  3
EE 263  Introduction to Linear Dynamical Systems  3
EE 364A  Convex Optimization I  3
MS&E 152  Introduction to Decision Analysis  3-4
MS&E 252  Decision Analysis I: Foundations of Decision Analysis  3-4
STATS 206  Applied Multivariate Analysis  3
STATS 315A  Modern Applied Statistics: Learning  2-3
STATS 315B  Modern Applied Statistics: Data Mining  2-3
BMI 231  
BMI 260  Genomics  3
GENE 211  Genomics  3
One course from the list above or the following:
BIOE 222A  
BIOE 222B  
CHEMENG 150  Biochemical Engineering  3
CHEMENG 174  Environmental Microbiology I  3
APPHYS 294  Cellular Biophysics  3
BIO 104  Advanced Molecular Biology  5
BIO 118  Genetic Analysis of Biological Processes  4
BIO 129A  
BIO 129B  
BIO 188  
BIO 189  
BIO 214  Advanced Cell Biology  4
BIO 217  
BIO 230  Molecular and Cellular Immunology  4
CHEM 135  
CHEM 171  Physical Chemistry I  4
BIOC 218  
BIOC 241  Biological Macromolecules  3-5
SBIO 228  
One course from the following:
BIOE 220  Introduction to Imaging and Image-based Human Anatomy  3
BIOE 222A  
BIOE 222B  
CHEMENG 150  Biochemical Engineering  3
CHEMENG 174  Environmental Microbiology I  3
CS 262  
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
CS 374  Statistical and Machine Learning Methods for Genomics  3
CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving  3
CS 273A  The Human Genome Source Code  3
CS 273B  Deep Learning in Genomics and Biomedicine  3
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 275  Translational Bioinformatics  4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
CS 373  Statistical and Machine Learning Methods for Genomics  3
CS 374  
CS 264  Beyond Worst-Case Analysis  3
CS 265  Randomized Algorithms and Probabilistic Analysis  3
CS 266  
CS 267  Graph Algorithms  3
CS 269I  Incentives in Computer Science  3
CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving  3
CS 272  Introduction to Biomedical Informatics Research Methodology  3-5
CS 273A  The Human Genome Source Code  3
CS 273B  Deep Learning in Genomics and Biomedicine  3
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 275  Translational Bioinformatics  4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
CS 373  Statistical and Machine Learning Methods for Genomics  3
CS 374  
CS 264  Beyond Worst-Case Analysis  3
CS 265  Randomized Algorithms and Probabilistic Analysis  3
CS 266  
CS 267  Graph Algorithms  3
CS 269I  Incentives in Computer Science  3
CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving  3
CS 272  Introduction to Biomedical Informatics Research Methodology  3-5
CS 273A  The Human Genome Source Code  3
CS 273B  Deep Learning in Genomics and Biomedicine  3
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 275  Translational Bioinformatics  4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
CS 373  Statistical and Machine Learning Methods for Genomics  3
CS 374  
CS 264  Beyond Worst-Case Analysis  3
CS 265  Randomized Algorithms and Probabilistic Analysis  3
CS 266  
CS 267  Graph Algorithms  3
CS 269I  Incentives in Computer Science  3
CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving  3
CS 272  Introduction to Biomedical Informatics Research Methodology  3-5
CS 273A  The Human Genome Source Code  3
CS 273B  Deep Learning in Genomics and Biomedicine  3
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 275  Translational Bioinformatics  4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
CS 373  Statistical and Machine Learning Methods for Genomics  3
CS 374  
CS 264  Beyond Worst-Case Analysis  3
CS 265  Randomized Algorithms and Probabilistic Analysis  3
CS 266  
CS 267  Graph Algorithms  3
CS 269I  Incentives in Computer Science  3
CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving  3
CS 272  Introduction to Biomedical Informatics Research Methodology  3-5
CS 273A  The Human Genome Source Code  3
CS 273B  Deep Learning in Genomics and Biomedicine  3
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 275  Translational Bioinformatics  4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
CS 373  Statistical and Machine Learning Methods for Genomics  3
CS 374  
CS 264  Beyond Worst-Case Analysis  3
CS 265  Randomized Algorithms and Probabilistic Analysis  3
CS 266  
CS 267  Graph Algorithms  3
CS 269I  Incentives in Computer Science  3
CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving  3
CS 272  Introduction to Biomedical Informatics Research Methodology  3-5
CS 273A  The Human Genome Source Code  3
CS 273B  Deep Learning in Genomics and Biomedicine  3
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 275  Translational Bioinformatics  4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
### Computer Engineering Track

For this track there is a 10 unit minimum for ENGR Fundamentals and a 31 unit minimum for Depth (for track and elective courses)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 108</td>
<td>Digital System Design and Digital Systems Architecture</td>
<td>6-8</td>
</tr>
<tr>
<td>EE 180</td>
<td>Digital System Design and Digital Systems Architecture</td>
<td>6-8</td>
</tr>
</tbody>
</table>

Select two of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 101A</td>
<td>Circuits I</td>
<td>8</td>
</tr>
<tr>
<td>EE 101B</td>
<td>Circuits II</td>
<td></td>
</tr>
<tr>
<td>EE 102A</td>
<td>Signal Processing and Linear Systems I</td>
<td></td>
</tr>
<tr>
<td>EE 102B</td>
<td>Signal Processing and Linear Systems II</td>
<td></td>
</tr>
</tbody>
</table>

Satisfy the requirements of one of the following concentrations:

1) Digital Systems Concentration

- EE 109 Digital Systems Design Lab
- EE 271 Introduction to VLSI Systems

Plus two of the following (6-8 units):

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 140</td>
<td>Operating Systems and Systems Programming (if not counted above)</td>
<td></td>
</tr>
<tr>
<td>CS 140E or C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME 210</td>
<td>Introduction to Mechatronics</td>
<td></td>
</tr>
<tr>
<td>ENGR 105</td>
<td>Feedback Control Design</td>
<td></td>
</tr>
</tbody>
</table>

Plus one of the following (3-4 units):

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 225A</td>
<td>Experimental Robotics</td>
<td></td>
</tr>
<tr>
<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
<td></td>
</tr>
<tr>
<td>ENGR 205</td>
<td>Introduction to Control Design Techniques</td>
<td></td>
</tr>
<tr>
<td>ENGR 207B</td>
<td>Linear Control Systems II</td>
<td></td>
</tr>
</tbody>
</table>

2) Robotics and Mechatronics Concentration

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 223A</td>
<td>Introduction to Robotics</td>
<td></td>
</tr>
<tr>
<td>ME 210</td>
<td>Introduction to Mechatronics</td>
<td></td>
</tr>
<tr>
<td>ENGR 105</td>
<td>Feedback Control Design</td>
<td></td>
</tr>
</tbody>
</table>

Plus one of the following (3-4 units):

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 225A</td>
<td>Experimental Robotics</td>
<td></td>
</tr>
<tr>
<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
<td></td>
</tr>
<tr>
<td>ENGR 205</td>
<td>Introduction to Control Design Techniques</td>
<td></td>
</tr>
<tr>
<td>ENGR 207B</td>
<td>Linear Control Systems II</td>
<td></td>
</tr>
</tbody>
</table>

3) Networking Concentration

- EE 271 Introduction to VLSI Systems
- EE 273 Digital Systems Engineering
- EE 282 Computer Systems Architecture

Select two of the following (6-8 units):

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME 210</td>
<td>Introduction to Mechatronics</td>
<td></td>
</tr>
<tr>
<td>ENGR 105</td>
<td>Feedback Control Design</td>
<td></td>
</tr>
</tbody>
</table>

Track Electives: at least two additional courses from the lists above, the general CS electives list, or the following:

- ARTSTUDI 160 Intro to Digital / Physical Design
- ARTSTUDI 170 PHOTOGRAPHY I: BLACK AND WHITE
- ARTSTUDI 179 Digital Art I
- CME 302 Numerical Linear Algebra
- CME 306 Numerical Solution of Partial Differential Equations
- EE 168 Introduction to Digital Image Processing
- EE 262 Two-Dimensional Imaging
- EE 264 Digital Signal Processing
- EE 278 Introduction to Statistical Signal Processing
- EE 368 Digital Image Processing
- ME 101 Visual Thinking
- PSYCH 30 Introduction to Perception
- PSYCH 221 Image Systems Engineering

### Graphics Track

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 148</td>
<td>Introduction to Computer Graphics and Imaging</td>
<td>8</td>
</tr>
<tr>
<td>&amp; CS 248</td>
<td>Interactive Computer Graphics</td>
<td>5</td>
</tr>
</tbody>
</table>

Select one of the following:

- CS 205A Mathematical Methods for Robotics, Vision, and Graphics (strongly recommended as a preferred choice)
- CME 104 Linear Algebra and Partial Differential Equations for Engineers (Note: students taking CME 104 are also required to take its prerequisite course, CME 102)
- CME 108 Introduction to Scientific Computing
- MATH 52 Integral Calculus of Several Variables
- MATH 113 Linear Algebra and Matrix Theory

Select two of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
<td>6-8</td>
</tr>
<tr>
<td>or CS 131</td>
<td>Computer Vision: Foundations and Applications</td>
<td></td>
</tr>
<tr>
<td>CS 233</td>
<td>Geometric and Topological Data Analysis</td>
<td></td>
</tr>
<tr>
<td>CS 268</td>
<td>Geometric Algorithms</td>
<td></td>
</tr>
<tr>
<td>CS 348B</td>
<td>Computer Graphics: Image Synthesis Techniques</td>
<td></td>
</tr>
<tr>
<td>CS 348C</td>
<td>Computer Graphics: Animation and Simulation</td>
<td></td>
</tr>
<tr>
<td>CS 448</td>
<td>Topics in Computer Graphics</td>
<td></td>
</tr>
</tbody>
</table>

### Human-Computer Interaction Track

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 147</td>
<td>Introduction to Human-Computer Interaction Design</td>
<td>4</td>
</tr>
<tr>
<td>CS 247</td>
<td>Human-Computer Interaction Design Studio</td>
<td>4</td>
</tr>
</tbody>
</table>

Any three of the following:

- CS 142 Web Applications
- CS 148 Introduction to Computer Graphics and Imaging
- CS 194H User Interface Design Project
Stanford University

CS 210A  Software Project Experience with Corporate Partners
CS 376  Human-Computer Interaction Research
Any CS 377 'Topics in HCI' of three or more units
CS 448B  Data Visualization
ME 216M  Introduction to the Design of Smart Products
At least two additional courses from above list, the general CS electives list, or the following: 4
Any d.school class of 3 or more units
Any class of 3 or more units at hci.stanford.edu under the 'courses' link
Communication-
COMM 121  Behavior and Social Media
COMM 124  Lies, Trust, and Tech
or COMM 224  Lies, Trust, and Tech
COMM 140  Virtual People
or COMM 240
COMM 166  Media Psychology
or COMM 272  Media Psychology
COMM 182  Language and Technology
Art Studio-
ARTSTUDI 160  Intro to Digital / Physical Design
ARTSTUDI 162  Embodied Interfaces
ARTSTUDI 163  Drawing with Code
ARTSTUDI 164  DESIGN IN PUBLIC SPACES
ARTSTUDI 165  Social Media and Performative Practices
ARTSTUDI 168  Data as Material
ARTSTUDI 264  Advanced Interaction Design
ARTSTUDI 266  Sculptural Screens / Malleable Media
ARTSTUDI 267  Emerging Technology Studio
Sym Sys-
SYMSYS 245  Cognition in Interaction Design
Psychology-
PSYCH 30  Introduction to Perception
PSYCH 45  Introduction to Learning and Memory
PSYCH 70  Self and Society: Introduction to Social Psychology
PSYCH 75  Introduction to Cultural Psychology
PSYCH 110  Research Methods and Experimental Design
PSYCH 131  Language and Thought
PSYCH 154  Judgment and Decision-Making
Empirical Methods-
MS&E 125  Introduction to Applied Statistics
PSYCH 252  Statistical Methods for Behavioral and Social Sciences
PSYCH 254  Affective Neuroscience
PSYCH 110  Research Methods and Experimental Design
STATS 203  Introduction to Regression Models and Analysis of Variance
EDUC 191  Introduction to Survey Research
HUMBIO 82A  Qualitative Research Methodology
ME Design-
ME 101  Visual Thinking
ME 115A  Introduction to Human Values in Design
ME 203  Design and Manufacturing
ME 210  Introduction to Mechatronics
ME 216A  Advanced Product Design: Needfinding
Learning Design + Tech-
EDUC 236  Beyond Bits and Atoms: Designing Technological Tools
EDUC 281  Technology for Learners
EDUC 239  Educating Young STEM Thinkers
EDUC 338  Innovations in Education
EDUC 342  Child Development and New Technologies
MS&E-
MS&E 185  Global Work
MS&E 331  Computer Music-
MUSIC 220A  Fundamentals of Computer-Generated Sound
MUSIC 220B  Compositional Algorithms, Psychoacoustics, and Computational Music
MUSIC 220C  Research Seminar in Computer-Generated Music
MUSIC 250A  Physical Interaction Design for Music
MUSIC 256A  Music, Computing, Design I: Art of Design for Computer Music
Optional Elective 4

