SCHOOL OF ENGINEERING

Courses offered by the School of Engineering are listed under the subject code ENGR on the (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=ENGR&filter-catalognumber-ENGR=on) Stanford Bulletin's (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=ENGR&filter-catalognumber-ENGR=on) ExploreCourses web site (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=ENGR&filter-catalognumber-ENGR=on).

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 expertise 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 (http://dschool.stanford.edu) (also known as "the d.school") 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.

Global Engineering Programs (GEP) offers a portfolio of international opportunities for Stanford engineering students. Current opportunities focus on self-designed engineering internships. These opportunities enhance engineering education by providing students with an opportunity to learn about technology and engineering in a global context, to build professional networks, and to gain real world experience in a culturally diverse and international environment. Need-based financial aid is available to undergraduate students to ensure that GEP programs are inclusive. GEP programs evolve each year so students are encouraged to check the GEP website (https://gep.stanford.edu) regularly for updated opportunities and details including application deadlines.

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 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:

- 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: If in doubt about requirements, courses should always be taken for a letter grade.

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. All students admitted to Stanford as undergraduates can have pathways to success in any engineering major at Stanford.

First Year Advice

For first year students thinking about getting started in engineering or other STEM majors, the School of Engineering has a simple online tool called the Roadmap (https://ughb.stanford.edu/roadmap/) which suggests which courses might be appropriate to take in the first year. In addition, the one-unit Autumn course, ENGR 1 Want to Be an Engineer?, offers a broad exposure to STEM majors within and outside of the School of Engineering. Faculty present an overview of their program and where study of that topic might lead. Other courses that might be of interest are the IntroSems (https://undergrad.stanford.edu/programs/introsems/) and Engineering Fundamentals (for a list and areas where they might apply to a major program go to Exploring Engineering (https://ughb.stanford.edu/plans-program-sheets/exploring-engineering-courses/) on the UGHB website).

Recommended Preparation

Freshman

Students who plan to enter Stanford as freshmen and intend to major in engineering are advised to take the highest level of mathematics offered in high school. (See the "AP Credit (http://exploredegrees.stanford.edu/undergraduatedegreesandprograms/#aptext)" section of this bulletin for information on advanced placement in mathematics.) High school courses in physics and chemistry are strongly recommended, but not required. Additional elective course work in the humanities and social sciences is also recommended. Alternately, these courses can be taken after arrival at Stanford, and the best advice would be to begin early and have a detailed plan for completing requirements worked out.

Transfer Students

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

Transfer credit is given for courses taken elsewhere whenever the courses are equivalent or substantially similar to Stanford courses in scope and rigor. The policy of the School of Engineering is to study each transfer student's preparation and make a reasonable evaluation of the courses taken prior to transfer by means of a petition process. Inquiries may be addressed to Darlene Lazar at dlazar@stanford.edu, in 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 *(*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
- Biomechanical 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 Requirements 1 and 2 at the end of this section)
- Engineering fundamentals (two-three courses minimum, depending up 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 Handbook for Undergraduate Engineering Programs *(*http://ughb.stanford.edu*)* for additional information.

Dual Degree Programs

A Stanford undergraduate may work simultaneously toward two bachelor's degrees or toward a bachelor's and a master's degree, that is, B.A. and M.S., B.A. and M.A., B.S. and M.S., or B.S. and M.A. The degrees may be granted simultaneously or at the conclusion of different quarters. 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 *(*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. 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 the Graduate Admissions (http://gradadmissions.stanford.edu) website. 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
- Microrheology

- 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
- 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 the Stanford Computer Forum (http://forum.stanford.edu/research/areas.php) for additional information.

- 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
- Education and Learning Science
- 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

See EE Research at Stanford: The Big Picture (https://ee.stanford.edu/research/the-big-picture/) for additional information.

- Biomedical Devices, Sensors and Systems
- Biomedical Imaging
- Communications Systems
- Control and Optimization
- Data Science
- Electronic Devices
- Embedded Systems
- Energy Harvesting and Conversion
- Energy-Efficient Hardware Systems
- Information Theory and Applications
- Integrated Circuits and Power Electronics
- Machine Learning
- Mobile Networking
- Nanoelectronic Devices and NanoSystems
- Nanotechnology and NEMS/MEMS

- Photonics, Nanoscience and Quantum Technology
- Secure Distributed Systems
- Signal Processing and Multimedia
- Societal Networks
- Software Defined Networking

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 (http://exploredegrees.stanford.edu/soe-ug-majors/aeroastro/)
- Bioengineering (http://exploredegrees.stanford.edu/soe-ug-majors/bioengineering/)
- Chemical Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/chemeng/)
- Civil Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/civilengineering/)
- Computer Science (http://exploredegrees.stanford.edu/soe-ug-majors/cs/)
- Electrical Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/ee/)
- Environmental Systems Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/ese/)
- Management Science and Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/msande/)
- Materials Science and Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/matsci/)
- Mechanical Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/mecheng/)

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

- Architectural Design (http://exploredegrees.stanford.edu/soe-ug-majors/archdesign/)
- Atmosphere/Energy (http://exploredegrees.stanford.edu/soe-ug-majors/atmos-energy/)
- Biomechanical Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/biomechanicalengineering/)
- Biomedical Computation (http://exploredegrees.stanford.edu/soe-ug-majors/biomedicalcomputation/)
- Engineering Physics (http://exploredegrees.stanford.edu/soe-ug-majors/engrphysics/)
- Product Design (http://exploredegrees.stanford.edu/soe-ug-majors/productdesign/)

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/

undergraduatedegreesandprograms/#bachelorstext)" section of this bulletin.

Undergraduate Honors in the School of Engineering

The following bachelor's programs in the School of Engineering offer an honors option for qualified students:

- Aeronautics and Astronautics (http://exploredegrees.stanford.edu/soe-ug-majors/aeroastro/)
- Architectural Design (http://exploredegrees.stanford.edu/soe-ug-majors/archdesign/)
- Atmosphere/Energy (http://exploredegrees.stanford.edu/soe-ug-majors/atmos-energy/)
- Bioengineering (http://exploredegrees.stanford.edu/soe-ug-majors/bioengineering/)
- Biomechanical Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/biomechanicalengineering/)
- Biomedical Computation (http://exploredegrees.stanford.edu/soe-ug-majors/biomedicalcomputation/)
- Civil Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/civilengineering/)
- Computer Science (http://exploredegrees.stanford.edu/soe-ug-majors/cs/)
- Electrical Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/ee/)
- Engineering Physics (http://exploredegrees.stanford.edu/soe-ug-majors/engrphysics/)
- Environmental Systems Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/ese/)
- Materials Science and Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/matsci/)
- Mechanical Engineering (http://exploredegrees.stanford.edu/soe-ug-majors/mecheng/)

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, differential equations, an introduction to discrete mathematics, and an understanding of statistics and probability theory. Students are encouraged to select courses on these topics. Courses that satisfy the math requirement are listed in the Undergraduate Handbook (http://ughb.stanford.edu) on the Approved Courses page of the Courses and Planning section.

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 in the Undergraduate Handbook (http://ughb.stanford.edu) on the Approved Courses page of the Courses and Planning section.

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):

		Units
CS 106A	Programming Methodology	5
CS 106AX	Programming Methodologies in JavaScript and Python	5
CS 106B	Programming Abstractions	5
ENGR 10	Introduction to Engineering Analysis	4
ENGR 14	Intro to Solid Mechanics	3
ENGR 15	Dynamics	3
ENGR 20	Introduction to Chemical Engineering	4
ENGR 21	Engineering of Systems	3
ENGR 40A	Introductory Electronics	3
ENGR 40B	Introductory Electronics Part II	2
ENGR 40M	An Intro to Making: What is EE	3-5
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis [1,2]	4
ENGR 50E	Introduction to Materials Science, Energy Emphasis [1]	4
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis [1]	4
ENGR 60	Engineering Economics and Sustainability	3
ENGR 62	Introduction to Optimization (same as MS&E 111)	4
ENGR 80	Introduction to Bioengineering (Engineering Living Matter) (same as BIOE 80)	4

ENGR 90	Environmental Science and Technology (same as CEE 70)	3

[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 in the Undergraduate Handbook (http://ughb.stanford.edu) on the Approved Courses page of the Courses and Planning section.

Basic Requirement 5 (Engineering Topics)

In order to satisfy ABET (Accreditation Board for Engineering and Technology) requirements, a student majoring in 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 in the Undergraduate Handbook (http://ughb.stanford.edu) on the individual major page as listed in the Degree Programs section.

Experimentation

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 (http://explorecourses.stanford.edu) web site or the Bing Overseas Studies (http://bosp.stanford.edu) web site. Students should consult their department or program's student services office for applicability of Overseas Studies courses to a major or minor program.

See the "Undergraduate Majors and Minors (http://exploredegrees.stanford.edu/soe-ug-majors/)" menu item on the left side of this page for program-by-program descriptions of major degree requirements. All programs are listed below to facilitate export as a pdf; use the Print option in the right hand menu of this page to create such a pdf for all the tabs in the School of Engineering.

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

		Units
Mathematics		
24 units minimum		
MATH 19	Calculus (required) [1]	3
MATH 20	Calculus (required) [1]	3
MATH 21	Calculus (required) [1]	4
CME 100/ENGR 154	Vector Calculus for Engineers (required) [2]	5
or MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
CME 102/ENGR 155A	Ordinary Differential Equations for Engineers (required) [2]	5
or MATH 53	Ordinary Differential Equations with Linear Algebra	
CME 106/ENGR 155C	Introduction to Probability and Statistics for Engineers (required)	4-5
or STATS 110	Statistical Methods in Engineering and the Physical Sciences	
or STATS 116	Theory of Probability	
or CS 109	Introduction to Probability for Computer Scientists	
CME 104	Linear Algebra and Partial Differential Equations for Engineers (recommended) [2]	5
or MATH 52	Integral Calculus of Several Variables	
CME 108	Introduction to Scientific Computing (recommended)	3
Science		
20 units minimum		
PHYSICS 41	Mechanics (required) [3]	4
or PHYSICS 41E	Mechanics, Concepts, Calculations, and Context	
PHYSICS 43	Electricity and Magnetism (required) [3]	4
PHYSICS 45	Light and Heat (required)	4
CHEM 31M	Chemical Principles: From Molecules to Solids (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		3-5
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.		3-5
AA 252	Techniques of Failure Analysis (recommended)	3
Engineering Fundamentals (three courses required)		
11 units minimum		
ENGR 21	Engineering of Systems (required)	3
CS 106A	Programming Methodology	3-5
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		3-5
Aero/Astro Depth Requirements		
35 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
ME 70	Introductory Fluids Engineering (required)	3
AA 100	Introduction to Aeronautics and Astronautics (required)	3
AA 131	Space Flight (required)	3
AA 141	Atmospheric Flight (required)	3
AA 151	Lightweight Structures (required)	3
AA 174A	Principles of Robot Autonomy I (required)	5
AA 190	Directed Research and Writing in Aero/Astro (required) satisfies the Writing in the Major requirement, (WIM)	3-5
Aero/Astro Focus Electives		
12 units minimum		
AA 102	Introduction to Applied Aerodynamics (recommended)	3
AA 103	Air and Space Propulsion	3
AA 113	Aerospace Computational Science	3
AA 135	Introduction to Space Policy	3
AA 156	Mechanics of Composite Materials	3
AA 173	Flight Mechanics & Controls	3
CS 237B	Principles of Robot Autonomy II (AA 174B)	3-4
AA 199	Independent Study in Aero/Astro	1-5
AA 261	Building an Aerospace Startup from the Ground Up	3
AA 272	Global Positioning Systems	3
AA 279A	Space Mechanics	3
MS&E 178	The Spirit of Entrepreneurship	2
Aero/Astro Suggested Courses (not required)		
AA 149	Operation of Aerospace Systems	1
Aero/Astro Capstone Requirement		
7 units minimum. Select either the Spacecraft or Aircraft course sequence		
AA 136A	Spacecraft Design	3-5
AA 136B	Spacecraft Design Laboratory	3-5
AA 146A	Aircraft Design	4
AA 146B	Aircraft Design Laboratory	3

For additional information and sample programs see the Handbook for Undergraduate Engineering (http://ughb.stanford.edu) and the Aeronautics and Astronautics Undergraduate Program Sheet (https://ughb.stanford.edu/program-sheets/).

All courses taken for the major must be taken for a letter grade if that option is offered by the instructor.

Minimum Combined GPA for all courses in Engineering Topics (Engineering Fundamentals and Depth courses) is 2.0.

Transfer and AP credits in Math, Science, Fundamentals, and the Technology in Society course must be approved by the School of Engineering Dean's office.

1 A score of 4 on the Calculus BC test or 5 on the AB test only gives students 8 units, not 10 units, so is equal to MATH 19 + MATH 20, but not MATH 21. The Math Placement Exam determines what math course the student starts with.

2 It is recommended that the CME series (100, 102, 104) be taken rather than the MATH series (51, 52, 53). It is recommended that students taking the MATH series also take CME 192 Introduction to MATLAB.

3 A score of 5 on the AP Physics C Mechanics test places the student out of PHYSICS 41. Similarly, a score of 5 on the AP Physics Electricity and Magnetism test places the student out of PHYSICS 43.

Honors Program

The Department of Aeronautics and Astronautics honors program has been designed to allow undergraduates with strong records and enthusiasm for independent research to engage in a significant project leading to a degree with departmental honors.

Students who meet the eligibility criteria and wish to be considered for the honors program should apply to the program by the end of the junior year. All applications are subject to the review and final approval by the Aero/Astro Undergraduate Curriculum Committee.

Application Requirements:

- One-page written statement describing the research topic and signed adviser form
- GPA of 3.5 or higher in the major
- Unofficial Stanford transcript (from Axess)
- Signature of thesis adviser

Honors criteria:

- Maintain the 3.5 GPA required for admissions to the honors program.
- Arrangement with an Aero/Astro faculty member who agrees to serve as the thesis adviser. The adviser must be a member of the Academic Council.
- Under the direction of the thesis adviser, complete at least two quarters of research with a minimum of 9 units of independent research; 3 of these units may be used towards a student's Aero/Astro Focus Elective requirement.
- Submit an honors thesis (20-30 pages). Thesis is due by April 30th of senior year in order to be eligible for University prizes.
- Attend Research Experience for Undergraduates Poster Session or present in another suitable forum approved by the faculty adviser.

COVID-19-Related Degree Requirement Changes

For information on how Architectural Design (AD) degree requirements have been affected by the pandemic, see the "COVID-19 Policies tab (http://exploredegrees.stanford.edu/schoolofengineering/civilandenvironmentalengineering/#covid19policiestext)" in the "Civil and Environmental Engineering" of this bulletin. For University-wide policy changes related to the pandemic, see the "COVID-19 and Academic Continuity (http://exploredegrees.stanford.edu/covid-19-policy-changes/)" section of this bulletin.

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

		Units
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	4/5
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 32B or CEE 32D)	4
CEE 120A	Building Modeling for Design & Construction	3
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 32D	Construction: The Writing of Architecture	
CEE 32G	Architecture Since 1900	
CEE 32H	Responsive Structures	
CEE 32T	Making and Remaking the Architect: Edward Durell Stone and Stanford	
CEE 32U	California Modernism: The Web of Apprenticeship	
CEE 32V	Architectural Design Lecture Series Course	
CEE 32W	Making Meaning: A Purposeful Life in Design	
CEE 33B	Japanese Modern Architecture	
CEE 33C	Housing Visions	
CEE 131C	How Buildings are Made -- Materiality and Construction Methods	
CEE 131D	Urban Design Studio	
CEE 139	Design Portfolio Methods	
CEE 151	Negotiation	
Total Units		70-80

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 120B, CEE 120C, CEE 134B, CEE 156, CEE 159, CEE 172, CEE 172A, CEE 176A, CEE 180, CEE 181, CEE 182, CEE 183, CEE 226, CEE 241, OR CEE 242; ME 203. Students should investigate any prerequisites for the listed courses and carefully plan course sequences with the AD director.
   Electives:
   - CEE 32A, CEE 32B, CEE 32D, CEE 32F, CEE 32G, CEE 32H, CEE 32Q, CEE 32R, CEE 32S, CEE 32T, CEE 32U, CEE 32V, CEE 32W, CEE 33B, CEE 33C, CEE 101B, CEE 101C, CEE 120A, CEE 120B, CEE 120C, CEE 122A, CEE 122B, CEE 124, CEE 131A, CEE 131B, CEE 131C, CEE 131F, CEE 134B, CEE 139, CEE 172A, CEE 176A, CEE 180, CEE 181, CEE 182, CEE 183
   - ENGR 50, ENGR 103
   - ME 101, ME 110, ME 115A/B/C, ME 120, ME 203
   - ARTSTUDI 13BX, 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 142, ARTHIST 143A, ARTHIST 188A
   - FILMPROD 114
   - TAPS 137
   - SINY 122; URBANST 110, URBANST 113, URBANST 163, URBANST 171
3. A course may only be counted towards one elective or core requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth/Core is 2.0.

Architectural Design Honors Program

The AD honors 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.
5. A pdf of the thesis, including the signature page signed by both readers, should be submitted to the student services officer. Students will be sent email instructions on how to archive a permanent electronic copy in Terman Engineering library.

COVID-19-Related Degree Requirement Changes

For information on how Atmosphere/Energy (A/E) degree requirements have been affected by the pandemic, see the "COVID-19 Policies tab (http://exploredegrees.stanford.edu/schoolofengineering/civilandenvironmentalengineering/#covid19policiestext)" in the "Civil and Environmental Engineering" of this bulletin. For University-wide policy changes related to the pandemic, see the "COVID-19 and Academic Continuity (http://exploredegrees.stanford.edu/covid-19-policy-changes/)" section of this bulletin.

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

		Units
Mathematics and Science (45 units minimum):		
Mathematics		**23**
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**
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 31M	Chemical Principles: From Molecules to Solids	
CEE 70	Environmental Science and Technology [1]	
Technology in Society (1 course)		**3-5**
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	The Rise of Digital Culture	
OR one of these WIM courses (do not fulfill TiS):		
CEE 100	Managing Sustainable Building Projects	
ENGR/CEE 102W	Technical and Professional Communication	
EARTHSYS 200	Environmental Communication in Action: The SAGE Project	
Fundamentals and Depth: At least 40 units total must be from the School of Engineering		
Engineering Fundamentals		
Two courses minimum (recommend 3), including at least one of the following:		7-9
ENGR 50E	Introduction to Materials Science, Energy Emphasis (ENGR 25E also accepted (no longer offered))	
Plus at least one of the following:		
ENGR 10	Introduction to Engineering Analysis	
A third Fundamental is optional but recommended (3-4 units)		
CS 106A	Programming Methodology	
Engineering Depth		
Required: 6-8 units. Introductory seminars may not count toward Engineering Depth [2]		
CEE 64	Air Pollution and Global Warming: History, Science, and Solutions (cannot also fulfill science requirement)	3
CEE 107A	Understanding Energy	3-5
or CEE 107S	Understanding Energy - Essentials	
34- 36 units from the following with at least four courses from each group; at least 40 of the units in ENGR Fundamentals and Depth must be from the School of Engineering:		36
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 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 111	Biology and Global Change [5]	
EARTHSYS 142	Remote Sensing of Land [5]	
or EARTHSYS 14	Fundamentals of Geographic Information Science (GIS)	
EARTHSYS 159	Economic, Legal, and Political Analysis of Climate-Change Policy	
EARTHSYS 188	Social and Environmental Tradeoffs in Climate Decision-Making [5]	
PHYSICS 199	The Physics of Energy and Climate Change [5]	
EARTH 2	Climate and Society [5]	
EARTHSYS 196	Implementing Climate Solutions at Scale [5]	
Group B: Energy		
CEE 107R	E^3: Extreme Energy Efficiency	
CEE 156	Building Systems Design & Analysis	
CEE 173S	Electricity Economics	
CEE 176A	Energy Efficient Buildings	
CEE 176B	100% Clean, Renewable Energy and Storage for Everything	
CEE 177S	Engineering and Sustainable Development	
EARTHSYS 101	Energy and the Environment [5]	
EARTHSYS 102	Fundamentals of Renewable Power [5]	
ENERGY 104	Sustainable Energy for 9 Billion	
ENGR 50E	Introduction to Materials Science, Energy Emphasis [3]	
MATSCI 144	Thermodynamic Evaluation of Green Energy Technologies	
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	
ME 182	Electric Transportation	
POLISCI 73	Energy Policy in California and the West [5]	
OSPSANTG 29	Sustainable Cities: Comparative Transportation Systems in Latin America [5]	
Total Units		95-101

1 Can count as a science requirement or Engineering Fundamental, but not both.

2 CEE 64 can count as a science requirement or as Engineering Depth, but not both.

3 ENGR 50E can count as Engineering Fundamental or Engineering Depth, but not both.

4 A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

5 Courses outside of the School of Engineering (SoE) do not count toward the 40 units of engineering coursework required in the Fundamentals plus Depth categories.

Honors Program

The A/E honors program offers eligible students the opportunity to engage in guided original research, or project design, over the course of an academic year. Interested student must adhere to the following requirements:

1. Prospective honors students write up and submit a 1-2 page letter applying to the honors program in A/E describing the problem to be investigated. The letter must be signed by the student, the current primary adviser, and the proposed honors adviser, if different, and submitted to the student services office in the Department of Civil and Environmental Engineering (CEE). The application must include an unofficial Stanford transcript. Applications must be received in the fourth quarter prior to graduation. It is strongly suggested that prospective honors students meet with the proposed honors adviser well in advance of submitting an application.
2. Students must maintain a GPA of at least 3.5.
3. Students must complete an honors thesis or project over a period of three quarters. The typical length of the written report is 15-20 pages. The deadline for submission of the report is to be decided by the honors adviser, but should be no later than the end of the third week in May.
4. The report must be read and evaluated by the student's honors adviser and one other reader. It is the student's responsibility to find and obtain both the adviser and the reader. At least one of the two must be a member of the Academic Council in the School of Engineering.
5. Students must present the completed work in an appropriate forum, e.g. in the same session as honors theses are presented in the department of the adviser. All honors programs require some public presentation of the thesis or project.
6. Students may take up to 10 units of CEE 199H Undergraduate Honors Thesis(optional). However, students must take ENGR 202S Directed Writing Projects or its equivalent (required). Units for the writing class are beyond those required for the A/E major.
7. Two copies of the signed thesis must be provided to the CEE student services office no later than two weeks before the end of the student's graduation quarter. A pdf of the thesis, including the signature page signed by both readers, should be submitted to the student services officer by May 15. Students will be sent email instructions on how to archive a permanent electronic copy in Terman Engineering library.