Information Track—

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 124  From Languages to Information</td>
</tr>
<tr>
<td>CS 145  Introduction to Databases</td>
</tr>
<tr>
<td>Two courses, from different areas:</td>
</tr>
<tr>
<td>1) Information-based AI applications</td>
</tr>
<tr>
<td>CS 224N  Natural Language Processing with Deep Learning</td>
</tr>
<tr>
<td>CS 224S  Spoken Language Processing</td>
</tr>
<tr>
<td>CS 229  Machine Learning</td>
</tr>
<tr>
<td>CS 233  Geometric and Topological Data Analysis</td>
</tr>
<tr>
<td>CS 234  Reinforcement Learning</td>
</tr>
<tr>
<td>2) Database and Information Systems</td>
</tr>
<tr>
<td>CS 140  Operating Systems and Systems Programming</td>
</tr>
<tr>
<td>or CS 140E  Operating systems design and implementation</td>
</tr>
<tr>
<td>CS 142  Web Applications</td>
</tr>
<tr>
<td>CS 245  Database Systems Principles</td>
</tr>
<tr>
<td>CS 246  Mining Massive Data Sets</td>
</tr>
<tr>
<td>CS 341  Project in Mining Massive Data Sets</td>
</tr>
<tr>
<td>CS 345  (Offered occasionally)</td>
</tr>
<tr>
<td>CS 346</td>
</tr>
<tr>
<td>CS 347</td>
</tr>
<tr>
<td>3) Information Systems in Biology</td>
</tr>
<tr>
<td>CS 262</td>
</tr>
<tr>
<td>CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving</td>
</tr>
<tr>
<td>CS 274  Representations and Algorithms for Computational Molecular Biology</td>
</tr>
<tr>
<td>4) Information Systems on the Web</td>
</tr>
<tr>
<td>CS 224W  Analysis of Networks</td>
</tr>
<tr>
<td>CS 276  Information Retrieval and Web Search</td>
</tr>
<tr>
<td>At least three additional courses from the above areas or the general CS electives list. 4</td>
</tr>
</tbody>
</table>


Systems Track—

CS 140 Operating Systems and Systems Programming or CS 140E Operating systems design and implementation

Select one of the following: 3-4
CS 143 Compilers
EE 180 Digital Systems Architecture

Two additional courses from the list above or the following: 6-8
CS 144 Introduction to Computer Networking
CS 145 Introduction to Databases
CS 149 Parallel Computing
CS 155 Computer and Network Security
CS 190
CS 240 Advanced Topics in Operating Systems
CS 242 Programming Languages
CS 243 Program Analysis and Optimizations
CS 244 Advanced Topics in Networking
CS 245 Database Systems Principles
EE 271 Introduction to VLSI Systems
EE 282 Computer Systems Architecture

Track Electives: at least three additional courses selected from the list above, the general CS electives list, or the following: 4
CS 240E
CS 241 Embedded Systems Workshop
CS 244E
CS 316 Advanced Multi-Core Systems
CS 341 Project in Mining Massive Data Sets
CS 343 (Not given this year)
CS 344 Topics in Computer Networks (3 or more units, any suffix)
CS 345 (Advanced Topics in Database Systems - 3 or more units, any suffix)
CS 346
CS 347
CS 349 Topics in Programming Systems (with permission of undergraduate advisor)
CS 448 Topics in Computer Graphics
EE 108 Digital System Design
EE 382C Interconnection Networks
EE 384A Internet Routing Protocols and Standards
EE 384B Multimedia Communication over the Internet
EE 384C Wireless Local and Wide Area Networks
EE 384S Performance Engineering of Computer Systems & Networks
EE 384X

Theory Track—

CS 154 Introduction to Automata and Complexity Theory

Select one of the following: 3
CS 167
CS 168 The Modern Algorithmic Toolbox
CS 255 Introduction to Cryptography
CS 261 Optimization and Algorithmic Paradigms
CS 264 Beyond Worst-Case Analysis
CS 265 Randomized Algorithms and Probabilistic Analysis
CS 268 Geometric Algorithms

Two additional courses from the list above or the following: 6-8
CS 143 Compilers
CS 155 Computer and Network Security
CS 157 Logic and Automated Reasoning or PHIL 151 Metalogic
CS 166 Data Structures
CS 228 Probabilistic Graphical Models: Principles and Techniques
CS 233 Geometric and Topological Data Analysis
CS 242 Programming Languages
CS 250 Algebraic Error Correcting Codes
CS 251 Bitcoin and Crypto Currencies
CS 254 Computational Complexity
CS 259 (with permission of undergraduate advisor)
CS 262
CS 263 Algorithms for Modern Data Models
CS 266
CS 267 Graph Algorithms
CS 269I Incentives in Computer Science
CS 352 Pseudo-Randomness
CS 354 (Not given this year)
CS 355 (Not given this year)
CS 357 (Not given this year)
CS 358 Topics in Programming Language Theory
CS 359 Topics in the Theory of Computation (with permission of undergraduate advisor)
CS 364A
CS 367 (Not given this year)
CS 369 Topics in Analysis of Algorithms (with permission of undergraduate advisor)
CS 374
MS&E 310 Linear Programming
Track Electives: at least three additional courses from the lists above, 9-12 the general CS electives list, or the following: 4
CS 269G Almost Linear Time Graph Algorithms
CME 302 Numerical Linear Algebra
CME 305 Discrete Mathematics and Algorithms
PHIL 152 Computability and Logic

Unspecialized Track—

CS 154 Introduction to Automata and Complexity Theory

Select one of the following: 4
CS 140 Operating Systems and Systems Programming or CS 140E Operating systems design and implementation
CS 143 Compilers

One additional course from the list above or the following: 3-4
CS 144 Introduction to Computer Networking
CS 155 Computer and Network Security
CS 190
CS 242 Programming Languages
CS 244 Advanced Topics in Networking
EE 180 Digital Systems Architecture

Select one of the following: 3-4
CS 221 Artificial Intelligence: Principles and Techniques
Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu)
For additional information and sample programs see the Handbook for Undergraduate Engineering Programs for further information.

which must be CS courses numbered 100 or above. See Handbook for
include a minimum of 25 units and seven courses, at least four of
Students may propose an individually designed track. Proposals should
Individually Designed Track—

Select one of the following: 3-4
CS 145 Introduction to Databases
CS 147 Introduction to Human-Computer Interaction Design
CS 148 Introduction to Computer Graphics and Imaging
CS 248 Interactive Computer Graphics
CS 262
At least two courses from the general CS electives list 4

Individually Designed Track—
Students may propose an individually designed track. Proposals should include a minimum of 25 units and seven courses, at least four of which must be CS courses numbered 100 or above. See Handbook for Undergraduate Engineering Programs for further information.

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu)

1 MATH 19, MATH 20, and MATH 21 OR MATH 41 and MATH 42 OR AP Calculus Credit may be used as long as at least 26 MATH units are taken. AP Calculus Credit must be approved by the School of Engineering.

2 The math electives list consists of: MATH 51, MATH 104, MATH 108, MATH 109, MATH 110, MATH 113; CS 157, CS 205A; PHIL 151; CME 100, CME 102, CME 103 (or EE103), CME 104. Completion of MATH 52 and MATH 53 will together count as one math elective. Restrictions: CS 157 and PHIL 151 may not be used in combination to satisfy the math electives requirement. Students who have taken both MATH 51 and MATH 52 may not count CME 100 as an elective. Courses counted as math electives cannot also count as CS electives, and vice versa.

3 The science elective may be any course of 3 or more units from the School of Engineering Science list (Fig. 4-2 in the UGHB), PSYCH 30, or AP Chemistry Credit. 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. AP Chemistry Credit and AP Physics Credit must be approved by the School of Engineering.


5 CS 205A Mathematical Methods for Robotics, Vision, and Graphics is strongly recommended in this list for the Graphics track. Students taking CME 104 Linear Algebra and Partial Differential Equations for Engineers are also required to take its prerequisite, CME 102 Ordinary Differential Equations for Engineers.

6 Independent study projects (CS 191 Senior Project or CS 191W Writing Intensive Senior Project) require faculty sponsorship and must be approved by the adviser, faculty sponsor, and the CS senior project adviser (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.

Electrical Engineering (EE)
Completion of the undergraduate program in Electrical Engineering leads to the conferral of the Bachelor of Science in Electrical Engineering.

Mission of the Undergraduate Program in Electrical Engineering
The mission of the undergraduate program of the Department of Electrical Engineering is to augment the liberal education expected of all Stanford undergraduates, to impart basic understanding of electrical engineering and to develop skills in the design and building of systems that directly impact societal needs.

The program includes a balanced foundation in the physical sciences, mathematics, and computing; core courses in electronics, information systems and digital systems; and develops specific skills in the analysis and design of systems. Students in the major have broad flexibility to select from disciplinary areas beyond the core, including hardware and software, information systems and science, and physical technology and science, as well as electives in multidisciplinary areas, including bioelectronics and bio-imaging, energy and environment and music.

The program prepares students for a broad range of careers—both industrial and government—as well as for professional and academic graduate education.

Requirements

Mathematics 1
Select one sequence: May also be satisfied with AP Calculus.

MATH 19 & MATH 20 and Calculus
MATH 21 and Calculus

Select one 2-course sequence: 10

CME 100 Vector Calculus for Engineers
CME 102 and Ordinary Differential Equations for Engineers
(Same as ENGR 154 and ENGR 155A)

MATH 51 Linear Algebra and Differential Calculus of Several Variables
MATH 53 and Ordinary Differential Equations with Linear Algebra 2

EE Math. One additional 100-level course. Select one: 3

EE 103 Introduction to Matrix Methods (Preferred)
MATH 113 Linear Algebra and Matrix Theory

CS 103 Mathematical Foundations of Computing

Statistics/Probability. Select one: 3-4

EE 178 Probabilistic Systems Analysis (Preferred)
CS 109 Introduction to Probability for Computer Scientists

Science

Minimum 12 units

Select one sequence: 12

PHYSICS 41 Mechanics
& EE 42 and Introduction to Electromagnetics and Its Applications 3

PHYSICS 41 Mechanics
& PHYSICS 43 and Electricity and Magnetism 3
Disciplinary Area

Design Course

Select one. Students may select their Design course from any Disciplinary Area.

EE 109  Digital Systems Design Lab (WIM/Design)
EE 133  Analog Communications Design Laboratory (WIM/Design)
EE 134  Introduction to Photonics (WIM/Design)
EE 153  Power Electronics (WIM/Design)
EE 155  Green Electronics (WIM/Design)

Design Course

Select one. Students may select their Design course from any Disciplinary Area.

EE 109  Digital Systems Design Lab (WIM/Design)
EE 133  Analog Communications Design Laboratory (WIM/Design)
EE 134  Introduction to Photonics (WIM/Design)
EE 153  Power Electronics (WIM/Design)
EE 155  Green Electronics (WIM/Design)
EE 158  Introduction to Digital Image Processing (WIM/Design)
EE 262  Two-Dimensional Imaging (Design)
EE 264  Digital Signal Processing (Design)
EE 264W  Digital Signal Processing (WIM/Design)
EE 267  Virtual Reality (Design)
CS 194  Software Project (Design)
CS 194W  Software Project (WIM/Design)

Electives

Minimum 17 units. Students may select electives from the disciplinary areas, from the multidisciplinary elective areas; or any combination of disciplinary and multidisciplinary areas. May include up to two additional Engineering Fundamentals, any CS 193 course and any letter graded EE courses (minus any previously noted restrictions). Freshman and Sophomore seminars, EE 191 and CS 106A do not count toward the 60 units. Students may have fewer elective units if they have more units in their disciplinary area.

1 Math 41 and Math 42 are no longer offered and have been replaced by Math 19, Math 20, and Math 21.
2 MATH 52 may be taken in place of MATH 51. CME 102 can be taken in place of MATH 53.
3 EE 42 may be used in place of PHYSICS 43 (if not used in EE electives area). The EE introductory class ENGR 40A and ENGR 40B or ENGR 40M may be taken concurrently with either EE 42 or PHYSICS 43. There are no prerequisites for ENGR 40A and ENGR 40B or ENGR 40M.
4 For upper division students, a 200-level seminar in their disciplinary area will be accepted, on petition.
5 Students may petition to have either PHYSICS 65 or the combination of PHYSICS 45 and PHYSICS 70 count as an alternative to EE 65.
6 EE 191W may satisfy WIM only if it is a follow-up to an REU, independent study project or as part of an honors thesis project where a faculty agrees to provide supervision of writing a technical paper and with suitable support from the Writing Center.
7 To satisfy Design, must take EE 264 or EE 267 for 4 units and complete the laboratory project.

Disciplinary Areas

Hardware and Software

<table>
<thead>
<tr>
<th>Units</th>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 180</td>
<td>Digital Systems Architecture (Required)</td>
</tr>
<tr>
<td>EE 107</td>
<td>Embedded Networked Systems</td>
</tr>
<tr>
<td>EE 109</td>
<td>Digital Systems Design Lab (WIM/Design)</td>
</tr>
<tr>
<td>EE 118</td>
<td>Introduction to Mechatronics</td>
</tr>
<tr>
<td>EE 155</td>
<td>Green Electronics (Design)</td>
</tr>
<tr>
<td>EE 213</td>
<td>Digital MOS Integrated Circuits</td>
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<tr>
<td>EE 264</td>
<td>Digital Signal Processing (Design)</td>
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<tr>
<td>EE 264W</td>
<td>Digital Signal Processing</td>
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<tr>
<td>EE 267</td>
<td>Virtual Reality</td>
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<tr>
<td>EE 271</td>
<td>Introduction to VLSI Systems</td>
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<td>EE 272</td>
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<td>EE 273</td>
<td>Digital Systems Engineering</td>
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<tr>
<td>EE 282</td>
<td>Computer Systems Architecture</td>
</tr>
<tr>
<td>EE 285</td>
<td>Embedded Systems Workshop</td>
</tr>
<tr>
<td>CS 107</td>
<td>Computer Organization and Systems (Required prerequisite for EE 180; CS 107E preferred)</td>
</tr>
<tr>
<td>CS 107E</td>
<td>Computer Systems from the Ground Up</td>
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<tr>
<td>CS 108</td>
<td>Object-Oriented Systems Design</td>
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<td>CS 110</td>
<td>Principles of Computer Systems</td>
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<tr>
<td>CS 131</td>
<td>Computer Vision: Foundations and Applications</td>
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<tr>
<td>CS 140</td>
<td>Operating Systems and Systems Programming</td>
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<tr>
<td>CS 143</td>
<td>Compilers</td>
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<td>CS 144</td>
<td>Introduction to Computer Networking</td>
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<tr>
<td>CS 145</td>
<td>Introduction to Databases</td>
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<td>CS 148</td>
<td>Introduction to Computer Graphics and Imaging</td>
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<td>CS 149</td>
<td>Parallel Computing</td>
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<td>CS 155</td>
<td>Computer and Network Security</td>
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<tr>
<td>CS 194W</td>
<td>Software Project (WIM/Design)</td>
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<tr>
<td>CS 221</td>
<td>Artificial Intelligence: Principles and Techniques</td>
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<tr>
<td>CS 223A</td>
<td>Introduction to Robotics</td>
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<tr>
<td>CS 224N</td>
<td>Natural Language Processing with Deep Learning</td>
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<tr>
<td>CS 225A</td>
<td>Experimental Robotics</td>
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<tr>
<td>CS 229</td>
<td>Machine Learning</td>
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<tr>
<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
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<tr>
<td>CS 231N</td>
<td>Convolutional Neural Networks for Visual Recognition</td>
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<td>CS 241</td>
<td>Embedded Systems Workshop</td>
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<tr>
<td>CS 244</td>
<td>Advanced Topics in Networking</td>
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<tr>
<td>EE 102B</td>
<td>Signal Processing and Linear Systems II (Required)</td>
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<td>EE 103</td>
<td>Introduction to Matrix Methods</td>
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<td>EE 104</td>
<td>Introduction to Machine Learning</td>
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<td>EE 107</td>
<td>Embedded Networked Systems</td>
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<tr>
<td>EE 118</td>
<td>Introduction to Mechatronics</td>
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<tr>
<td>EE 124</td>
<td>Introduction to Neuroelectrical Engineering</td>
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<td>EE 133</td>
<td>Analog Communications Design Laboratory (WIM/Design)</td>
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<td>Green Electronics (WIM/Design)</td>
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<td>EE 168</td>
<td>Introduction to Digital Image Processing (WIM/Design)</td>
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<td>EE 169</td>
<td>Introduction to Bioimaging</td>
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<td>EE 179</td>
<td>Analog and Digital Communication Systems</td>
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<td>EE 261</td>
<td>The Fourier Transform and Its Applications</td>
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<td>EE 262</td>
<td>Two-Dimensional Imaging (Design)</td>
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<td>Introduction to Linear Dynamical Systems</td>
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<tr>
<td>EE 278</td>
<td>Introduction to Statistical Signal Processing</td>
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<td>EE 279</td>
<td>Introduction to Digital Communication</td>
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<td>CS 107</td>
<td>Computer Organization and Systems</td>
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<td>Machine Learning</td>
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<td>ENGR 105</td>
<td>Feedback Control Design</td>
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<td>ENGR 205</td>
<td>Introduction to Control Design Techniques</td>
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<td>EE 101B</td>
<td>Circuits II (Required)</td>
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<td>EE 107</td>
<td>Embedded Networked Systems</td>
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<tr>
<td>EE 114</td>
<td>Fundamentals of Analog Integrated Circuit Design</td>
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<td>EE 116</td>
<td>Semiconductor Device Physics</td>
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<td>EE 118</td>
<td>Introduction to Mechatronics</td>
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<tr>
<td>EE 124</td>
<td>Introduction to Neuroelectrical Engineering</td>
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<td>EE 133</td>
<td>Analog Communications Design Laboratory (WIM/Design)</td>
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<td>EE 134</td>
<td>Introduction to Photonics (WIM/Design)</td>
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<td>EE 216</td>
<td>Principles and Models of Semiconductor Devices</td>
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<td>EE 222</td>
<td>Applied Quantum Mechanics I</td>
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<td>Applied Quantum Mechanics II</td>
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<td>Basic Physics for Solid State Electronics</td>
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<td>EE 236A</td>
<td>Modern Optics</td>
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<td>Computer Systems Architecture</td>
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<td>CS 107</td>
<td>Computer Organization and Systems</td>
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<td>CS 116</td>
<td>Understanding Energy (Formerly CEE 173A)</td>
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<td>Introduction to Sensing Networks for CEE</td>
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<td>Energy Efficient Buildings</td>
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<td>CEE 176B</td>
<td>Electric Power: Renewables and Efficiency</td>
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<td>Introduction to Control Design Techniques</td>
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<tr>
<td>MATSCI 142</td>
<td>Quantum Mechanics of Nanoscale Materials (Formerly MATSCI 157)</td>
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<tr>
<td>MATSCI 152</td>
<td>Electronic Materials Engineering</td>
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</table>
MATSCI 156  Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution  3-4
ME 185  Electric Vehicle Design  3
ME 227  Vehicle Dynamics and Control  3
ME 271E  Aerial Robot Design  3

Music
EE 102B  Signal Processing and Linear Systems II  4
EE 109  Digital Systems Design Lab (WIM/Design)  4
EE 264  Digital Signal Processing (Design)  3-4
EE 264W  Digital Signal Processing (WIM/Design)  5
MUSIC 250A  Physical Interaction Design for Music  3-4
MUSIC 250B  Interactive Sound Art  1-4
MUSIC 256A  Music, Computing, Design I: Art of Design for Computer Music  3-4
MUSIC 256B  Music, Computing, Design II: Virtual and Augmented Reality for Music  3-4
MUSIC 257  Neuroplasticity and Musical Gaming  3-5
MUSIC 320A  Introduction to Audio Signal Processing Part I: Spectrum Analysis  3-4
MUSIC 320B  Introduction to Audio Signal Processing Part II: Digital Filters  3-4
MUSIC 420A  Signal Processing Models in Musical Acoustics  3-4
MUSIC 421A  Audio Applications of the Fast Fourier Transform  3-4
MUSIC 422  Perceptual Audio Coding  3
MUSIC 424  Signal Processing Techniques for Digital Audio Effects  3-4

MATH 53  Ordinary Differential Equations with Linear Algebra  5
or CME 102  Ordinary Differential Equations for Engineers
MATH 131P  Partial Differential Equations (or CME 204 or MATH 173 or MATH 220 or PHYSICS 111)  3

Science
PHYSICS 41  Mechanics (or PHYSICS 61)  4
PHYSICS 42  Classical Mechanics Laboratory (or PHYSICS 62)  1
PHYSICS 43  Electricity and Magnetism (or PHYSICS 63)  4
PHYSICS 67  Introduction to Laboratory Physics  1
PHYSICS 45  Light and Heat (or PHYSICS 65)  4
PHYSICS 46  Light and Heat Laboratory (or PHYSICS 67)  1
PHYSICS 70  Foundations of Modern Physics (if taking the 40 series)  4

Technology in Society
One course required; course must be on the School of Engineering Approved List, Fig 4-3 in the UGHB, the year it is taken. See Basic Requirement 4.

Engineering Fundamentals
Two courses minimum (CS 106A or X recommended)  6-10

Engineering Physics Depth (core)
Advanced Mathematics:
One advanced math elective such as  3-5
EE 261  The Fourier Transform and Its Applications
PHYSICS 112  Mathematical Methods for Theoretical Physics
CS 109  Introduction to Probability for Computer Scientists
CME 106  Introduction to Probability and Statistics for Engineers
Also qualified are EE 263, any Math or Statistics course numbered 100 or above, and any CME course numbered 200 or above, except CME 206.

Advanced Mechanics:  3-4
AA 242A  Classical Dynamics (or ME 333 or PHYSICS 110)  3
Intermediate Electricity and Magnetism  6-8
Select one of the following sequences:
PHYSICS 120  Intermediate Electricity and Magnetism I & PHYSICS 121 and Intermediate Electricity and Magnetism II
EE 142  Engineering Electromagnetics & EE 242  and Electromagnetic Waves

Numerical Methods
Select one of the following:  3-4
APPPHYS 215  Numerical Methods for Physicists and Engineers
CME 108  Introduction to Scientific Computing
CME 206/ ME 300C  Introduction to Numerical Methods for Engineering
PHYSICS 113  Computational Physics

Electronics Lab
Select one of the following:  3-5
ENGR 40A & ENGR 40B  Introductory Electronics and Introductory Electronics Part II (ENGR 40A alone is not allowed)
EE 101B  Circuits II
EE 122A
PHYSICS 105  Intermediate Physics Laboratory I: Analog Electronics
APPPHYS 207  Laboratory Electronics

Writing in the Major (WIM)
Select one of the following:  4-5
AA 190  Directed Research and Writing in Aero/Astro (for Aerospace specialty only)
Select three courses from one specialty area:

See Undergraduate Engineering Handbook for important details.