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

COVID-19-Related Degree Requirement Changes

For information on how Aeronautics and Astronautics degree requirements have been affected by the pandemic, see the "COVID-19 Policies tab (http://exploredegrees.stanford.edu/schoolofengineering/bioengineering/#covid19policiestext)" in the "Bioengineering" of this bulletin. For University-wide policy changes related to the pandemic, see the "COVID-19 and Academic Continuity (http://exploredegrees.stanford.edu/covid-19-policy-changes/)" section of this bulletin.

Bioengineering (BIOE)

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

Mission of the Undergraduate Program in Bioengineering

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

		Units
Mathematics		
14 units minimum (Prerequisites: 10 units of AP or IB credit or Mathematics 20-series) [1]		
Select one of the following sequences:		
CME 100 & CME 102	Vector Calculus for Engineers and Ordinary Differential Equations for Engineers (Recommended)	10
MATH 51 & MATH 53	Linear Algebra, Multivariable Calculus, and Modern Applications and Ordinary Differential Equations with Linear Algebra	10
Select one of the following:		
CME 106	Introduction to Probability and Statistics for Engineers (Recommended)	4-5
or STATS 110	Statistical Methods in Engineering and the Physical Sciences	
or STATS 141	Biostatistics	
Science		
26 units minimum [2]		
CHEM 31M	Chemical Principles: From Molecules to Solids (formerly 31X)	5
or CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	
CHEM 33	Structure and Reactivity of Organic Molecules	5
BIO 83	Biochemistry & Molecular Biology (Recommended)	4
or BIO 82	Genetics	
BIO 84	Physiology	4
PHYSICS 41	Mechanics	4
PHYSICS 43	Electricity and Magnetism	4
Technology in Society		
BIOE 131	Ethics in Bioengineering (WIM)	3
Engineering Fundamentals		
BIOE 80	Introduction to Bioengineering (Engineering Living Matter)	4
CS 106A	Programming Methodology (or CS 106B or CS 106X)	5
Fundamentals Elective; see UGHB for approved course list; only one CS class allowed to count toward Fundamentals requirements.		3-5
Bioengineering Core		
BIOE 42	Physical Biology	4
BIOE 44	Fundamentals for Engineering Biology Lab	4
BIOE 101	Systems Biology	3
BIOE 103	Systems Physiology and Design	4
BIOE 123	Bioengineering Systems Prototyping Lab	4
BIOE 141A	Senior Capstone Design I	4
BIOE 141B	Senior Capstone Design II	4
Bioengineering Depth Electives		
Four courses, minimum 12 units:		12
BIOE 122	BioSecurity and Pandemic Resilience	
BIOE 201C	Diagnostic Devices Lab	
BIOE 209	Mathematical Modeling of Biological Systems	
BIOE 211	Biophysics of Multi-cellular Systems and Amorphous Computing	
BIOE 212	Introduction to Biomedical Informatics Research Methodology	
BIOE 214	Representations and Algorithms for Computational Molecular Biology	
BIOE 217	Translational Bioinformatics	
BIOE 220	Introduction to Imaging and Image-based Human Anatomy	
or BIOE 51	Anatomy for Bioengineers	
BIOE 221	Physics and Engineering of Radionuclide-based Medical Imaging	
BIOE 222	Physics and Engineering Principles of Multi-modality Molecular Imaging of Living Subjects	
BIOE 223	Physics and Engineering of X-Ray Computed Tomography	
BIOE 224	Probes and Applications for Multi-modality Molecular Imaging of Living Subjects	
BIOE 225	Intro to Ultrasound Physics and Ultrasound Neuromodulation	
BIOE 227	Functional MRI Methods	
BIOE 231	Protein Engineering	
BIOE 244	Advanced Frameworks and Approaches for Engineering Integrated Genetic Systems	
BIOE 260	Tissue Engineering	
BIOE 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
BIOE 281	Biomechanics of Movement	
BIOE 291	Principles and Practice of Optogenetics for Optical Control of Biological Tissues	
Total Units		104-107

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, Multivariable Calculus, and Modern Applications 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 31M Chemical Principles: From Molecules to Solids) 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.

[3] A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu). 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 an electronic pdf copy of their thesis, including the signature page signed by both readers, to Bioengineering student services . Students are sent email instructions on how to archive a permanent electronic copy in Terman Engineering library.
5. Present thesis synopsis at the Bioengineering Honors Poster Fair at the end of Spring Quarter.

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

COVID-19-Related Degree Requirement Changes

Grading

The Biomechanical Engineering program counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that normally require a letter grade.

Other Undergraduate Policies

The Biomechanical Engineering program encourages students to take courses for letter grades when possible in order to have complete records for use when seeking future opportunities, including employment in industry and students seeking to apply for graduate studies. Per University policy, students can change grading basis through the end of Week 8 in all four quarters in 2020-21. Students are encouraged to reach out directly to Biomechanical Engineering Program Director, Marc Elliot Levenston <levenston@stanford.edu>, for questions about petitions, especially in situations related to COVID-19 policies and grading basis

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

		Units
Mathematics		**21**
21 units minimum; CME sequence is recommended, but MATH sequence is acceptable; see Basic Requirement 1 [1]		
CME 102/ ENGR 155A	Ordinary Differential Equations for Engineers	
or MATH 53	Ordinary Differential Equations with Linear Algebra	
Select one of the following:		
CME 106/ ENGR 155C	Introduction to Probability and Statistics for Engineers	
STATS 110	Statistical Methods in Engineering and the Physical Sciences	
STATS 116	Theory of Probability	
STATS 141	Biostatistics	
Science (22 units Minimum)		
CHEM 31M	Chemical Principles: From Molecules to Solids (or CHEM 31A & CHEM 31B)	5
PHYSICS 41	Mechanics	4
Biology or Human Biology A/B core courses [2]		8-10
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4
or BIOE 44	Fundamentals for Engineering Biology Lab	
Technology in Society		
One course required; BIOE 131 satisfies both TiS and WIM requirements. TiS course must be on School of Engineering Approved Courses list in the UGHB the year taken		3-5
Engineering Topics (Engineering Science and Design)		
Engineering Fundamentals (minimum two courses; see Basic Requirement 3):		
ENGR 14	Intro to Solid Mechanics	3
Pick one of the following:		
ENGR 80	Introduction to Bioengineering (Engineering Living Matter)	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	
Engineering Depth		
ENGR 15	Dynamics	3
ME 30	Engineering Thermodynamics	3
ME 70	Introductory Fluids Engineering	3
ME 80	Mechanics of Materials	3
ME 389	Biomechanical Research Symposium [4]	1
Mechanical Engineering/ Biomechanical Engineering Depth		
Students are encouraged to carefully select ME and BME depth courses that complement each other and form a cohesive plan of study.		

Options to complete the ME depth sequence (3 courses, minimum 9 units): [5]		9
ENGR 105	Feedback Control Design	
ME 102	Foundations of Product Realization	
ME 103	Product Realization: Design and Making	
ME 104	Mechanical Systems Design	
ME 131	Heat Transfer	
ME 133	Intermediate Fluid Mechanics	
ME 151	Introduction to Computational Mechanics	
ME 152	Material Behaviors and Failure Prediction	
ME 161	Dynamic Systems, Vibrations and Control	
Options to complete the BME depth sequence (3 courses, minimum 9 units); (alternative courses may be allowed but only if petitioned for use in advance of being taken) [5]		9
BIOE 260	Tissue Engineering	
BIOE/ME 285	Computational Modeling in the Cardiovascular System	
ME 234	Introduction to Neuromechanics	
ME 281	Biomechanics of Movement	
ME 283	Introduction to Biomechanics and Mechanobiology	
ME 287	Mechanics of Biological Tissues	
ME 337	Mechanics of Growth	
Total Units		79-83

1 Math: 21 units required and must include a course in differential equations (CME 102 or MATH 53; one of these required) and a course in calculus-based Statistics (CME 106 Introduction to Probability and Statistics for Engineers or STATS 110 Statistical Methods in Engineering and the Physical Sciences or STATS 116 Theory of Probability or STATS 141 Biostatistics).

2 Students satisfy the Biology requirement by either:
- taking two of the following: BIO 82 Genetics , BIO 83 Biochemistry & Molecular Biology, BIO 84 Physiologyor BIO 86 Cell Biology requires BIO 83); or
- taking two of the following: HUMBIO 2A Genetics, Evolution, and Ecology, HUMBIO 3A Cell and Developmental Biology, or HUMBIO 4A The Human Organism

3 There are two options for fulfilling the WIM requirement. The first option is to complete BIOE 131 Ethics in Bioengineering, which also fulfills the TiS requirement. 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 If ME 389 is not offered, other options include BIOE 393, ME 571, or course by petition.

5 Courses may only be listed once on the program sheet i.e no double counting. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

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.
- Submit an application to the ME student services office no later than the second week of the term two quarters before anticipated conferral (e.g., Autumn for Spring conferral, Spring for Autumn conferral). An application consists of:
  - A one-page written statement describing the research topic, with signatures indicating approval of both the thesis adviser and thesis reader on a cover page
  - An unofficial Stanford transcript;
- 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.
- 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 by the third week of the quarter in which they intend to confer. Further revisions and final endorsement by the adviser and reader are to be finished by week six, when two bound copies are to be submitted to the Mechanical Engineering student services office. A pdf of the thesis, including the signature page signed by both readers, should also be submitted to the student services officer. Students are sent email instructions on how to archive a permanent electronic copy in Terman Engineering library.
  - Present the thesis at the Mechanical Engineering Poster Session held in mid-April. If the poster session is not not offered or the student does not confer in the Spring, an alternative presentation will be approved on a case by case basis with advisor and BME Program Director approval.

Note: Students may not use work completed towards an honors degree to satisfy BME course requirements

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

COVID-19-Related Degree Requirement Changes

The BMC Program counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that otherwise require a letter grade. Students are encouraged to enroll in the letter grade option for degree requirements whenever possible.