Specialty Tracks

Select one of the following:

- Design Course
  - ME 210 Introduction to Mechatronics
  - or EE 118 Introduction to Mechatronics

- Energy Systems:
  - ME 131A Heat Transfer
  - ME 131B Fluid Mechanics: Compressible Flow and Turbomachinery
  - ME 140 Advanced Thermal Systems

- Renewable Energy:
  - CEE 176B Electric Power: Renewables and Efficiency
  - EE 153 Power Electronics
  - EE 155 Green Electronics
  - EE 293A Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution
  - EE 293B Fundamentals of Energy Processes
  - MATSCI 156 Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution
  - MATSCI 302 Solar Cells
  - MATSCI 316 Nanoscale Science, Engineering, and Technology
  - ME 260 Fuel Cell Science and Technology

- Biophysics:
  - APPPHYS 205 Introduction to Biophysics
  - BIO 132 Advanced Imaging Lab in Biophysics

- BIO 41
- BIO 42 Physical Biology
- BIO 44 Fundamentals for Engineering Biology Lab
- BIO 101 Systems Biology
- BIO 103 Systems Physiology and Design
- BIO 123 Biomedical System Prototyping Lab
- BIO 211 Biophysics of Multi-cellular Systems and Amorphous Computing
- BIO 214 Representations and Algorithms for Computational Molecular Biology
- EE 169 Introduction to Bioimaging
- or EE 369A Medical Imaging Systems I

- Computational Science:
  - CME 212 Advanced Software Development for Scientists and Engineers
  - CME 215A Advanced Computational Fluid Dynamics
  - CME 215B Advanced Computational Fluid Dynamics
  - Any CME course with course number greater than 300 and less than 390
  - CS 103 Mathematical Foundations of Computing
  - CS 154 Introduction to Automata and Complexity Theory
  - CS 161 Design and Analysis of Algorithms
  - CS 205B Mathematical Methods for Fluids, Vision, and Interfaces
  - CS 221 Artificial Intelligence: Principles and Techniques
  - CS 228 Probabilistic Graphical Models: Principles and Techniques
  - CS 229 Machine Learning
  - STATS 202 Data Mining and Analysis
  - STATS 213 Introduction to Graphical Models

- Quantum Science & Engineering
  - APPPHYS 203 Atoms, Fields and Photons
  - APPPHYS 225 Probability and Quantum Mechanics
  - APPPHYS 383 Introduction to Atomic Processes

### Quantum Mechanics

Select one of the following sequences: 6-8

- EE 222 and Applied Quantum Mechanics II
- PHYSICS 130 Quantum Mechanics I
- & PHYSICS 131 and Quantum Mechanics II

### Thermodynamics and Statistical Mechanics

Select one of the following: 3-8

- PHYSICS 170 Thermodynamics, Kinetic Theory, and Statistical Mechanics I
- PHYSICS 171 Thermodynamics, Kinetic Theory, and Statistical Mechanics II
- or ME 346A Introduction to Statistical Mechanics

### Design Course

Select one of the following: 3-4

- AA 236A Spacecraft Design
- CS 108 Object-Oriented Systems Design
- EE 133 Analog Communications Design Laboratory
- ME 203 Design and Manufacturing
- ME 210 Introduction to Mechatronics
- PHYSICS 108 Advanced Physics Laboratory: Project

### Specialty Tracks

See Undergraduate Engineering Handbook for important details. Select three courses from one specialty area:

#### Aerospace Physics:

- AA 203 Introduction to Optimal Control and Dynamic Optimization
- AA 244A Introduction to Plasma Physics and Engineering
- AA 251 Introduction to the Space Environment
- AA 279A Space Mechanics
- ME 161 Dynamic Systems, Vibrations and Control

#### Materials Science:

- Any MATSCI courses numbered 151 to 199 (except 159Q) or PHYSICS 172

#### Electromechanical System Design:

- ME 80 Mechanics of Materials
- ME 112 Mechanical Systems Design
Requirements and Timeline for Honors in Engineering Physics:

1. Declare the honors program in Axess (ENGR-BSH, Subplan: Engineering Physics)
2. Obtain application form from the student services officer.
3. Apply to honors program by October 15 in the Autumn Quarter of the senior year.
4. Maintain an overall GPA of at least 3.5.
5. Optional: Under direction of the thesis adviser, students may enroll for research units in ENGR 199(W) or in departmental courses such as AA 190 or ME 191(H).
6. Submit a completed thesis draft to the research adviser and second reader by April 15.
7. Present the thesis work in an oral presentation or poster session in an appropriate forum (e.g., an event that showcases undergraduate research and is organized by the department of the adviser, the school of the adviser, or the University).
8. Incorporate feedback, which the adviser and second reader should provide by April 30, and obtain final endorsement signatures from the thesis adviser and second reader by May 15.
9. Submit one signed, single-sided copy to the student services officer by May 15. Students are sent email instructions on how to archive a permanent electronic copy in Terman Engineering library.

Environmental Systems Engineering (EnvSE)

Completion of the undergraduate program in Environmental Systems Engineering leads to the conferral of the Bachelor of Science in Environmental Systems Engineering.

Mission of the Undergraduate Program in Environmental Systems Engineering

The mission of the undergraduate program in Environmental Systems Engineering is to prepare students for incorporating environmentally sustainable design, strategies and practices into natural and built systems and infrastructure involving buildings, water supply, and coastal regions. Courses in the program are multidisciplinary in nature, combining math/science/engineering fundamentals, and tools and skills considered essential for an engineer, along with a choice of one of three focus areas for more in-depth study: coastal environments, freshwater environments, or urban environments. This major offers the opportunity for a more focused curriculum than the Environmental and Water Studies concentration in the Civil Engineering degree program. The program of study, which includes a capstone experience, aims to equip engineering students to take on the complex challenges of the twenty-first century involving natural and built environments, in consulting and industry as well as in graduate school.

Requirements

Mathematics and Science
See Basic Requirement 1 and 2

Technology in Society (TiS)
One 3-5 unit course required, course chosen must be on the SoE Approved Courses list at <ughs Stanford.edu> the year taken; see Basic Requirement 4

Engineering Fundamentals
Two courses minimum (see Basic Requirement 3), including:
ENGR 70A Programming Methodology 5
(ENGR 70X)
ENGR 14 Intro to Solid Mechanics 3
Fundamental Tools/Skills 2
in visual, oral/written communication, and modeling/analysis
Specialty Courses, in either
Coastal environments (see below) 37
or freshwater environments (see below)
or urban environments (see below)
Urban Environments Focus Area (37 units)

1. Math must include CME 100 Vector Calculus for Engineers (or MATH 51 Linear Algebra and Differential Calculus of Several Variables), and either a Probability/Statistics course or MATH 102 Ordinary Differential Equations for Engineers (or MATH 53 Ordinary Differential Equations with Linear Algebra). Science must include PHYSICS 41 Mechanics; and either CHEM 31B Chemical Principles II or CHEM 31X Chemical Principles Accelerated (or PHYSICS 43 Electricity and Magnetism, for Urban focus area only).

2. Fundamental tools/skills must include:
   1. CEE 1 Introduction to Environmental Systems Engineering
   2. at least one visual communication class from CEE 31 Accessing Architecture Through Drawing / CEE 31Q Accessing Architecture Through Drawing, CEE 131F Principles of Freehand Drawing, ME 101 Visual Thinking, ME 110 Design Sketching, ARTSTUDI 160 Intro to Digital / Physical Design, or OSPPARIS 44 EAP: Analytical Drawing and Graphic Art;
   3. at least one oral/written communication class from ENGR 103 Public Speaking, ENGR 102W Writing for Engineers, ENGR 202W Technical Writing, CEE 151 Negotiation, CEE 175P Persuasive Communication for Environmental Scientists, Practitioners, and Entrepreneurs, EARTHSYS 191 Concepts in Environmental Communication or EARTHSYS 200 Environmental Communication in Action: The SAGE Project;
   4. at least one modeling/analysis class from CEE 101D Computations in Civil and Environmental Engineering(or CEE 101S) if not counted as Math, CEE 120A Building Information Modeling Workshop (or CEE 120S Building Information Modeling Special Study), CEE 155 Introduction to Sensing Networks for CEE, CEE 226 Life Cycle Assessment for Complex Systems, CME 211 Software Development for Scientists and Engineers, CS 110 Big Data: Tools and Techniques, Discoveries and Pitfalls, EARTHSYS 142 Remote Sensing of Land, EARTHSYS 144 Fundamentals of Geographic Information Science (GIS), EARTHSYS 211 Fundamentals of Modeling, or ENGR 150 Data Challenge Lab.

Urban Environments Focus Area (37 units) Required

CEE 100  Managing Sustainable Building Projects  4
CEE 101B  Mechanics of Fluids  4
CEE 146S  Engineering Economics and Sustainability  3
CEE 176A  Energy Efficient Buildings  3-4

Electives (at least two of the 4 areas below must be included)

Building Systems

CEE 102  Legal Principles in Design, Construction, and Project Delivery  3
CEE 130  Architectural Design: 3-D Modeling, Methodology, and Process  5
CEE 156  Building Systems  4
CEE 161C  Natural Ventilation of Buildings  3

Energy Systems

CEE 107A  Understanding Energy  4-5
CEE 176B  Electric Power: Renewables and Efficiency  3-4
EE 151  Sustainable Energy Systems  3
ENERGY 171  Energy Infrastructure, Technology and Economics  3
or
ENERGY 191  Optimization of Energy Systems  3-4

Water Systems

CEE 165C  Water Resources Management  3
CEE 166A  Watersheds and Wetlands  4
CEE 166B  Floods and Dams and Aqueducts  4
CEE 174A  Providing Safe Water for the Developing and Developed World  3
CEE 174B  Wastewater Treatment: From Disposal to Resource Recovery  3

Urban Planning, Design, Analysis

CEE 6  Physics of Cities  3
CEE 171  Environmental Planning Methods  3
Coastal Environments Focus Area (37 units)

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<th>Course Title</th>
<th>Units</th>
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<td>BIOHOPK 150H</td>
<td>Ecological Mechanics</td>
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<tr>
<td>GEOPHYS 191</td>
<td>Observing Freshwater</td>
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<td>GS 130</td>
<td>Soil Physics and Hydrology</td>
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<tr>
<td>OSPAU STL 25</td>
<td>Freshwater Systems</td>
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**Capstone (1 class required)**

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<td>CEE 126</td>
<td>International Urbanization Seminar: Cross-Cultural Collaboration for Sustainable Urban Development</td>
<td>4-5</td>
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<td>CEE 141A</td>
<td>Infrastructure Project Development</td>
<td>3</td>
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<td>CEE 169</td>
<td>Environmental and Water Resources Engineering Design</td>
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<td>CEE 179C</td>
<td>Environmental Engineering Design</td>
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<td>CEE 224X</td>
<td>Sustainable Urban Systems Project</td>
<td>1-5</td>
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<td>CEE 224Y</td>
<td>Sustainable Urban Systems Project</td>
<td>3-5</td>
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<tr>
<td>CEE 224Z</td>
<td>Sustainable Urban Systems Project</td>
<td>3-5</td>
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<tr>
<td>CEE 199</td>
<td>Undergraduate Research in Civil and Environmental Engineering</td>
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**Electives**

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<td>Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation</td>
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<tr>
<td>CEE 166A</td>
<td>Watersheds and Wetlands</td>
<td>4</td>
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<tr>
<td>CEE 166B</td>
<td>Floods and Dams and Aqueducts</td>
<td>4</td>
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<tr>
<td>CEE 171</td>
<td>Environmental Planning Methods</td>
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<td>or</td>
<td>CEE 265E</td>
<td>Adaptation to Sea Level Rise and Extreme Weather Events</td>
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<tr>
<td>CEE 174A</td>
<td>Providing Safe Water for the Developing and Developed World</td>
<td>3</td>
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<td>CEE 174B</td>
<td>Wastewater Treatment: From Disposal to Resource Recovery</td>
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<td>CEE 177</td>
<td>Aquatic Chemistry and Biology</td>
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<td>CEE 272</td>
<td>Coastal Contaminants</td>
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<td>BIO 30</td>
<td>Ecology for Everyone</td>
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<td>or</td>
<td>BIOHOPK 172H</td>
<td>Marine Ecology: From Organisms to Ecosystems</td>
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<td>EARTHSYS 116</td>
<td>Ecology of the Hawaiian Islands</td>
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<td>OSPAU STL 10</td>
<td>Coral Reef Ecosystems</td>
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<td>ESS 8</td>
<td>The Oceans: An Introduction to the Marine Environment</td>
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<td>or</td>
<td>BIOHOPK 182H</td>
<td>Stanford at Sea</td>
</tr>
<tr>
<td>or</td>
<td>EARTHSYS 141</td>
<td>Remote Sensing of the Oceans</td>
</tr>
<tr>
<td>or</td>
<td>EARTHSYS 151</td>
<td>Biological Oceanography</td>
</tr>
<tr>
<td>or</td>
<td>EARTHSYS 152</td>
<td>Marine Chemistry</td>
</tr>
</tbody>
</table>

Capstone (1 class required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE 126</td>
<td>International Urbanization Seminar: Cross-Cultural Collaboration for Sustainable Urban Development</td>
<td>4-5</td>
</tr>
<tr>
<td>CEE 141A</td>
<td>Infrastructure Project Development</td>
<td>3</td>
</tr>
<tr>
<td>CEE 169</td>
<td>Environmental and Water Resources Engineering Design</td>
<td>5</td>
</tr>
<tr>
<td>CEE 179C</td>
<td>Environmental Engineering Design</td>
<td>5</td>
</tr>
<tr>
<td>CEE 224X</td>
<td>Sustainable Urban Systems Project</td>
<td>3-5</td>
</tr>
<tr>
<td>CEE 224Y</td>
<td>Sustainable Urban Systems Project</td>
<td>3-5</td>
</tr>
<tr>
<td>CEE 224Z</td>
<td>Sustainable Urban Systems Project</td>
<td>3-5</td>
</tr>
<tr>
<td>BIOHOPK 168H</td>
<td>Disease Ecology: from parasites evolution to the socio-economic impacts of pathogens on nations</td>
<td>3</td>
</tr>
<tr>
<td>CEE 199</td>
<td>Undergraduate Research in Civil and Environmental Engineering</td>
<td>3-4</td>
</tr>
</tbody>
</table>

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).

**Individually Designed Majors in Engineering (IDMENS)**

Completion of the undergraduate program in Individually Designed Majors in Engineering (IDMEN) leads to the conferral of the Bachelor of Science in an Individually Designed Major: (approved title). The approved title of the IDMEN also appears on the transcript.

**Mission of the Undergraduate Program in Individually Designed Majors in Engineering**

The mission of the undergraduate program in Individually Designed Majors in Engineering (IDMEN) is to provide students with an understanding of engineering principles and the analytical and problem solving, design, and communication skills necessary to be successful in the field. The B.S. 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. Core courses in the curriculum include engineering fundamentals, mathematics, technology in society, and the sciences. Students then take additional courses pertinent to their IDMEN major. The program prepares students for careers in government and the corporate sector, and for graduate study.

**B.S. in Individually Designed Majors in Engineering**

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 units minimum, see Basic Requirement 1 in right sidebar); science (17 units minimum, see Basic Requirement 2); a Technology in Society (one course from School of Engineering Approved Courses list; the course must be on the list the year it is taken; see Basic Requirement 4); at least two Engineering Fundamentals courses, see Basic Requirement 3 for a list of courses; a minimum of 34 units of engineering depth courses, including a capstone depth course with content relevant to proposed goals; 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. 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 and on the diploma in this form: “Individually Designed Major in Subplan”, where “Subplan” is the title approved by the IDMEN Subcommittee.

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, engineering fundamentals, 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 a member of the School of Engineering and of the Academic Council, 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. Planning forms may be obtained from the Handbook of Student Affairs, Huang Engineering Center, Suite 135. An IDMEN for Undergraduate Engineering Programs at http://ughb.stanford.edu. Once a quarter. Planning forms may be obtained from the Handbook of Student Affairs, Huang Engineering Center, Suite 135. An IDMEN for Undergraduate Engineering Programs at http://ughb.stanford.edu.

Management Science and Engineering (MS&E)

Completion of the undergraduate program in Management Science and Engineering leads to the conferral of the Bachelor of Science in Management Science and Engineering.

Requirements

Mathematics and Science

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 100 Vector Calculus for Engineers or MATH 51 Linear Algebra and Differential Calculus of Several Variables</td>
<td>23</td>
</tr>
<tr>
<td>CME 103 Introduction to Matrix Methods</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 120 Probabilistic Analysis</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 121 Introduction to Stochastic Modeling</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 125 Introduction to Applied Statistics</td>
<td></td>
</tr>
<tr>
<td>Select one of the following sequences:</td>
<td>8</td>
</tr>
<tr>
<td>CHEM 31B Chemical Principles II &amp; CHEM 33 and Structure and Reactivity of Organic Molecules</td>
<td></td>
</tr>
</tbody>
</table>

Technology in Society

Select one of the following: see SoE Basic Requirement 4 3-5

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMM 120W Digital Media in Society</td>
<td></td>
</tr>
<tr>
<td>CS 181 Computers, Ethics, and Public Policy</td>
<td></td>
</tr>
<tr>
<td>ENGR 131 Ethical Issues in Engineering</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 193 Technology and National Security</td>
<td></td>
</tr>
<tr>
<td>STS 1 The Public Life of Science and Technology</td>
<td></td>
</tr>
</tbody>
</table>

Engineering Fundamentals 2

Two courses; see SoE Basic Requirement 3 8-10

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 106A Programming Methodology</td>
<td></td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 10 Introduction to Engineering Analysis</td>
<td></td>
</tr>
<tr>
<td>ENGR 14 Intro to Solid Mechanics</td>
<td></td>
</tr>
<tr>
<td>ENGR 15 Dynamics</td>
<td></td>
</tr>
<tr>
<td>ENGR 20 Introduction to Chemical Engineering</td>
<td></td>
</tr>
<tr>
<td>ENGR 25B Biotechnology</td>
<td></td>
</tr>
<tr>
<td>ENGR 25E Energy: Chemical Transformations for Production, Storage, and Use</td>
<td></td>
</tr>
<tr>
<td>ENGR 40 Introductory Electronics</td>
<td></td>
</tr>
<tr>
<td>ENGR 40A Introductory Electronics</td>
<td></td>
</tr>
<tr>
<td>ENGR 40M An Intro to Making: What is EE</td>
<td></td>
</tr>
<tr>
<td>ENGR 50 Introduction to Materials Science, Nanotechnology Emphasis</td>
<td></td>
</tr>
<tr>
<td>ENGR 50E Introduction to Materials Science, Energy Emphasis</td>
<td></td>
</tr>
<tr>
<td>ENGR 50M Introduction to Materials Science, Biomaterials Emphasis</td>
<td></td>
</tr>
<tr>
<td>ENGR 80 Introduction to Bioengineering (Engineering Living Matter)</td>
<td></td>
</tr>
<tr>
<td>ENGR 90 Environmental Science and Technology</td>
<td></td>
</tr>
</tbody>
</table>

Engineering Depth 2

Core Courses (all six required) 25-27

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 106B Programming Abstractions</td>
<td></td>
</tr>
<tr>
<td>or CS 106X Programming Abstractions (Accelerated)</td>
<td></td>
</tr>
<tr>
<td>ECON 50 Economic Analysis I</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 108 Senior Project (WIM)</td>
<td></td>
</tr>
<tr>
<td>or MS&amp;E 111X Introduction to Optimization (Accelerated)</td>
<td></td>
</tr>
<tr>
<td>or MS&amp;E 111 Introduction to Optimization</td>
<td></td>
</tr>
<tr>
<td>or MS&amp;E 140 Accounting for Managers and Entrepreneurs</td>
<td></td>
</tr>
<tr>
<td>or MS&amp;E 140X Financial Accounting Concepts and Analysis</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 180 Organizations: Theory and Management</td>
<td></td>
</tr>
</tbody>
</table>

Area Courses (see below) 27

Choose four or five courses (minimum 15 units) from a primary area and two courses (minimum 6 units) from each of the other two areas.

Depth Areas

Finance and Decision Area

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Accounting Concepts and Analysis</td>
<td>6-15</td>
</tr>
</tbody>
</table>
Students choosing F&D as their primary area must take at least two of ECON 51, MS&E 145 (or 245A), and MS&E 152 (or 252), as part of their 15 units

Introductory (no prerequisites)
- MS&E 147 Finance and Society for non-MBAs
- MS&E 152 Introduction to Decision Analysis

Intermediate (has prerequisites and/or appropriate for juniors and seniors)
- MS&E 145 Introduction to Investment Science
- MS&E 146 Corporate Financial Management
- MS&E 252 Decision Analysis I: Foundations of Decision Analysis

Advanced (intended primarily for graduate students, but may be taken by advanced undergraduates)
- MS&E 245A Investment Science
- MS&E 246 Financial Risk Analytics
- MS&E 250A Engineering Risk Analysis
- MS&E 250B Project Course in Engineering Risk Analysis
- MS&E 245B Advanced Investment Science

**Operations and Analytics Area** 6-15 units

Students choosing O&A as their primary area may also include CS 161, CS 229, and STATS 202 in their selections.

Methods
- MS&E 112 Mathematical Programming and Combinatorial Optimization
- MS&E 135 Networks
- MS&E 213 Introduction to Optimization Theory
- MS&E 223 Simulation
- MS&E 226 "Small" Data
- MS&E 231 Introduction to Computational Social Science
- MS&E 237 Networks, Markets, and Crowds
- MS&E 251 Stochastic Control

Applications
- MS&E 130 Information Networks and Services
- MS&E 233 Networked Markets
- MS&E 234 Data Privacy and Ethics
- MS&E 235 Analytics in Action
- MS&E 260 Introduction to Operations Management
- MS&E 262 Supply Chain Management
- MS&E 263 Healthcare Operations Management
- MS&E 267 Service Operations and the Design of Marketplaces
- MS&E 330 Law, Order & Algorithms

**Organizations, Technology, and Policy Area** 6-15 units

Students choosing OT&P as their primary area must take at least two of ENGR 145, MS&E 175, MS&E 184, and MS&E 185 as part of their 15 units

Introductory (no prerequisites)
- ENGR 131 Ethical Issues in Engineering
- MS&E 190 Methods and Models for Policy and Strategy Analysis
- MS&E 193 Technology and National Security

Advanced (has prerequisites and/or appropriate for juniors and seniors)
- ENGR 145 Technology Entrepreneurship
- MS&E 175 Innovation, Creativity, and Change
- or MS&E 177 Creativity Rules
- MS&E 183 Leadership in Action

**Mathematics**

- MS&E 184 New Directions in the Psychology of Technology and Work
- MS&E 185 Global Work
- MS&E 188 Organizing for Good
- MS&E 243 Energy and Environmental Policy Analysis
- MS&E 292 Health Policy Modeling
- MS&E 294 Climate Policy Analysis
- MS&E 295 Energy Policy Analysis

1. Math and Science must total a minimum of 44 units. Electives must come from the School of Engineering approved list, or, PSYCH 50, PSYCH 70, or PSYCH 100. Recommended engineering fundamentals are ENGR 131, ENGR 145, ENGR 150, ENGR 151, and ENGR 152.
3. Students may petition to place out of CS 106A Programming Methodology.
4. 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.

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).

**Materials Science and Engineering (MATSCI)**

Completion of the undergraduate program in Materials Science and Engineering leads to the conferral of the Bachelor of Science in Materials Science and Engineering.

**Mission of the Undergraduate Program in Materials Science and Engineering**

The mission of the undergraduate program in Materials Science and Engineering is to provide students with a strong foundation in materials science and engineering with emphasis on the fundamental scientific and engineering principles which underlie the knowledge and implementation of material structure, processing, properties, and performance of all classes of materials used in engineering systems. Courses in the program develop students' knowledge of modern materials science and engineering, teach them to apply this knowledge analytically to create effective and novel solutions to practical problems, and develop their communication skills and ability to work collaboratively. The program prepares students for careers in industry and for further study in graduate school.

The B.S. in Materials Science and Engineering provides training for the materials engineer and also preparatory training for graduate work in materials science. Capable undergraduates are encouraged to take at least one year of graduate study to extend their course work through the coterminal degree program which leads to an M.S. in Materials Science and Engineering. Coterminal degree programs are encouraged both for undergraduate majors in Materials Science and Engineering and for undergraduate majors in related disciplines.