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

		Units
Mathematics		
21 unit minimum, see Basic Requirement 1		
MATH 19	Calculus (or AP Calculus)	3
MATH 20	Calculus (or AP Calculus)	3
MATH 21	Calculus (or AP Calculus)	4
CS 103	Mathematical Foundations of Computing	3-5
CS 109	Introduction to Probability for Computer Scientists	3-5
Science		
17 units minimum, see Basic Requirement 2		
PHYSICS 41	Mechanics	4
CHEM 31M	Chemical Principles: From Molecules to Solids (formerly CHEM 31X)	5
or CHEM 31B	Chemical Principles II	
CHEM 33	Structure and Reactivity of Organic Molecules	5
BIO 82	Genetics (or HUMBIO 2A)	4
BIO 83	Biochemistry & Molecular Biology (or BIO 84 or HUMBIO 3A)	4
BIO 86	Cell Biology (or HUMBIO 4A)	4
Engineering Fundamentals		
CS 106B	Programming Abstractions [4]	5
or CS 106X	Programming Abstractions	
For the second required course, see concentrations [4]		
Technology in Society		
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.		3-5
Engineering		
CS 107	Computer Organization and Systems	3-5
CS 161	Design and Analysis of Algorithms	3-5
Select one of the following:		3
CS 270	Modeling Biomedical Systems	
CS 273A	The Human Genome Source Code	
CS 274	Representations and Algorithms for Computational Molecular Biology	
CS 275	Translational Bioinformatics	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
CME 209	Mathematical Modeling of Biological Systems	
Research: 6 units of biomedical computation research in any department [2,3]		6
Engineering Depth Concentration (select one of the following concentrations): [7]		
Cellular/Molecular Concentration		
Mathematics: Select one of the following:		
CME 100	Vector Calculus for Engineers	
STATS 141	Biostatistics	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
One additional Engineering Fundamental [4]		
BIO 104	Advance Molecular Biology: Epigenetics and Proteostasis	
CHEM 141	The Chemical Principles of Life I (or CHEM 171) [4]	
Cell/Mol Electives (two courses) [5,6]		
Informatics Electives (two courses) [5,6]		
Simulation Electives (two courses) [5, 6]		
Simulation, Informatics, or Cell/Mol Elective (one course) [5,6]		
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 [4]		
Informatics Core (three courses):		
CS 145	Data Management and Data Systems	
or CS 147	Introduction to Human-Computer Interaction Design	
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) [5,6]		
Cellular Electives (two courses) [5,6]		
Organs Electives (two courses) [5,6]		6-10
Organs/Organisms Concentration		
Mathematics (select one of the following):		
CME 100	Vector Calculus for Engineers	
STATS 141	Biostatistics	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
One additional Engineering Fundamental [4]		
Biology (two courses):		
BIO 112	Human Physiology	
CHEM 141	The Chemical Principles of Life I (or BIOE 220)	
Two additional Organs Electives [5,6]		
Simulation Electives (two courses) [5,6]		
Informatics Electives (two courses) [5,6]		
Simulation, Informatics, or Organs Elective (one course) [5,6]		
Simulation Concentration		
Mathematics:		
CME 100	Vector Calculus for Engineers	
or MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
ME 30	Engineering Thermodynamics (Fulfills 2nd Engineering Fundamental)	3
Simulation Core:		

CME 102	Ordinary Differential Equations for Engineers	5
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		90-104

1 Acceptable substitutes for CS 109 are STATS 116 Theory of Probability, MS&E 120 Introduction to Probability, MS&E 220 Probabilistic Analysis, EE 178 Probabilistic Systems Analysis, MATH 151, and CME 106 Introduction to Probability and Statistics for Engineers .

2 Research projects require pre-approval of BMC Coordinators

3 Research units taken as CS 191W Writing Intensive Senior Project or in conjunction with ENGR 199W Writing of Original Research for Engineers fulfill the Writing in the Major (WIM) requirement. CS 272 Introduction to Biomedical Informatics Research Methodology, which does not have to be taken in conjunction with research, also fulfills the WIM requirement.

4 One 3-5 unit course required; CS 106A Programming Methodology may not be used. See Engineering Fundamentals list in Handbook for Undergraduate Engineering Programs or on Approved Courses page at ughb.stanford.edu.

5 The list of electives is continually updated to include all applicable courses. For the current list of electives, see http://bmc.stanford.edu.

6 A course may only be counted towards one elective or core requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Topics (Engineering Fundamentals and Depth courses) is 2.0.

7 A total of 40 Engineering Fundamentals and Core/Depth units must be taken. The core classes only provide 27 Engineering units, so the remaining units must be taken from within the electives.

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 the Honors Program Application Webform found on the BMC website and should be prepared to upload 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://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 20-30 pages and must be approved by the student's research adviser and by a second reader.
5. Students submit an electronic pdf of their thesis, including the signature page signed by both readers, to Bioengineering student services. Students should review deadlines on the BMC website. (https://bioengineering.stanford.edu/academics/undergraduate-programs/biomedical-computation/honors/) Students are sent email instructions on how to archive a permanent electronic copy in Terman Engineering library.
6. As the culmination of the honors project, each student presents their results in the Bioengineering Honors Poster Fair in spring quarter of their senior year.

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

Chemical Engineering

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

Mission of the Undergraduate Program in Chemical Engineering

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

Requirements

		Units
Mathematics (24-30 units) [1]		**10**
The following sequence or approved AP credit		
MATH 19	Calculus	
MATH 20	Calculus	
MATH 21	Calculus	
Select one of the following:		5-10
CME 100	Vector Calculus for Engineers	
MATH 51 & MATH 52	Linear Algebra, Multivariable Calculus, and Modern Applications and Integral Calculus of Several Variables	
Select one of the following:		5
CME 102	Ordinary Differential Equations for Engineers	
or MATH 53	Ordinary Differential Equations with Linear Algebra	
Select one of the following:		4-5
CME 104	Linear Algebra and Partial Differential Equations for Engineers	
or CME 106	Introduction to Probability and Statistics for Engineers	
Science (23-29 units) [1]		

CHEM 31M	Chemical Principles: From Molecules to Solids	5
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
PHYSICS 41	Mechanics	4
or PHYSICS 41E	Mechanics, Concepts, Calculations, and Context	
PHYSICS 43	Electricity and Magnetism	4
Technology in Society (3-5 units)		
One course required, see Basic Requirement 4; course chosen must be on the SoE-Approved Courses list at <ughb.stanford.edu> the year taken.		3-5
Engineering Fundamentals (7-9 units)		
Two courses minimum; see Basic Requirement 3		
CHEMENG/ENGR 20	Introduction to Chemical Engineering	4
Fundamentals Elective from another School of Engineering department		3-5
See the UGHB for a list of courses.		
Chemical Engineering Depth (51 units minimum)		
CHEMENG 100	Chemical Process Modeling, Dynamics, and Control	3
CHEMENG 110A	Introduction to Chemical Engineering Thermodynamics [3]	3
CHEMENG 110B	Multi-Component and Multi-Phase Thermodynamics	3
CHEMENG 120A	Fluid Mechanics	4
CHEMENG 120B	Energy and Mass Transport	4
CHEMENG 130A	Microkinetics - Molecular Principles of Chemical Kinetics	3
CHEMENG 130B	Introduction to kinetics and reactor design	3
CHEMENG 150	Biochemical Engineering	3
CHEMENG 180	Chemical Engineering Plant Design	4
CHEMENG 181	Biochemistry I	4
CHEMENG 185A	Chemical Engineering Laboratory A (WIM)	5
CHEMENG 185B	Chemical Engineering Laboratory B	5
CHEM 171	Foundations of Physical Chemistry [4]	4
Select 1 of the following:		3
CHEMENG 140	Micro and Nanoscale Fabrication Engineering	
CHEMENG 142	Basic Principles of Heterogeneous Catalysis with Applications in Energy Transformations	
CHEMENG 160	Polymer Science and Engineering	
CHEMENG 174	Environmental Microbiology I	
CHEMENG 177	Data Science and Machine Learning Approaches in Chemical and Materials Engineering	
CHEMENG 183	Biochemistry II	
CHEMENG 190	Undergraduate Research in Chemical Engineering	
CHEMENG 190H	Undergraduate Honors Research in Chemical Engineering	
CHEMENG 196	Creating and Leading New Ventures in Engineering and Science-based Industries	
Total Units		108-118

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 31M.

2. A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

3. Students who completed CHEM 171 prior to academic year 2020-21 may substitute CHEMENG 110A with CHEM 171.

4. Students who completed CHEM 173 prior to academic year 2020-21 may substitute CHEM 171 with CHEM 173.

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

Honors Program in Chemical Engineering

The Department of Chemical Engineering offers a program leading to the degree of Bachelor of Science in Chemical Engineering with Honors. Qualified undergraduate majors conduct independent study and research at an advanced level with faculty mentors, graduate students, and fellow undergraduates. This three quarter sequential program requires concurrent participation each quarter in the CHEMENG 191H Undergraduate Honors Seminar; completion of a faculty-approved thesis; and participation in the Chemical Engineering Honors Poster Session held annually during the Mason Lecture Series Spring Quarter. The last requirement may be fulfilled through an alternative, public, oral presentation with the approval of the department chair. A research proposal/application must be submitted at least five quarters prior to graduation with work to begin at a minimum of four quarters prior to graduation.

Admission to the honors program is by application and submission of a research proposal and is subject to approvals by faculty advisers, sponsors, and the chair of the department. Declared Chemical Engineering majors with a cumulative grade point average (GPA) of 3.5 or higher are encouraged to apply. Students must submit their applications no later than the first week in March during Winter Quarter of their junior year, assuming a June degree conferral the following year, e.g. the 2020-2021 deadline is March 1, 2021. An application includes a Stanford transcript in addition to the research proposal, approved by both the student's research thesis adviser, a faculty reader, and, if required, a chemical engineering faculty sponsor. The research adviser or the reader or, alternatively, a faculty sponsor, must be a faculty member in the Department of Chemical Engineering. Students must start their research no later than Spring Quarter their junior year and are encouraged to consider incorporating research opportunities such as those sponsored by Undergraduate Academic Life into their honors research proposal; see http://ual.stanford.edu/OO/research_opps/Grants (http://ual.stanford.edu/OO/research_opps/Grants/). See departmental student services staff in Shriram Center room 129, for more information about the application process, a proposal template, and other assistance.

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

1. Maintain an overall grade point average (GPA) of at least 3.5 as calculated on the unofficial transcript.
2. Complete at least three quarters of research with an aggregate enrollment of a minimum of nine units in CHEMENG 190H Undergraduate Honors Research in Chemical Engineering for a letter grade; up to three units may be used towards the Chemical Engineering depth elective requirements. All quarters must focus on the same topic. The same faculty adviser and faculty reader should be maintained throughout if feasible.
3. Enroll in CHEMENG 191H Undergraduate Honors Seminar, concurrently with each quarter of enrollment in CHEMENG 190H Undergraduate Honors Research in Chemical Engineering.

4. Participate with a poster and oral presentation of thesis work at the Chemical Engineering Honors Poster Session held during the Mason Lectures week, Spring Quarter, or, at the Undergraduate Program Committee's discretion, at a comparable public event. Submit at the same time to student services one copy of the poster in electronic format.
5. Submit final drafts of a thesis simultaneously to the adviser and the reader and, if appropriate, to the Chemical Engineering faculty sponsor, no later than April 5, 2021, or the first school day of the second week of the quarter in which the degree is to be conferred.
6. Complete all work and thesis revisions and obtain indicated faculty approvals on the Certificate of Final Reading of Thesis forms by April 30, 2021, or the end of the first month of the graduation quarter.
7. Submit to departmental student services one (1) final copy of the honors thesis, as approved by the appropriate faculty. Include in each thesis an original, completed, faculty signature sheet immediately following the title page. The 2020-2021 deadline is May 3, 2021.
8. Submit to student services a copy of the honors thesis in electronic format at the same time as the final copy of the thesis.