**Requirements**

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mathematics</strong> 20 units minimum; see Basic Requirement 1</td>
</tr>
</tbody>
</table>

Select one of the following: 5
Three of the following courses:

MATSCI 145, MATSCI 144, MATSCI 143, MATSCI 142

One of the following courses:

- Engineering Depth
- Materials Science Fundamentals

Select one of the following:

- MATH 52: Integral Calculus of Several Variables
- CME 104/ENGR 155B: Linear Algebra and Partial Differential Equations for Engineers

Select one of the following:

- MATH 53: Ordinary Differential Equations with Linear Algebra
- CME 102/ENGR 155A: Ordinary Differential Equations for Engineers

One additional course

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; course chosen must be on the SoE Approved Courses list at <ughb.stanford.edu> the year taken; see Basic Requirement 3

Engineering Fundamentals

Three courses minimum; see Basic Requirement 4

Select one of the following:

- ENGR 50: Introduction to Materials Science, Nanotechnology Emphasis
- ENGR 50E: Introduction to Materials Science, Energy Emphasis
- ENGR 50M: Introduction to Materials Science, Biomaterials Emphasis

At least two additional courses

6-9

Materials Science and Engineering Depth

Materials Science Fundamentals:

- MATSCI 142: Quantum Mechanics of Nanoscale Materials
- MATSCI 143: Nanostructure and Characterization
- MATSCI 144: Thermodynamic Evaluation of Green Energy Technologies
- MATSCI 145: Nanomaterials Synthesis

Two of the following courses:

- MATSCI 151: Microstructure and Mechanical Properties
- MATSCI 152: Electronic Materials Engineering
- MATSCI 156: Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution
- MATSCI 158: Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life
- MATSCI 190: Organic and Biological Materials
- MATSCI 192: Materials Chemistry
- MATSCI 193: Atomic Arrangements in Solids
- MATSCI 194: Thermodynamics and Phase Equilibria
- MATSCI 195: Waves and Diffraction in Solids
- MATSCI 196: Defects in Crystalline Solids
- MATSCI 197: Rate Processes in Materials
- MATSCI 198: Mechanical Properties of Materials
- MATSCI 199: Electronic and Optical Properties of Solids

Engineering Depth

16

One of the following courses:

- MATSCI 161: Energy Materials Laboratory (WIM)
- MATSCI 164: Electronic and Photonic Materials and Devices Laboratory (WIM)

Three of the following courses:

Focus Area Options 6

1. Basic Requirement 1 (20 units minimum): see a list of approved Math Courses (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Approved_Courses).
2. Basic Requirement 2 (20 units minimum): see a list of approved Science Courses (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Approved_Courses).
3. Basic Requirement 3 (one course minimum): see a list of approved Technology in Society Courses (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Approved_Courses).
4. Basic Requirement 4 (3 courses minimum): see a list of approved Engineering Fundamentals (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Approved_Courses) Courses. If both ENGR 50 Introduction to Materials Science, Nanotechnology Emphasis, ENGR 50E Introduction to Materials Science, Energy Emphasis, and/or ENGR 50M Introduction to Materials Science, Biomaterials Emphasis are taken, one may be used for the Materials Science Fundamentals requirement.
5. ENGR 30 may be substituted for MATSCI 144 Thermodynamic Science Fundamentals requirement.
6. Focus Area Options: 10 units from one of the following Focus Area Options below.

Focus Area Options

Bioengineering (10 units minimum)

- BIOE 220: Introduction to Imaging and Image-based Human Anatomy
- BIOE 281: Biomechanics of Movement
- BIOE 284B: Cardiovascular Bioengineering
- BIOE 333: Interfacial Phenomena and Bionanotechnology
- BIOE 381: Orthopaedic Bioengineering
- MATSCI 190: Organic and Biological Materials
- MATSCI 380: Nano-Biotechnology
- MATSCI 381: Biomaterials in Regenerative Medicine
- MATSCI 382: Biochips and Medical Imaging

Chemical Engineering (10 units minimum)

- CHEM 171: Physical Chemistry I
- CHEMENG 130: Separation Processes
- CHEMENG 140: Micro and Nanoscale Fabrication Engineering
- CHEMENG 150: Biochemical Engineering
- CHEMENG 160: Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life

Chemistry (10 units minimum)

- CHEM 151: Inorganic Chemistry I
- CHEM 153: Inorganic Chemistry II
- CHEM 171: Physical Chemistry I
- CHEM 173: Physical Chemistry II
- CHEM 175: Physical Chemistry III
- CHEM 181: Biochemistry I
- CHEM 183: Biochemistry II
- CHEM 185: Biophysical Chemistry

Electronics & Photonics (10 units minimum)

- EE 101A: Circuits
Petition for a self-defined cohesive program.

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (http://ughb.stanford.edu).

**Mechanical Engineering (ME)**

Completion of the undergraduate program in Mechanical Engineering leads to the conferral of the Bachelor of Science in Mechanical Engineering.

**Mission of the Undergraduate Program in Mechanical Engineering**

The mission of the undergraduate program in Mechanical Engineering is to provide students with a balance of theoretical and practical experiences that enable them to address a variety of societal needs. The curriculum encompasses elements from a wide range of disciplines built around the themes of biomedicine, computational engineering, design, energy, and multiscale engineering. Course work may include mechatronics, computational simulation, solid and fluid dynamics, micro-, and nanomechanics, and design. The program prepares students for entry-level work as mechanical engineers and for graduate studies in either an engineering discipline or other fields where a broad engineering background is useful.

**Requirements**

### Mathematics

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 102/</td>
<td>Ordinary Differential Equations for Engineers</td>
</tr>
<tr>
<td>ENGR 155A</td>
<td>Ordinary Differential Equations with Linear Algebra</td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 106/</td>
<td>Introduction to Probability and Statistics for Engineers</td>
</tr>
<tr>
<td>ENGR 155C</td>
<td>Statistical Methods in Engineering and the Physical Sciences</td>
</tr>
</tbody>
</table>

**Science**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 31X</td>
<td>Chemical Principles Accelerated</td>
</tr>
</tbody>
</table>

Plus additional required courses 1

**Technology in Society**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>One course required; must be on SoE Approved Courses list at &lt;ughb.stanford.edu&gt; the year taken.; see Basic Requirement 4</td>
<td></td>
</tr>
</tbody>
</table>

**Engineering Fundamentals**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 40M</td>
<td>An Intro to Making: What is EE</td>
</tr>
<tr>
<td>ENGR 70A</td>
<td>Programming Methodology (same as CS 106A)</td>
</tr>
</tbody>
</table>

**Engineering Depth**

Minimum of 68 Engineering Science and Design ABET units; see Basic Requirement 5

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 14</td>
<td>Intro to Solid Mechanics</td>
</tr>
<tr>
<td>ENGR 15</td>
<td>Dynamics</td>
</tr>
<tr>
<td>ME 30</td>
<td>Engineering Thermodynamics</td>
</tr>
<tr>
<td>ME 70</td>
<td>Introductory Fluids Engineering</td>
</tr>
<tr>
<td>ME 80</td>
<td>Mechanics of Materials</td>
</tr>
<tr>
<td>ME 101</td>
<td>Visual Thinking</td>
</tr>
<tr>
<td>ME 103D</td>
<td>Engineering Drawing and Design</td>
</tr>
</tbody>
</table>

**Basic Requirement 1**

24 units minimum; see Basic Requirement 1

**Basic Requirement 2**

20 units minimum; see Basic Requirement 2

**Basic Requirement 3**

Two courses minimum; see Basic Requirement 3

**Basic Requirement 4**

One course required; must be on SoE Approved Courses list at <ughb.stanford.edu> the year taken.; see Basic Requirement 4

**Basic Requirement 5**

Minimum of 68 Engineering Science and Design ABET units; see Basic Requirement 5
The mission of the undergraduate program in Product Design is to prepare students for careers in industry and for graduate study. The program teaches a design process that encourages creativity, craftsmanship, and personal expression, and emphasizes brainstorming and need finding. The course work provides students with the skills necessary to carry projects from initial concept to completion of working prototypes. Students studying product design follow the basic course work in design and manufacturing and must be taken in consecutive quarters. Students that take the ME 170A and ME 170B are a 2-quarter Capstone Design Sequence designated in the course work. The program prepares students for careers in industry and for graduate study.

Requirements

Mathematics and Science

Mathematics

20 units minimum

Recommended: one course in Statistics

23 units minimum: 12 units Physics and 3-5 units of an additional science class from School of Engineering approved list, and 8 units minimum of behavioral sciences.

1 Math and science must total 45 units.

2 Courses ME 103D and ME 203 must be taken concurrently.

3 ME 170A and ME 170B are a 2-quarter Capstone Design Sequence and must be taken in consecutive quarters. Students that take the Capstone Design Sequence may use ME 170B as an alternative to ME 113. ME 170A will then be counted as an ME Elective Course.

4 ME 112, ME 131A, and ME 140 or ME 141, together fulfill the WIM requirement.

Options to complete the ME depth sequence: see the list of options in the ME major section of the Handbook for Undergraduate Engineering Programs (http://ughb.stanford.edu).

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).

Product Design (PD)

Completion of the undergraduate program in Product Design leads to the conferral of the Bachelor of Science in Engineering. The subplan Product Design appears on the transcript and on the diploma.

Mission of the Undergraduate Program in Product Design

The mission of the undergraduate program in Product Design is to graduate students who can synthesize technology, human factors, and business factors in the service of human need. The program teaches a design process that encourages creativity, craftsmanship, aesthetics, and personal expression, and emphasizes brainstorming and need finding. The course work provides students with the skills necessary to carry projects from initial concept to completion of working prototypes. Students studying product design follow the basic Mechanical Engineering curriculum and are expected to meet the University requirements for a Bachelor of Science degree. The program prepares students for careers in industry and for graduate study.

Requirements

Mathematics and Science

Mathematics

20 units minimum

Recommended: one course in Statistics

Science

23 units minimum: 12 units Physics and 3-5 units of an additional science class from School of Engineering approved list, and 8 units minimum of behavioral sciences.

1 School of Engineering approved science list available at http://ughb.stanford.edu. PSYCH electives numbered 30-200 or HUMBIO 82A or HUMBIO 160 are preapproved. If the Psychology elective was taken prior to the requirement being increased to 3 units minimum in 2012-13, student may be short 1 unit in science/behavioral science; this is approved without petition.

2 If ENGR 14 and/or ME 110, and/or ME 101 were taken prior to the courses being offered for 3 and 2 units, depth total may be reduced by 1-3 units with no petition required.

3 ME 103D and ME 203 should be taken concurrently.

4 ME 112 meets the Writing in the Major (WIM) requirement for Product Design.

5 ME 215C is the only course that can be waived if a student takes a quarter overseas. Students should plan their overseas quarter to take place in sophomore year, or Spring Quarter of the junior year only. If the student selects to go overseas junior year, the total depth units are reduced by 3; this is approved without petition.

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).
The joint major program (JMP), authorized by the Academic Senate for a pilot period of six years beginning in 2014-15, permits students to major in both Computer Science and one of ten Humanities majors. See the "Joint Major Program (http://exploredegrees.stanford.edu/undergraduatedegreesandprograms/#jointmajortext)" section of this bulletin for a description of University requirements for the JMP. See also the Undergraduate Advising and Research JMP web site and its associated FAQs.

Students completing the JMP receive a B.A.S. (Bachelor of Arts and Science).

Because the JMP is new and experimental, changes to procedures may occur; students are advised to check the relevant section of the bulletin periodically.

Mission
The Joint Major provides a unique opportunity to gain mastery in two disciplines: Computer Science and a selected humanities field. Unlike the double major or dual major, the Joint Major emphasizes integration of the two fields through a cohesive, transdisciplinary course of study and integrated capstone experience. The Joint Major not only blends the intellectual traditions of two Stanford departments it does so in a way that reduces the total unit requirement for each major.

Computer Science Major Requirements in the Joint Major Program
(See the respective humanities department Joint Major Program section of this bulletin for details on humanities major requirements.)