Upon faculty approval, departmental student services to submit one electronic copy of each honors thesis to Student Affairs, School of Engineering.

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 any of seven areas: structures, construction, environmental, energy/climate, fluid mechanics/hydrology, urban systems, or sensors/analytics. 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 major prepares students for careers in consulting, industry and government, as well as for graduate studies in engineering.

Requirements

		Units
Mathematics and Science		**45**
45 units minimum; see Basic Requirement 1 and 2 [1]		
Technology in Society		
One course required		
CEE 102A	Legal / Ethical Principles in Design, Construction, Project Delivery	3
Engineering Fundamentals		
Two courses required		
ENGR 14	Intro to Solid Mechanics	3
ENGR 90/CEE 70	Environmental Science and Technology	3
Engineering Depth		
Minimum of 68 Engineering Fundamentals plus Engineering Depth; see Basic Requirement 5		
CEE 100	Managing Sustainable Building Projects [2]	4
CS 106A	Programming Methodology (or CS 106B, CS 106X, CEE 101D)	5
ME 30	Engineering Thermodynamics (or CHEMENG 110A)	3
CEE 146S	Engineering Economics and Sustainability	3
CEE 183	Integrated Civil Engineering Design Project (Senior Capstone Design Course)	4
Focus Area Electives: at least 12 units in 1 major focus are, + at least 6 units each in 3 other focus areas (see below; no double counting) [4]		**30**
Additional CEE elective units (either select from focus areas below, from additional approved courses (see Footnote 5), or must be pre-approved by CEE Curriculum Comm.)		**13**
Total Units		116

1 Mathematics must include CME 100 Vector Calculus for Engineers and CME 102 Ordinary Differential Equations for Engineers (or MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications and Differential Calculus of Several Variables and MATH 53 Ordinary Differential Equations with Linear Algebra) and a Statistics course (STATS 101 Data Science 101 or STATS 110 Statistical Methods in Engineering and the Physical Sciences or CME 106 Introduction to Probability and Statistics for Engineers or CEE 203 Probabilistic Models in Civil Engineering). Science must include PHYSICS 41 Mechanics (or PHYSICS 41E Mechanics, Concepts, Calculations, and Context); either PHYSICS 43 Electricity and Magnetism or PHYSICS 45 Light and Heat; either CHEM 31A Chemical Principles I or CHEM 31M Chemical Principles: From Molecules to Solids; at least one of CEE 177 Aquatic Chemistry and Biology (required for major focus in fluid mechanics/ hydrology or environmental quality) or GEOLSCI 1 Introduction to Geology (required for major focus in structural, construction, urban systems, energy/climate or sensing/analytics); and additional physics, chemistry or mathematics to reach 45 units.

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

3 A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

4 To satisfy ABET criteria, electives must include at least 2 of the following 4 courses: CEE 101A, 101B, 101C, 101D.

5 Preapproved courses for additional CEE elective units: ENGR 10, 15, 21, 25E, 40M (or 40A), 50 (or 50E or 50M); CEE 74N, 80N; and up to 4 units of CEE 199 or CEE 199L.

Construction Engineering Focus

		Units
CEE 120A	Building Modeling for Design & Construction	3
CEE 122A & CEE 122B	Computer Integrated Architecture/ Engineering/Construction and Computer Integrated A/E/C (each quarter = 2 units; must take both quarters)	4
CEE 131C	How Buildings are Made -- Materiality and Construction Methods	4
CEE 141A	Infrastructure Project Development	3
CEE 141B	Infrastructure Project Delivery	3
CEE 144	Design and Innovation for the Circular Economy	3
CEE 241	Managing Fabrication and Construction	4

Energy and Climate Focus

		Units
CEE 63	Weather and Storms	3
CEE 64	Air Pollution and Global Warming: History, Science, and Solutions	3
CEE 107A	Understanding Energy (or CEE 107S)	3-5
CEE 107R	E^3: Extreme Energy Efficiency	3
CEE 156	Building Systems Design & Analysis	4
CEE 172	Air Quality Management	3
CEE 176A	Energy Efficient Buildings	3
CEE 176B	100% Clean, Renewable Energy and Storage for Everything	3-4

Environmental Fluid Mechanics & Hydrology Focus

		Units
CEE 101B	Mechanics of Fluids	4
CEE 161I	Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation	3
CEE 162D	Introduction to Physical Oceanography	4
CEE 162F	Coastal Processes	3
CEE 162I	Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation	3
CEE 166A	Watershed Hydrologic Processes and Models	3
CEE 166B	Water Resources and Hazards	3
CEE 175A	California Coast: Science, Policy, and Law	3-4

Environmental Quality Engineering for Human Health Focus

		Units
CEE 172	Air Quality Management	3
CEE 174A	Providing Safe Water for the Developing and Developed World	3
CEE 174B	Wastewater Treatment: From Disposal to Resource Recovery	3
CEE 175A	California Coast: Science, Policy, and Law (alt. years)	3-4
CEE 178	Introduction to Human Exposure Analysis	3
CEE 265D	Water and Sanitation in Developing Countries	3

Sensing, Analytics and Control Focus

		Units
CEE 101D	Computations in Civil and Environmental Engineering	3
CEE 154	Data Analytics for Physical Systems	3-4
CEE 155	Introduction to Sensing Networks for CEE	3-4
CEE 156	Building Systems Design & Analysis	3
CEE 177L	Smart Cities & Communities	3
ME 161	Dynamic Systems, Vibrations and Control	3-4
ME 210	Introduction to Mechatronics	4

Structural Engineering and Mechanics Focus

		Units
CEE 101A	Mechanics of Materials	4
CEE 101C	Geotechnical Engineering	4
CEE 101D	Computations in Civil and Environmental Engineering	3
CEE 180	Structural Analysis	4
CEE 182	Structural Design	4
CEE 192	Properties of Rocks and Geomaterials	3-4
ME 151	Introduction to Computational Mechanics	4

Urban Systems Focus

		Units
CEE 120A	Building Modeling for Design & Construction	3
CEE 130	Architectural Design: 3-D Modeling, Methodology, and Process	5
CEE 156	Building Systems Design & Analysis	4
CEE 176A	Energy Efficient Buildings	3-4
CEE 177L	Smart Cities & Communities	3
CEE 243	Intro to Urban Sys Engrg	3

Honors Program

This program leads to a B.S. with honors for undergraduates majoring in Civil Engineering or in Environmental Systems Engineering. It is designed to encourage qualified students to undertake a more intensive study of civil and environmental engineering than is required for the normal majors through a substantial, independent research project.

The program involves an in-depth research study in an area proposed to and agreed to by a Department of Civil and Environmental Engineering faculty adviser and completion of a thesis of high quality. A written proposal for the research to be undertaken must be submitted and approved by the faculty adviser in the fourth quarter prior to graduation. At the time of application, the student must have an overall grade point average (GPA) of at least 3.3 for course work at Stanford; this GPA must be maintained to graduation. The thesis is supervised by a CEE faculty adviser and must involve input from the School of Engineering writing program by means of ENGR 202S Directed Writing Projects or ENGR 199W Writing of Original Research for Engineers. The written thesis must be approved by the thesis adviser. Students are encouraged to present their results in a seminar for faculty and students. Up to 10 units of CEE 199H Undergraduate Honors Thesis, may be taken to support the research and writing (not to duplicate ENGR 202S or ENGR 199W). These units are beyond the normal Civil Engineering or Environmental Systems Engineering major program requirements.

For additional information on the major, minor, honors 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)—

		Units
CS 103	Mathematical Foundations of Computing	5
CS 109	Introduction to Probability for Computer Scientists	5
MATH 19	Calculus [1]	3
MATH 20	Calculus [1]	3
MATH 21	Calculus [1]	4
Plus two electives [2]		

Science (11 units minimum)—

		Units
PHYSICS 41	Mechanics	4
or PHYSICS 21	Mechanics, Fluids, and Heat	
or PHYSICS 41E	Mechanics, Concepts, Calculations, and Context	
PHYSICS 43	Electricity and Magnetism	4
or PHYSICS 23	Electricity, Magnetism, and Optics	
Science elective [3]		3

Technology in Society (3-5 units)—

One course; course chosen must be on the SoE Approved Courses list at https://ughb.stanford.edu/ the year taken; see Basic Requirements 4 in the School of Engineering section

Engineering Fundamentals (13 units minimum; see Basic Requirement 3 in the School of Engineering section)—

		Units
CS 106B	Programming Abstractions	5
or CS 106X	Programming Abstractions	
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)		3-5
*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.		

Writing in the Major—

		Units
Select one of the following:		
CS 181W	Computers, Ethics, and Public Policy	
CS 182W	Ethics, Public Policy, and Technological Change	
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)—

		Units
CS 107	Computer Organization and Systems	5
or CS 107E	Computer Systems from the Ground Up	
CS 110	Principles of Computer Systems	5
or CS 111	Operating Systems Principles	
CS 161	Design and Analysis of Algorithms	5

Senior Project (3 units)—

		Units
CS 191	Senior Project [7]	
CS 191W	Writing Intensive Senior Project [7]	
CS 194	Software Project	
CS 194H	User Interface Design Project	
CS 194W	Software Project	
CS 210B	Software Project Experience with Corporate Partners	
CS 294S	Research Project in Software Systems and Security	
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—

		Units
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	
CS 237A	Principles of Robot Autonomy I	
Select one additional course from the Areas above or from the following:		
AI Methods:		
CS 157	Computational Logic	
CS 205L	Continuous Mathematical Methods with an Emphasis on Machine Learning	
CS 230	Deep Learning	
CS 236	Deep Generative Models	
STATS 315A	Modern Applied Statistics: Learning	
STATS 315B	Modern Applied Statistics: Data Mining	
Comp Bio:		

CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
CS 371	Computational Biology in Four Dimensions	
Information and the Web:		
CS 276	Information Retrieval and Web Search	
CS 224W	Machine Learning with Graphs	
Other:		
CS 151	Logic Programming	
CS 227B	General Game Playing	
CS 379	Interdisciplinary Topics (Offered occasionally)	
Robotics and Control:		
CS 327A	Advanced Robotic Manipulation	
CS 329	Topics in Artificial Intelligence (with advisor approval)	
ENGR 205	Introduction to Control Design Techniques	
MS&E 251	Introduction to Stochastic Control with Applications	
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 courses listed below. Students can replace one of these electives with a course found at https://cs.stanford.edu/explore (https://cs.stanford.edu/explore/): [5]		
CS 237B	Principles of Robot Autonomy II	
CS 257	Logic and Artificial Intelligence	
CS 275	Translational Bioinformatics	
CS 326	Topics in Advanced Robotic Manipulation	
CS 330	Deep Multi-task and Meta Learning	
CS 336		
CS 338	Physical Human Robot Interaction	
CS 398	Computational Education	
CS 428	Computation and Cognition: The Probabilistic Approach	
EE 263	Introduction to Linear Dynamical Systems	
EE 278	Introduction to Statistical Signal Processing	
EE 364A	Convex Optimization I	
EE 364B	Convex Optimization II	
ECON 286	Game Theory and Economic Applications	
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	
MS&E 352	Decision Analysis II: Professional Decision Analysis	
MS&E 355	Influence Diagrams and Probabilistics Networks	
PHIL 152	Computability and Logic	
PSYCH 204A	Human Neuroimaging Methods	
PSYCH 204B	Computational Neuroimaging	
PSYCH 209	Neural Network Models of Cognition	
STATS 200	Introduction to Statistical Inference	
STATS 202	Data Mining and Analysis	
STATS 205	Introduction to Nonparametric Statistics	

Biocomputation Track—

		Units
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	
CS 228	Probabilistic Graphical Models: Principles and Techniques	
CS 229	Machine Learning	
CS 231A	Computer Vision: From 3D Reconstruction to Recognition	
Select one of the following:		
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	
CS 270	Modeling Biomedical Systems	
CS 273A	The Human Genome Source Code	
CS 274	Representations and Algorithms for Computational Molecular Biology	
CS 275	Translational Bioinformatics	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
One additional course from the lists above or the following:		3-4
CS 124	From Languages to Information	
CS 145	Data Management and Data Systems	
CS 147	Introduction to Human-Computer Interaction Design	
CS 148	Introduction to Computer Graphics and Imaging	
CS 248	Interactive Computer Graphics	
One course selected from the following:		3-4
CS 108	Object-Oriented Systems Design	4
CS 124	From Languages to Information	3-4
CS 131	Computer Vision: Foundations and Applications	3-4
CS 140	Operating Systems and Systems Programming [4]	3-4
or CS 140E	Operating systems design and implementation	
CS 142	Web Applications	3
CS 143	Compilers	3-4
CS 144	Introduction to Computer Networking	3-4
CS 145	Data Management and Data Systems	3-4
CS 146	Introduction to Game Design and Development	3
CS 147	Introduction to Human-Computer Interaction Design	3-5
CS 148	Introduction to Computer Graphics and Imaging	3-4
CS 149	Parallel Computing	3-4
CS 151	Logic Programming	3
CS 154	Introduction to the Theory of Computation	3-4
CS 155	Computer and Network Security	3
CS 157	Computational Logic	3
or PHIL 151	Metalogic	
CS 163	The Practice of Theory Research	3
CS 166	Data Structures	3-4
CS 168	The Modern Algorithmic Toolbox	3-4
CS 190	Software Design Studio	3-4

CS 195	Supervised Undergraduate Research (4 units max)	3-4
CS 197	Computer Science Research	4
CS 205L	Continuous Mathematical Methods with an Emphasis on Machine Learning	3
CS 210A	Software Project Experience with Corporate Partners	3-4
CS 217	Hardware Accelerators for Machine Learning	3-4
CS 221	Artificial Intelligence: Principles and Techniques	3-4
CS 223A	Introduction to Robotics	3
CS 224N	Natural Language Processing with Deep Learning	3-4
CS 224S	Spoken Language Processing	2-4
CS 224U	Natural Language Understanding	3-4
CS 224W	Machine Learning with Graphs	3-4
CS 225A	Experimental Robotics	3
CS 227B	General Game Playing	3
CS 228	Probabilistic Graphical Models: Principles and Techniques	3-4
CS 229	Machine Learning	3-4
CS 229M	Machine Learning Theory	3
CS 230	Deep Learning	3-4
CS 231A	Computer Vision: From 3D Reconstruction to Recognition	3-4
CS 231N	Convolutional Neural Networks for Visual Recognition	3-4
CS 232	Digital Image Processing	3
CS 233	Geometric and Topological Data Analysis	3
CS 234	Reinforcement Learning	3
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	3-4
CS 236	Deep Generative Models	3
CS 237A	Principles of Robot Autonomy I	3-5
CS 237B	Principles of Robot Autonomy II	3-4
CS 238	Decision Making under Uncertainty	3-4
CS 240	Advanced Topics in Operating Systems	3
CS 240LX	Advanced Systems Laboratory, Accelerated	3
CS 242	Programming Languages	3
CS 243	Program Analysis and Optimizations	3-4
CS 244	Advanced Topics in Networking	3-4
CS 244B	Distributed Systems	3
CS 245	Principles of Data-Intensive Systems	3
CS 246	Mining Massive Data Sets	3-4
CS 247	(Any suffix)	3-4
CS 248	Interactive Computer Graphics	3-4
CS 251	Cryptocurrencies and blockchain technologies	3
CS 252	Analysis of Boolean Functions	3
CS 254	Computational Complexity	3
CS 254B	Computational Complexity II	3
CS 255	Introduction to Cryptography	3
CS 261	Optimization and Algorithmic Paradigms	3
CS 263	Counting and Sampling	3
CS 265	Randomized Algorithms and Probabilistic Analysis	3
CS 269Q	Elements of Quantum Computer Programming	3
CS 269I	Incentives in Computer Science (Not Given This Year)	3
CS 270	Modeling Biomedical Systems	3
CS 271	Artificial Intelligence in Healthcare	3-4
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 278	Social Computing	3
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	3
CS 330	Deep Multi-task and Meta Learning	3
CS 336	(Robot Perception and Decision Making: not offered this year)	
CS 348	(any suffix)	
CS 351	Open Problems in Coding Theory	3
CS 352	Pseudo-Randomness	3-4
CS 369L	Algorithmic Perspective on Machine Learning	3
CS 371	Computational Biology in Four Dimensions	3
CS 398	Computational Education	4
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	3
STATS 315B	Modern Applied Statistics: Data Mining	3
GENE 211	Genomics	3
One course from the following:		3-5
CS 145	Data Management and Data Systems	3-4
CS 147	Introduction to Human-Computer Interaction Design	3-5
CS 221	Artificial Intelligence: Principles and Techniques	3-4
CS 228	Probabilistic Graphical Models: Principles and Techniques	3-4
CS 229	Machine Learning	3-4
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	3-4
CS 270	Modeling Biomedical Systems	3
CS 271	Artificial Intelligence in Healthcare	3-4
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
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	3
STATS 315B	Modern Applied Statistics: Data Mining	3
GENE 211	Genomics	3
One course selected from the list above or the following:		
CHEMENG 150	Biochemical Engineering	3
CHEMENG 174	Environmental Microbiology I	3
APPPHYS 294	Cellular Biophysics	3
BIO 104	Advance Molecular Biology: Epigenetics and Proteostasis	5
BIO 118	(Not Given This Year)	4
BIO 214	Advanced Cell Biology	4
BIO 230	Molecular and Cellular Immunology	4
CHEM 141	The Chemical Principles of Life I	4
CHEM 171	Foundations of Physical Chemistry	4
BIOC 241	Biological Macromolecules	3-5
One course from the following:		
BIOE 220	Introduction to Imaging and Image-based Human Anatomy	3
CHEMENG 150	Biochemical Engineering	3
CHEMENG 174	Environmental Microbiology I	3
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	3-4
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
ME 281	Biomechanics of Movement	3
APPPHYS 294	Cellular Biophysics	3
BIO 104	Advance Molecular Biology: Epigenetics and Proteostasis	5
BIO 112	Human Physiology	4
BIO 118	(Not Given This Year)	4
BIO 158	Developmental Neurobiology	4
BIO 183	Theoretical Population Genetics	3
BIO 214	Advanced Cell Biology	4
BIO 230	Molecular and Cellular Immunology	4
CHEM 171	Foundations of Physical Chemistry	4
CHEM 141	The Chemical Principles of Life I	4
BIOC 241	Biological Macromolecules	3-5
DBIO 210	Developmental Biology	4
GENE 211	Genomics	3
SURG 101	Regional Study of Human Structure	5

Computer Engineering Track—

		Units
For this track there is a 10 unit minimum for ENGR Fundamentals and a 29 unit minimum for Depth (for track and elective courses)		
EE 108	Digital System Design	4
EE 180	Digital Systems Architecture	4
Select two of the following:		8
EE 101A	Circuits I	
EE 101B	Circuits II	
EE 102A	Signal Processing and Linear Systems I	
EE 102B	Signal Processing and Linear Systems II	
Satisfy the requirements of one of the following concentrations:		
1) Digital Systems Concentration		
CS 140	Operating Systems and Systems Programming [4]	
or CS 140E	Operating systems design and implementation	
or CS 143	Compilers	
EE 109	Digital Systems Design Lab	
EE 271	Introduction to VLSI Systems	
Plus two of the following (6-8 units):		
CS 140	Operating Systems and Systems Programming (if not counted above) [4]	
or CS 140E	Operating systems design and implementation	
or CS 143	Compilers	
CS 144	Introduction to Computer Networking	
CS 149	Parallel Computing	
CS 190	Software Design Studio	
CS 217	Hardware Accelerators for Machine Learning	
CS 244	Advanced Topics in Networking	
EE 273	Digital Systems Engineering	
EE 282	Computer Systems Architecture	
2) Robotics and Mechatronics Concentration		
CS 205L	Continuous Mathematical Methods with an Emphasis on Machine Learning	
CS 223A	Introduction to Robotics	
ME 210	Introduction to Mechatronics	
ENGR 105	Feedback Control Design	
Plus one of the following (3-4 units):		
CS 225A	Experimental Robotics	
CS 231A	Computer Vision: From 3D Reconstruction to Recognition	
ENGR 205	Introduction to Control Design Techniques	
ENGR 207B	Linear Control Systems II	
3) Networking Concentration		
CS 140	Operating Systems and Systems Programming (CS 140E can substitute for CS 140) [4]	
CS 144	Introduction to Computer Networking	
Plus three of the following (9-11 units):		
CS 240	Advanced Topics in Operating Systems	
or CS 240LX	Advanced Systems Laboratory, Accelerated	
CS 241	Embedded Systems Workshop	
CS 244	Advanced Topics in Networking	
CS 244B	Distributed Systems	
EE 179	Analog and Digital Communication Systems	

Graphics Track—

		Units
CS 148	Introduction to Computer Graphics and Imaging	4
CS 244	Advanced Topics in Networking	4

Select one of the following: [6]		3-5
CS 205L	Continuous Mathematical Methods with an Emphasis on Machine Learning	
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:		6-8
CS 146	Introduction to Game Design and Development	
CS 231A	Computer Vision: From 3D Reconstruction to Recognition	
or CS 131	Computer Vision: Foundations and Applications	
CS 233	Geometric and Topological Data Analysis	
CS 348	(Computer Graphics: any suffix)	
CS 448	Topics in Computer Graphics	
Track Electives: at least two additional courses from the lists above, the general CS electives list, or the courses listed below. Students can replace one of these electives with a course found at: https://cs.stanford.edu/explore (https://cs.stanford.edu/explore/): [5]		6-8
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	Three-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	

Human-Computer Interaction Track—

		Units
CS 147	Introduction to Human-Computer Interaction Design	5
CS 247	(Any suffix)	4
CS 347	Human-Computer Interaction: Foundations and Frontiers	4
CS 142	Web Applications	3
Any one of the following:		
CS 194H	User Interface Design Project	
CS 206	Exploring Computational Journalism	
CS 210A	Software Project Experience with Corporate Partners	
CS 247	(Any suffix beyond the course used above)	
CS 278	Social Computing	
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 the above areas or the general CS electives list. Students can replace one of these electives with a course found at https://cs.stanford.edu/explore (https://cs.stanford.edu/explore/)		
Optional Elective [5]		