The CS requirements for the Joint Major follow the CS requirements for the CS-BS degree with the following exceptions:

1. Two of the depth electives are waived. The waived depth electives are listed below for each CS track.
2. The Senior Project is fulfilled with a joint capstone project. The student enrolls in CS191 or 191W (3 units) during the senior year. Depending on the X department, enrollment in an additional Humanities capstone course may also be required. But, at a minimum, 3 units of CS191 or 191W must be completed.
3. There is no double-counting of units between majors. If a course is required for both the CS and Humanities majors, the student will work with one of the departments to identify an additional course - one which will benefit the academic plan - to apply to that major's total units requirement.
4. For CS, WIM can be satisfied with CS181W or CS191W.

Depth Electives for CS Tracks for students completing a Joint Major:

Artificial Intelligence Track:
One Track Elective (rather than three).

Biocomputation Track:
One course from Note 3 of the Department Program Sheet, plus one course from Note 4 of the Program Sheet.

Computer Engineering Track:
• EE 108A and 108B
• One of the following: EE 101A, 101B, 102A, 102B
• Satisfy the requirements of one of the following concentrations:
  1. Digital Systems Concentration: CS 140 or 143; EE 109, 271; plus one of CS 140 or 143 (if not counted above), 144, 149, 240E, 244: EE 273, 282
  2. Robotics and Mechatronics Concentration: CS 205A, 223A, ME 210; ENGR 105
  3. Networking Concentration: CS 140, 144; plus two of the following, CS 240, 240E, 244, 244B, 244E, 249A, 249B, EE 179, EE 276

Graphics Track:
No Track Electives required (rather than two)

HCI Track:
No Interdisciplinary HCI Electives required

Information Track:
One Track Elective (rather than three)

Systems Track:
One Track Elective (rather than three)

Theory Track:
One Track Elective (rather than three)

Unspecialized Track:
No Track Electives required (rather than two)

Individually Designed Track:
Proposals should include a minimum of five (rather than seven) courses, at least four of which must be CS courses numbered 100 or above.

Declaring a Joint Major Program
To declare the joint major, students must first declare each major through Axess, and then submit the Declaration or Change of Undergraduate Major, Minor, Honors, or Degree Program. (https://stanford.box.com/change-UG-program) The Major-Minor and Multiple Major Course Approval Form (https://stanford.box.com/MajMin-MultMaj) is required for graduation for students with a joint major.

Dropping a Joint Major Program
To drop the joint major, students must submit the Declaration or Change of Undergraduate Major, Minor, Honors, or Degree Program. (https://stanford.box.com/change-UG-program). Students may also consult the Student Services Center (http://studentservicescenter.stanford.edu) with questions concerning dropping the joint major.

Transcript and Diploma
Students completing a joint major graduate with a B.A.S. degree. The two majors are identified on the transcript with a notation indicating that the student has completed a "Joint Major". The two majors are identified on the transcript with a notation indicating that the student has completed a "Joint Major".

Minor in the School of Engineering
An undergraduate minor in some Engineering programs may be pursued by interested students; see the Handbook for Undergraduate Engineering Programs, or consult with a department's undergraduate program representative or the Office of Student Affairs, Huang Engineering Center, Suite 135.

General requirements and policies for a minor in the School of Engineering are:

1. A set of courses totaling not less than 20 and not more than 36 units, with a minimum of six courses of at least 3 units each. These courses must be taken for a letter grade except where letter grades are not offered, and a minimum GPA of 2.0 within the minor course...
list must be maintained (departments may require a higher GPA if they choose).

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. Courses used for the major and/or minor core must not be duplicated within any other of the student's degree programs; that is, students may not overlap (double-count) courses for completing core major and minor requirements.

Departmentally based minor programs are structured at the discretion of the sponsoring department, subject only to requirements 1, 2, 3, and 4 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) Minor

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. If any core classes (aside from ENGR 21; see footnote) are part of student's major or other degree program, the AA adviser can help select substitute courses to fulfill the AA minor requirements; no double counting allowed. All courses taken for the minor must be taken for a letter grade if that option is offered by the instructor. Minimum GPA for all minor courses combined is 2.0.

The following core courses fulfill the minor requirements:

**AA Core**

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 21 Engineering of Systems</td>
<td>3</td>
</tr>
<tr>
<td>AA 100 Introduction to Aeronautics and Astronautics</td>
<td>3</td>
</tr>
<tr>
<td>AA 131 Space Flight</td>
<td>1</td>
</tr>
<tr>
<td>AA 141 Atmospheric Flight</td>
<td>3</td>
</tr>
</tbody>
</table>

**AA Electives**

Choose 4 courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA 101 Introduction to Aero Fluid Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>AA 102 Introduction to Applied Aerodynamics</td>
<td>1</td>
</tr>
<tr>
<td>AA 103 Air and Space Propulsion</td>
<td>1</td>
</tr>
<tr>
<td>AA 111 Introduction to Aerospace Computational Engineering</td>
<td>1</td>
</tr>
<tr>
<td>AA 135 Introduction to Space Policy</td>
<td>1</td>
</tr>
<tr>
<td>AA 151 Lightweight Structures</td>
<td>1</td>
</tr>
<tr>
<td>AA 156 Mechanics and Composites</td>
<td>1</td>
</tr>
<tr>
<td>AA 171 Autonomous Systems</td>
<td>1</td>
</tr>
<tr>
<td>AA 173 Flight Mechanics and Controls</td>
<td>1</td>
</tr>
<tr>
<td>AA 175 Embedded Programming</td>
<td>1</td>
</tr>
<tr>
<td>AA 272C Global Positioning Systems</td>
<td>3</td>
</tr>
<tr>
<td>AA 279A Space Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 105 Feedback Control Design</td>
<td>3</td>
</tr>
</tbody>
</table>

1. This course will be offered in the future. Please see our website for future course offerings (https://aa.stanford.edu/academic/undergraduate-program).

2. ENGR 21 is waived as minor requirement if already taken as part of the major program.

Chemical Engineering Minor

The following core courses fulfill the minor requirements:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 20 Introduction to Chemical Engineering</td>
<td>4</td>
</tr>
<tr>
<td>CHEMENG 100 Chemical Process Modeling, Dynamics, and Control</td>
<td>3</td>
</tr>
<tr>
<td>CHEMENG 110 Equilibrium Thermodynamics</td>
<td>3</td>
</tr>
<tr>
<td>CHEMENG 120A Fluid Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>CHEMENG 120B Energy and Mass Transport</td>
<td>4</td>
</tr>
<tr>
<td>CHEMENG 170 Kinetics and Reactor Design</td>
<td>3</td>
</tr>
<tr>
<td>CHEMENG 185A Chemical Engineering Laboratory A</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 171 Physical Chemistry I</td>
<td>4</td>
</tr>
<tr>
<td>CHEMENG 180 Chemical Engineering Plant Design</td>
<td>3</td>
</tr>
</tbody>
</table>

Select one of the following:

- CHEMENG 140 Micro and Nanoscale Fabrication Engineering
- CHEMENG 142 Basic Principles of Heterogeneous Catalysis with Applications in Energy Transformations
- CHEMENG 160 Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life
- CHEMENG 162 Polymers for Clean Energy and Water
- CHEMENG 174 Environmental Microbiology I
- CHEMENG 181 Biochemistry I

Total Units: 36

Civil Engineering (CE) Minor

The civil engineering minor is intended to give students a focused introduction to one or more areas of civil engineering. Departmental expertise and undergraduate course offerings are available in the areas of Architectural Design, Construction Engineering and Management, and Structural and Geotechnical Engineering. Students interested in Environmental and Water Studies should refer to the Environmental Systems Engineering minor.

The minimum prerequisite for a civil engineering minor is MATH 19 Calculus (or MATH 20 Calculus or MATH 21 Calculus); however, many courses of interest require PHYSICS 41 Mechanics and/or MATH 51 Linear Algebra and Differential Calculus of Several Variables as prerequisites. The minimum prerequisite for a Civil Engineering minor focusing on architectural design is MATH 19 Calculus (or MATH 20 Calculus or MATH 21 Calculus) and a course in Statistics. Students should recognize that a minor in civil engineering is not an ABET-accredited degree program.

Since undergraduates having widely varying backgrounds may be interested in obtaining a civil engineering minor, and the field itself is so broad, no single set of course requirements will be appropriate for all students. Instead, interested students are encouraged to propose their own set of courses within the guidelines listed below. Additional information, including example minor programs, are provided on the CEE web site (http://cee.stanford.edu/prospective/undergrad/minor_overview.html) and in Chapter 6 of the Handbook for Undergraduate Engineering Programs (http://ughb.stanford.edu).

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 of letter-graded work, except where letter grades are not offered.

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. Example programs are given on the CEE webpage.
must complete a minimum of 23-25 units, as follows:

The options for completing a minor in EE are outlined below. Students include the standard mathematics sequence through MATH 51 (or CME 100).

**Computer Science (CS) Minor**
The following core courses fulfill the minor requirements. Prerequisites include the standard mathematics sequence through MATH 51 (or CME 100).

Introductory Programming (AP Credit may be used to fulfill this requirement):
- CS 106B Programming Abstractions 5
- or CS 106X Programming Abstractions (Accelerated)

Core:
- CS 103 Mathematical Foundations of Computing 5
- CS 107 Computer Organization and Systems 5
- or CS 107E Computer Systems from the Ground Up
- CS 109 Introduction to Probability for Computer Scientists 5

Electives (choose two courses from different areas):

**Artificial Intelligence**
- CS 124 From Languages to Information 4
- CS 221 Artificial Intelligence: Principles and Techniques 4
- CS 229 Machine Learning 3-4

**Human-Computer Interaction**
- CS 147 Introduction to Human-Computer Interaction Design 4

**Software**
- CS 108 Object-Oriented Systems Design 4
- CS 110 Principles of Computer Systems 5

**Systems**
- CS 140 Operating Systems and Systems Programming 4
- or CS 140E Operating systems design and implementation
- CS 143 Compilers 4
- CS 144 Introduction to Computer Networking 4
- CS 145 Introduction to Databases 4
- CS 148 Introduction to Computer Graphics and Imaging 4

**Theory**
- CS 154 Introduction to Automata and Complexity Theory 4
- CS 157 Logic and Automated Reasoning 3
- CS 161 Design and Analysis of Algorithms 5

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

**Electrical Engineering (EE) Minor**
The options for completing a minor in EE are outlined below. Students must complete a minimum of 23-25 units, as follows:

Select one:
- EE 42 Introduction to Electromagnetics and Its Applications 5
- EE 65 Modern Physics for Engineers
- ENGR 40A Introductory Electronics
- ENGR 40B & ENGR 40B and Introductory Electronics Part II
- ENGR 40M An Intro to Making: What is EE

**Environmental Systems Engineering (EnvSE) Minor**
The Environmental Systems Engineering minor is intended to give students a focused introduction to one or more areas of Environmental Systems 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 Systems Engineering minor is MATH 19 Calculus (or MATH 20 Calculus or MATH 21 Calculus); additionally, many courses of interest require PHYSICS 41 Mechanics and/or MATH 51 Linear Algebra and Differential Calculus of Several Variables as prerequisites. Students should recognize that a minor in Environmental Systems Engineering is not an ABET-accredited degree program.

Since undergraduates having widely varying backgrounds may be interested in obtaining an Environmental Systems 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. Additional information on preparing a minor program is available in the Undergraduate Engineering Handbook (http://web.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Handbooks).

General guidelines are—
- An Environmental Systems 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 of letter-graded work, except where letter grades are not offered.
- The list of courses must represent a coherent body of knowledge in a focused area, and should include classes that build upon one another. Example programs are available on the CEE web site (https://cee.stanford.edu/academics/undergraduate-programs/minor).

Professor Nicholas Ouellette (nto@stanford.edu) is the CEE undergraduate minor advisor in Environmental Systems Engineering. Students must consult with Professor Ouellette (https://cee.stanford.edu/people/nicholas-t-ouellette) in developing their minor program, and obtain approval of the finalized study list from him.