Information Track—

		Units
CS 124	From Languages to Information	4
CS 145	Data Management and Data Systems	4
Two courses, from different areas:		6-9
1) Information-based AI applications		
CS 224N	Natural Language Processing with Deep Learning	
CS 224S	Spoken Language Processing	
CS 229	Machine Learning	
CS 233	Geometric and Topological Data Analysis	
CS 234	Reinforcement Learning	
2) Database and Information Systems		
CS 140	Operating Systems and Systems Programming [4]	
or CS 140E	Operating systems design and implementation	
CS 142	Web Applications	
CS 151	Logic Programming	
CS 245	Principles of Data-Intensive Systems	
CS 246	Mining Massive Data Sets	
CS 341	Project in Mining Massive Data Sets	
3) Information Systems in Biology		
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	
CS 270	Modeling Biomedical Systems	
CS 274	Representations and Algorithms for Computational Molecular Biology	
4) Information Systems on the Web		
CS 224W	Machine Learning with Graphs	
CS 276	Information Retrieval and Web Search	
At least three additional courses from the above areas or the general CS electives list. Students can replace one of these electives with a course found at https://cs.stanford.edu/explore (https://cs.stanford.edu/explore/) [5]		

Systems Track—

		Units
CS 140	Operating Systems and Systems Programming [4]	4
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	Data Management and Data Systems	
CS 149	Parallel Computing	
CS 155	Computer and Network Security	
CS 190	Software Design Studio	
CS 217	Hardware Accelerators for Machine Learning	
CS 240	Advanced Topics in Operating Systems	
or CS 240LX	Advanced Systems Laboratory, Accelerated	

CS 242	Programming Languages	
CS 243	Program Analysis and Optimizations	
CS 244	Advanced Topics in Networking	
CS 245	Principles of Data-Intensive Systems	
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 courses listed below. Students can replace one of these electives with a course found at: https://cs.stanford.edu/explore (https://cs.stanford.edu/explore/) [5]		9-12
CS 241	Embedded Systems Workshop	
CS 269Q	Elements of Quantum Computer Programming	
CS 316	Advanced Multi-Core Systems	
CS 341	Project in Mining Massive Data Sets	
CS 344	Topics in Computer Networks (3 or more units, any suffix)	
CS 349	Topics in Programming Systems (with permission of undergraduate advisor)	
CS 357S	Formal Methods for Computer Systems	
CS 448	Topics in Computer Graphics	
EE 108	Digital System Design	
EE 382C	Interconnection Networks	
EE 384A	Internet Routing Protocols and Standards	
EE 384C	Wireless Local and Wide Area Networks	
EE 384E	Networked Wireless Systems	
EE 384S	Performance Engineering of Computer Systems & Networks	

Theory Track—

		Units
CS 154	Introduction to the Theory of Computation	4
Select one of the following:		3
CS 168	The Modern Algorithmic Toolbox	
CS 255	Introduction to Cryptography	
CS 261	Optimization and Algorithmic Paradigms	
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 151	Logic Programming	
CS 155	Computer and Network Security	
CS 157	Computational Logic	
or PHIL 151	Metalogic	
CS 163	The Practice of Theory Research	
CS 166	Data Structures	
CS 205L	Continuous Mathematical Methods with an Emphasis on Machine Learning	
CS 228	Probabilistic Graphical Models: Principles and Techniques	
CS 233	Geometric and Topological Data Analysis	
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	
CS 236	Deep Generative Models	
CS 242	Programming Languages	
CS 250	Algebraic Error Correcting Codes	
CS 251	Cryptocurrencies and blockchain technologies	
CS 252	Analysis of Boolean Functions	
CS 254	Computational Complexity	
CS 259	(With permission of undergraduate advisor. Course offered occasionally.)	
CS 263	Counting and Sampling	
CS 269I	Incentives in Computer Science (Not Given This Year)	
CS 351	Open Problems in Coding Theory	
CS 354	Topics in Intractability: Unfulfilled Algorithmic Fantasies (Not given this year)	
CS 355	Advanced Topics in Cryptography (Not given this year)	
CS 357	Advanced Topics in Formal Methods (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 369	Topics in Analysis of Algorithms (with permission of undergraduate advisor)	
MS&E 310	Linear Programming	
Track Electives: at least three additional courses from the lists above, the general CS electives list, or the courses listed below. Students can replace one of these electives with a course found at: https://cs.stanford.edu/explore (https://cs.stanford.edu/explore/) [5]		9-12
CS 254B	Computational Complexity II	
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—

		Units
CS 154	Introduction to the Theory of Computation	4
Select one of the following:		4
CS 140	Operating Systems and Systems Programming [4]	
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	Software Design Studio	
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	
CS 223A	Introduction to Robotics	
CS 228	Probabilistic Graphical Models: Principles and Techniques	
CS 229	Machine Learning	
CS 231A	Computer Vision: From 3D Reconstruction to Recognition	
Select one of the following:		3-4
CS 145	Data Management and Data Systems	

CS 147	Introduction to Human-Computer Interaction Design
CS 148	Introduction to Computer Graphics and Imaging
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation
CS 248	Interactive Computer Graphics
At least two courses from the general CS electives list [5]	

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. Proposals must be approved by the faculty advisor and Director of Undergraduate Studies. See Handbook for Undergraduate Engineering Programs for further information.

Footnotes for Track Course Lists

1. MATH 19, MATH 20, and MATH 21, 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 52, MATH 53, MATH 104, MATH 107, MATH 108, MATH 109, MATH 110, MATH 113; CS 157, CS 205L, PHIL 151; CME 100, CME 102, CME 104, ENGR 108. 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.
4. CS 111 and CS 140 cannot both be counted towards the BS requirements. However, it is acceptable to count both CS 111 and CS 140E towards the BS requirements.
5. General CS Electives: CS 108, CS 124, CS 131, CS 140 (or CS 140E), CS 142, CS 143, CS 144, CS 145, CS 146, CS 147, CS 148, CS 149, CS 154, CS 155, CS 157(or PHIL 151), CS 163, CS 166, CS 168, CS 190, CS 195 (4 units max), CS 197, CS 205L, CS 210A, CS 217, CS 221, CS 223A, CS 224N, CS 224S, CS 224U, CS 224W, CS 225A, CS 227B, CS 228, CS 229, CS 229M, CS 230, CS 231A, CS 231N, CS 232, CS 233, CS 234CS 234CS 234CS 234CS 234CS 234CS 234CS 234CS 234, CS 235, CS 237A, CS 237B, CS 238, CS 240, CS 240LX, CS 242, CS 243, CS 244, CS 244B, CS 245, CS 246, CS 247(any suffix), CS 248, CS 251, CS 252, CS 254, CS 254B, CS 255, CS 261, CS 263, CS 265, CS 269I, CS 269Q, CS 270, CS 271, CS 272, CS 273A, CS 273B, CS 274, CS 276, CS 278, CS 279, CS 330, CS 336, CS 348 (any suffix), CS 351, CS 352, CS 369L, CS 398, CME 108; EE 180, EE 282.
6. CS 205L 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.
7. 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 (Patrick 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 (UGHB) *(*http://ughb.stanford.edu*)*.
8. A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

Additional Information

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

Honors Program in Computer Science

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

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

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

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

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 bio-electronics 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

		Units
MATHEMATICS AND SCIENCE		
Minimum 40 units Math and Science combined.		
Mathematics [1]		
Select one sequence: May also be satisfied with AP Calculus.		10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
Select one 2-course sequence:		10
CME 100 & CME 102	Vector Calculus for Engineers and Ordinary Differential Equations for Engineers (Same as ENGR 154 and ENGR 155A)	
MATH 51 & MATH 53	Linear Algebra, Multivariable Calculus, and Modern Applications and Ordinary Differential Equations with Linear Algebra [2]	
EE Math. One additional 100-level course. Select one:		3
CS 103	Mathematical Foundations of Computing	
ENGR 108	Introduction to Matrix Methods (Preferred) [3]	
MATH 113	Linear Algebra and Matrix Theory	
Statistics/Probability		3-4
EE 178	Probabilistic Systems Analysis [3]	
Science		
Minimum 12 units		
Select one sequence:		12
PHYSICS 41 & EE 65	Mechanics and Modern Physics for Engineers [4]	
PHYSICS 61 & EE 65	Mechanics and Special Relativity and Modern Physics for Engineers [4]	
Science elective. One additional 4-5 unit course from approved list in Undergraduate Handbook, Figure 4-2.		4-5
TECHNOLOGY IN SOCIETY		
One course, see Basic Requirement 4 in the School of Engineering section. The course taken must be on the School of Engineering Approved Courses list, Fig 4-3, the year it is taken.		3-5
ENGINEERING TOPICS		
Minimum 60 units comprised of: Engineering Fundamentals (minimum 10 units), Core Electrical Engineering Courses (minimum 16 units) Disciplinary Area (minimum 17 units), Electives (maximum 17 units, restrictions apply).		
Engineering Fundamentals		**10**
2 courses required; minimum 10 units.		
Select one:		
CS 106B	Programming Abstractions	5
or CS 106X	Programming Abstractions	
Choose one Fundamental from the Approved List; Recommended: ENGR 40A and ENGR 40B or ENGR 40M (recommended before taking EE 101A); taking CS 106A or a second ENGR 40-series course not allowed for the Fundamentals elective. Choose from table in Undergraduate Handbook, Approved List.		5
Core Electrical Engineering Courses		**16**
Minimum 16 units.		
EE 42	Introduction to Electromagnetics and Its Applications [5]	
EE 100	The Electrical Engineering Profession [6]	
EE 101A	Circuits I	
EE 102A	Signal Processing and Linear Systems I	
EE 108	Digital System Design	
Disciplinary Area		**17**
Minimum 17 units, 5 courses: 1-2 Required, 1 WIM/Design and 2-3 disciplinary area electives.		
Writing in the Major (WIM)		**3-5**
Select one. A single course can concurrently meet the WIM and Design Requirements.		
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 168	Introduction to Digital Image Processing (WIM/Design)	
EE 191W	Special Studies and Reports in Electrical Engineering (WIM; Department approval required) [7]	
EE 264W	Digital Signal Processing (WIM/Design)	
EE 267W	Virtual Reality (WIM/Design)	
CS 194W	Software Project (WIM/Design)	
Design Course		**3-5**
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 168	Introduction to Digital Image Processing (WIM/Design)	
EE 185C	Engineering a Smart Object - Adding connectivity and Putting it ALL together (Design)	
EE 262	Three-Dimensional Imaging (Design)	
EE 264	Digital Signal Processing (Design) [8]	
EE 264W	Digital Signal Processing (WIM/Design)	
EE 267	Virtual Reality (Design) [8]	
EE 267W	Virtual Reality (WIM/Design)	
CS 194	Software Project (Design)	
CS 194W	Software Project (WIM/Design)	
Electives [9]		**17**