**Management Science and Engineering (MS&E) Minor**
The following courses are required to fulfill the minor requirements:

<table>
<thead>
<tr>
<th>Background requirements (two courses)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The following courses fulfill the minor requirements:

**Materials Science and Engineering (MATSCI) Minor**

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:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 100</td>
<td>Vector Calculus for Engineers</td>
<td>5</td>
</tr>
<tr>
<td>or MATH 51</td>
<td>Linear Algebra and Differential Calculus of Several Variables</td>
<td></td>
</tr>
<tr>
<td>CS 106A</td>
<td>Programming Methodology</td>
<td>5</td>
</tr>
</tbody>
</table>

**Minor requirements (seven courses, letter-graded)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 111</td>
<td>Introduction to Optimization</td>
<td>3-4</td>
</tr>
<tr>
<td>or MS&amp;E 111X</td>
<td>Introduction to Optimization (Accelerated)</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 120</td>
<td>Probabilistic Analysis</td>
<td>5</td>
</tr>
<tr>
<td>MS&amp;E 121</td>
<td>Introduction to Stochastic Modeling</td>
<td>4</td>
</tr>
<tr>
<td>MS&amp;E 125</td>
<td>Introduction to Applied Statistics</td>
<td>4</td>
</tr>
<tr>
<td>MS&amp;E 180</td>
<td>Organizations: Theory and Management</td>
<td>4</td>
</tr>
</tbody>
</table>

Electives (select any two 100- or 200-level MS&E courses) | 6

**Recommended courses**

In addition to the required background and minor courses, it is recommended that students also take the following courses.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECON 50</td>
<td>Economic Analysis I</td>
<td>5</td>
</tr>
<tr>
<td>MS&amp;E 140</td>
<td>Accounting for Managers and Entrepreneurs (may be used as one of the required electives above)</td>
<td>2-4</td>
</tr>
<tr>
<td>or MS&amp;E 140X</td>
<td>Financial Accounting Concepts and Analysis</td>
<td></td>
</tr>
</tbody>
</table>

**Materials Science Fundamentals and Engineering Depth**

Select six of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATSCI 142</td>
<td>Quantum Mechanics of Nanoscale Materials</td>
<td></td>
</tr>
<tr>
<td>MATSCI 143</td>
<td>Nanostructure and Characterization</td>
<td></td>
</tr>
<tr>
<td>MATSCI 144</td>
<td>Thermodynamic Evaluation of Green Energy Technologies</td>
<td></td>
</tr>
<tr>
<td>MATSCI 145</td>
<td>Nanomaterials Synthesis</td>
<td></td>
</tr>
<tr>
<td>MATSCI 151</td>
<td>Microstructure and Mechanical Properties</td>
<td></td>
</tr>
<tr>
<td>MATSCI 152</td>
<td>Electronic Materials Engineering</td>
<td></td>
</tr>
<tr>
<td>MATSCI 156</td>
<td>Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution</td>
<td></td>
</tr>
<tr>
<td>MATSCI 158</td>
<td>Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life</td>
<td></td>
</tr>
<tr>
<td>MATSCI 160</td>
<td>Nanomaterials Laboratory</td>
<td></td>
</tr>
<tr>
<td>MATSCI 161</td>
<td>Energy Materials Laboratory</td>
<td></td>
</tr>
<tr>
<td>MATSCI 162</td>
<td>X-Ray Diffraction Laboratory</td>
<td></td>
</tr>
<tr>
<td>MATSCI 163</td>
<td>Mechanical Behavior Laboratory</td>
<td></td>
</tr>
<tr>
<td>MATSCI 164</td>
<td>Electronic and Photonic Materials and Devices Laboratory</td>
<td></td>
</tr>
<tr>
<td>MATSCI 165</td>
<td>Nanoscale Materials Physics Computation Laboratory</td>
<td></td>
</tr>
<tr>
<td>MATSCI 190</td>
<td>Organic and Biological Materials</td>
<td></td>
</tr>
<tr>
<td>MATSCI 192</td>
<td>Materials Chemistry</td>
<td></td>
</tr>
<tr>
<td>MATSCI 193</td>
<td>Atomic Arrangements in Solids</td>
<td></td>
</tr>
<tr>
<td>MATSCI 194</td>
<td>Thermodynamics and Phase Equilibria</td>
<td></td>
</tr>
<tr>
<td>MATSCI 195</td>
<td>Waves and Diffraction in Solids</td>
<td></td>
</tr>
<tr>
<td>MATSCI 196</td>
<td>Defects in Crystalline Solids</td>
<td></td>
</tr>
<tr>
<td>MATSCI 197</td>
<td>Rate Processes in Materials</td>
<td></td>
</tr>
<tr>
<td>MATSCI 198</td>
<td>Mechanical Properties of Materials</td>
<td></td>
</tr>
<tr>
<td>MATSCI 199</td>
<td>Electronic and Optical Properties of Solids</td>
<td></td>
</tr>
</tbody>
</table>

**Total Units**: 28

---

**Mechanical Engineering (ME) Minor**

The following courses fulfill the minor requirements:

**Units**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 14</td>
<td>Intro to Solid Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 15</td>
<td>Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>ME 30</td>
<td>Engineering Thermodynamics</td>
<td>3</td>
</tr>
<tr>
<td>ME 70</td>
<td>Introductory Fluids Engineering</td>
<td>4</td>
</tr>
<tr>
<td>ME 101</td>
<td>Visual Thinking</td>
<td>4</td>
</tr>
</tbody>
</table>

Plus two of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME 80</td>
<td>Mechanics of Materials</td>
<td></td>
</tr>
<tr>
<td>ME 131A</td>
<td>Heat Transfer</td>
<td></td>
</tr>
<tr>
<td>ME 161</td>
<td>Dynamic Systems, Vibrations and Control</td>
<td></td>
</tr>
<tr>
<td>ME 203</td>
<td>Design and Manufacturing</td>
<td></td>
</tr>
</tbody>
</table>

**Total Units**: 26

**Thermosciences Minor**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 14</td>
<td>Intro to Solid Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>ME 30</td>
<td>Engineering Thermodynamics</td>
<td>3</td>
</tr>
<tr>
<td>ME 70</td>
<td>Introductory Fluids Engineering</td>
<td>4</td>
</tr>
<tr>
<td>ME 131A</td>
<td>Heat Transfer</td>
<td>5</td>
</tr>
<tr>
<td>ME 131B</td>
<td>Fluid Mechanics: Compressible Flow and Turbomachinery</td>
<td>4</td>
</tr>
<tr>
<td>ME 140</td>
<td>Advanced Thermal Systems</td>
<td>5</td>
</tr>
</tbody>
</table>

**Total units**: 24

**Mechanical Design Minor**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGR 14</td>
<td>Intro to Solid Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 15</td>
<td>Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>ME 80</td>
<td>Mechanics of Materials</td>
<td>4</td>
</tr>
<tr>
<td>ME 101</td>
<td>Visual Thinking</td>
<td>4</td>
</tr>
<tr>
<td>ME 112</td>
<td>Mechanical Systems Design</td>
<td>4</td>
</tr>
<tr>
<td>ME 203</td>
<td>Design and Manufacturing</td>
<td>4</td>
</tr>
</tbody>
</table>

Plus one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME 113</td>
<td>Mechanical Engineering Design</td>
<td>3-4</td>
</tr>
<tr>
<td>ME 210</td>
<td>Introduction to Mechatronics</td>
<td></td>
</tr>
<tr>
<td>ME 220</td>
<td>Introduction to Sensors</td>
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</table>

**Total units**: 25-26

* This minor aims to expose students to the breadth of ME in terms of topics and analytic and design activities. Prerequisites: MATH 19 Calculus, MATH 20 Calculus, MATH 21 Calculus, and PHYSICS 41 Mechanics.

** Prerequisites: MATH 19 Calculus, MATH 20 Calculus, MATH 21 Calculus, MATH 51 Linear Algebra and Differential Calculus of Several Variables (or CME 100 Vector Calculus for Engineers) and PHYSICS 41 Mechanics.
This minor aims to expose students to design activities supported by analysis. Prerequisites: MATH 19 Calculus, MATH 20 Calculus, MATH 21 Calculus, PHYSICS 42 Classical Mechanics Laboratory, and PHYSICS 41 Mechanics.

Master of Science in the School of Engineering

The M.S. degree is conferred on graduate students in engineering according to the University regulations stated in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)" 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. 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 graduate program by application through the appropriate department; the department then recommends approval to the Office of Student Affairs in the School of Engineering. The application should be submitted before completing 18 units of the proposed program; it should include a statement describing the objectives of the program, the coherence of the proposed course work, and why this course of study cannot conform to existing graduate programs. Normally, it would include the approval of at least one faculty member willing to serve as adviser. (A co-advising team may be appropriate for interdisciplinary programs.) 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. The actual transfer is accomplished through the Graduate Authorization Petition process.

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 which has experience with graduate-level teaching and advising in the program area.
2. The student’s program must include at least 21 units of courses within the School of Engineering with catalog numbers of 200 or above in which the student receives letter grades.
3. The program must include a total of at least 45 units.

Departments may have additional requirements or expectations for programs of study which they would recommend for this degree; further information may be found in departmental listings.

The M.S. in Engineering is rarely pursued as a coterminal program, and potential coterm students are encouraged to explore the range of master's options in the departments and interdisciplinary programs. In the unusual circumstance of a coterminal application to the M.S. in Engineering, the application process should be the same as described above, using either the Graduate Authorization Petition in Axess (for coterminal students who want to transfer between MS programs) or the Application for Admission to Coterminal Masters' Program (http://Registrar.stanford.edu/pdf/CotermApplc.pdf) for students who have not yet been admitted to a master’s program. The policy for transferring courses taken as an undergraduate prior to coterm admission to the M.S. in Engineering corresponds to the policy of the particular department in which the student's program is lodged and administered. A clear statement of the department’s coterminal policy, and how it applies to the applicant within the Master of Science in Engineering program, should be added to the application materials.

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 many 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 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 (NDO) 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) 204-3984; fax (650) 725-2868; or email scpd-customerservice@stanford.edu.

Engineer Degree in the School of Engineering

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 (http://exploredegrees.stanford.edu/graduatedegrees)" section of this bulletin, and further information is available in the individual departmental sections of this bulletin.

Doctor of Philosophy in the School of Engineering

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 (http://exploredegrees.stanford.edu/graduatedegrees)" section of this bulletin. Further information is found in departmental listings.

Dean: Jennifer Widom

Senior Associate Deans: Stacey Bent (Faculty and Academic Affairs), Laura L. Breyfogle (External Relations), Scott Calvert (Administration), Thomas Kenny (Student Affairs)

Associate Dean: Noé P. Lozano (Diversity Programs), Kirsti Copeland (Student Affairs)

Assistant Dean: Sally Gressens (Graduate Student Affairs)

Faculty Teaching General Engineering Courses


Associate Professors: Eric Darve, Chuck Eesley, Sarah Heilshorn, W. Matthias Ihme, Michael Lepech, Jan Liphardt, Nick Melosh, Amin Saberi, Thomas Jaramillo,

Assistant Professors: Sindy Tang
Professors (Teaching): Thomas H. Byers, Robert McGinn, Mehran Sahami

Senior Lecturers: Vadim Khayms

Lecturers: Jeff Epstein, Christopher Gregg, Kelly Harrison, David Jaffe, Victoria Kirst, Royal Kopperud, Hung Le, Cynthia Bailey Lee, Mary McDevitt, Chris Piech, Marty Stepp, Matt Vassar

Professor of the Practice: Tina Seelig

Overseas Studies Courses in Engineering

The Bing Overseas Studies Program (http://bosp.stanford.edu) manages Stanford study abroad programs for Stanford undergraduates. Students should consult their department or program's student services office for applicability of Overseas Studies courses to a major or minor program.

The Bing Overseas Studies course search site (https://undergrad.stanford.edu/programs/bosp/explore/search-courses) displays courses, locations, and quarters relevant to specific majors.

For course descriptions and additional offerings, see the listings in the Stanford Bulletin's ExploreCourses (http://explorecourses.stanford.edu) or Bing Overseas Studies (http://bosp.stanford.edu).

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<thead>
<tr>
<th>Units</th>
<th>Course Code</th>
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<tr>
<td>5</td>
<td>OSPBER 40M</td>
<td>An Intro to Making: What is EE</td>
</tr>
<tr>
<td>4</td>
<td>OSPBER 50M</td>
<td>Introductory Science of Materials</td>
</tr>
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<td>4</td>
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<td>Introductory Science of Materials</td>
</tr>
<tr>
<td>5</td>
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<td>An Intro to Making: What is EE</td>
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