Minimum 17 units. The elective units should be sufficient to meet the 60 unit total for the major, over and above the 40 units of Math and Science. Depending on units completed in the Disciplinary Area, elective units will be in the range of 17 units or less. 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 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 51 may be replaced by MATH 52. MATH 53 may be replaced by CME 102.
3. If used for math, ENGR 108 may not be used as an EE disciplinary elective. Students may petition to use CS 109 in place of EE 178.
4. Students may petition to have either PHYSICS 65 or the combination of PHYSICS 45 and PHYSICS 70 count as an alternative to EE 65.
5. Students may petition to use PHYSICS 43 or PHYSICS 63 in place of EE 42. 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.
6. For upper division students, a 200-level seminar in their disciplinary area will be accepted, on petition.
7. 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.
8. To satisfy Design, must take EE 264 or EE 267 for 4 units and complete the laboratory project.
9. A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

Disciplinary Areas

		Units
Hardware and Software		
EE 180	Digital Systems Architecture (Required)	4
EE 104	Introduction to Machine Learning	3-5
EE 107	Embedded Networked Systems	3
EE 109	Digital Systems Design Lab (WIM/Design)	4
EE 118	Introduction to Mechatronics	4
EE 155	Green Electronics (Design)	4
EE 185C	Engineering a Smart Object - Adding connectivity and Putting it ALL together (Design)	3
EE 264	Digital Signal Processing (Design)	3-4
EE 264W	Digital Signal Processing (WIM/Design)	5
EE 267	Virtual Reality (Design)	3-4
EE 267W	Virtual Reality (WIM/Design)	5
EE 271	Introduction to VLSI Systems	3
EE 272A	Design Projects in VLSI Systems I	3-4
EE 272B	Design Projects in VLSI Systems II	3-4
EE 273	Digital Systems Engineering	3
EE 282	Computer Systems Architecture	3
EE 285	Embedded Systems Workshop	3
CS 107	Computer Organization and Systems (Required prerequisite for EE 180; CS 107E preferred)	3-5
or CS 107E	Computer Systems from the Ground Up	
CS 108	Object-Oriented Systems Design	3-4
CS 110	Principles of Computer Systems	3-5
CS 131	Computer Vision: Foundations and Applications	3-4
CS 140	Operating Systems and Systems Programming	3-4
CS 143	Compilers	3-4
CS 144	Introduction to Computer Networking	3-4
CS 145	Data Management and Data Systems	3-4
CS 148	Introduction to Computer Graphics and Imaging	3-4
CS 149	Parallel Computing	3-4
CS 155	Computer and Network Security	3
CS 194W	Software Project (WIM/Design)	3
CS 221	Artificial Intelligence: Principles and Techniques	3-4
CS 223A	Introduction to Robotics	3
CS 224N	Natural Language Processing with Deep Learning	3-4
CS 225A	Experimental Robotics	3
CS 229	Machine Learning	3-4
CS 231A	Computer Vision: From 3D Reconstruction to Recognition	3-4
CS 231N	Convolutional Neural Networks for Visual Recognition	3-4
CS 241	Embedded Systems Workshop	3
CS 244	Advanced Topics in Networking	3-4
Information Systems and Science		
EE 102B	Signal Processing and Linear Systems II (Required)	4
EE 104	Introduction to Machine Learning	3-5
EE 107	Embedded Networked Systems	3
EE 118	Introduction to Mechatronics	4
EE 124	Introduction to Neuroelectrical Engineering	3
EE 133	Analog Communications Design Laboratory (WIM/Design)	3-4
EE 155	Green Electronics (WIM/Design)	4
EE 168	Introduction to Digital Image Processing (WIM/Design)	3-4
EE 169	Introduction to Bioimaging	3
EE 179	Analog and Digital Communication Systems	3
EE 260A	Principles of Robot Autonomy I	3-5
EE 260B	Principles of Robot Autonomy II	3-4
EE 261	The Fourier Transform and Its Applications	3
EE 262	Three-Dimensional Imaging (Design)	3
EE 263	Introduction to Linear Dynamical Systems	3
EE 264	Digital Signal Processing (Design)	3-4
EE 264W	Digital Signal Processing (WIM/Design)	5
EE 266	Introduction to Stochastic Control with Applications	3
EE 267	Virtual Reality (Design)	3-4
EE 267W	Virtual Reality (WIM/Design)	5
EE 269	Signal Processing for Machine Learning	3
EE 276	Information Theory	3

EE 278	Introduction to Statistical Signal Processing	3
EE 279	Introduction to Digital Communication	3
ENGR 105	Feedback Control Design	3
ENGR 205	Introduction to Control Design Techniques	3
CS 107	Computer Organization and Systems	3-5
CS 229	Machine Learning	3-4
Physical Technology and Science		
EE 101B	Circuits II (Required)	4
EE 107	Embedded Networked Systems	3
EE 114	Fundamentals of Analog Integrated Circuit Design	3-4
EE 116	Semiconductor Devices for Energy and Electronics	3
EE 118	Introduction to Mechatronics	4
EE 124	Introduction to Neuroelectrical Engineering	3
EE 133	Analog Communications Design Laboratory (WIM/Design)	3-4
EE 134	Introduction to Photonics (WIM/Design)	4
EE 142	Engineering Electromagnetics	3
EE 153	Power Electronics (WIM/Design)	3-4
EE 155	Green Electronics (WIM/Design)	4
EE 157	Electric Motors for Renewable Energy, Robotics, and Electric Vehicles	3
EE 212	Integrated Circuit Fabrication Processes	3
EE 214B	Advanced Integrated Circuit Design	3
EE 216	Principles and Models of Semiconductor Devices	3
EE 222	Applied Quantum Mechanics I	3
EE 223	Applied Quantum Mechanics II	3
EE 236A	Modern Optics	3
EE 236B	Guided Waves	3
EE 242	Electromagnetic Waves	3
EE 247	Introduction to Optical Fiber Communications	3
EE 264	Digital Signal Processing (Design)	3-4
EE 264W	Digital Signal Processing (WIM/Design)	5
EE 267	Virtual Reality (Design)	3-4
EE 267W	Virtual Reality (WIM/Design)	5
EE 271	Introduction to VLSI Systems	3
EE 272A	Design Projects in VLSI Systems I	3-4
EE 272B	Design Projects in VLSI Systems II	3-4
EE 273	Digital Systems Engineering	3
EE 282	Computer Systems Architecture	3
ENGR 105	Feedback Control Design	3
ENGR 205	Introduction to Control Design Techniques	3
CS 107	Computer Organization and Systems	3-5

Multidisciplinary Area Electives

Bio-electronics and Bio-imaging		
EE 101B	Circuits II	4
EE 102B	Signal Processing and Linear Systems II	4
EE 107	Embedded Networked Systems	3
EE 124	Introduction to Neuroelectrical Engineering	3
EE 134	Introduction to Photonics (WIM/Design)	4
EE 168	Introduction to Digital Image Processing (WIM/Design)	4
EE 169	Introduction to Bioimaging	3
EE 225	Biochips and Medical Imaging	3
EE 235	Analytical Methods in Biotechnology	3
BIOE 131	Ethics in Bioengineering	3
BIOE 248	Neuroengineering Laboratory	3
MED 275B	Biodesign Fundamentals	4
Energy and Environment		
EE 101B	Circuits II	4
EE 116	Semiconductor Devices for Energy and Electronics	3
EE 134	Introduction to Photonics (WIM/Design)	4
EE 153	Power Electronics (WIM/Design)	3-4
EE 155	Green Electronics (WIM/Design)	4
EE 157	Electric Motors for Renewable Energy, Robotics, and Electric Vehicles	3
EE 168	Introduction to Digital Image Processing (WIM/Design)	3-4
EE 180	Digital Systems Architecture	4
EE 263	Introduction to Linear Dynamical Systems	3
EE 293	Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors	3
EE 293B	Fundamentals of Energy Processes	3
CEE 107A	Understanding Energy (Formerly CEE 173A)	3-5
CEE 155	Introduction to Sensing Networks for CEE	3-4
CEE 176A	Energy Efficient Buildings	3
CEE 176B	100% Clean, Renewable Energy and Storage for Everything	3-4
ENGR 105	Feedback Control Design	3
ENGR 205	Introduction to Control Design Techniques	3
MATSCI 142	Quantum Mechanics of Nanoscale Materials (Formerly MATSCI 157)	4
MATSCI 152	Electronic Materials Engineering	4
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	3-4
ME 227	Vehicle Dynamics and Control	3
ME 271E		4
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 256A	Music, Computing, Design: The Art of Design	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
MUSIC 320B	Introduction to Audio Signal Processing Part II: Digital Filters	3-4
MUSIC 420A	Signal Processing Models in Musical Acoustics [2]	3-4
MUSIC 421A	Time-Frequency Audio Signal Processing [2]	3-4
MUSIC 422	Perceptual Audio Coding [2]	3
MUSIC 424	Signal Processing Techniques for Digital Audio Effects [2]	3-4

[1] ENGR 108 may be used for disciplinary area if not used for EE Math.
[2] Best taken as a coterm student.

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

Honors Program in Electrical Engineering

The Department of Electrical Engineering offers a program leading to a Bachelor of Science in Electrical Engineering with Honors. This program offers a unique opportunity for qualified undergraduate majors to conduct independent study and research at an advanced level with a faculty mentor, graduate students, and fellow undergraduates.

Admission to the honors program is by application. Declared EE majors with a grade point average (GPA) of at least 3.5 in Electrical Engineering are eligible to submit an application. Applications must be submitted by Autumn Quarter of the senior year, be signed by the thesis advisor and second reader (one must be a member of the EE Faculty), and include an honors proposal. Students need to declare honors on Axess.

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

1. Submit an application, including the thesis proposal, by Autumn Quarter of senior year signed by the thesis advisor and second reader (one must be a member of the Electrical Engineering faculty).
2. Declare the EE Honors major in Axess before the end of Autumn Quarter of senior year.
3. Maintain a grade point average of at least 3.5 in Electrical Engineering courses.
4. Complete at least 10 units of EE 191 or EE 191W with thesis adviser for a letter grade. EE 191 units do not count toward the required 60 units, with the exception of EE 191W if approved to satisfy WIM.
5. Submit one final copy of the honors thesis approved by the advisor and second reader to the EE Degree Progress Officer by May 15.
6. Attend poster and oral presentation held at the end of Spring Quarter or present in another suitable forum approved by the faculty advisor.

COVID-19-Related Degree Requirement Changes

The Engineering Physics program counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that otherwise require a letter grade.

Engineering Physics (EPHYS)

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

Mission of the Undergraduate Program in Engineering Physics

The mission of the undergraduate program in Engineering Physics is to provide students with a strong foundation in physics and mathematics, together with engineering and problem-solving skills. All majors take high-level math and physics courses as well as engineering courses. This background prepares them to tackle complex problems in multidisciplinary areas that are at the forefront of 21st-century technology such as aerospace physics, biophysics, computational science, quantum science & engineering, materials science, nanotechnology, electromechanical systems, renewable energy, and any other engineering field that requires a solid background in physics. Because the program emphasizes science, mathematics, and engineering, students are well prepared to pursue graduate work in engineering, physics, or applied physics.

Requirements

		Units
Mathematics		
Select one of the following sequences:		10
MATH 51 & MATH 52	Linear Algebra, Multivariable Calculus, and Modern Applications and Integral Calculus of Several Variables	
CME 100 & CME 104	Vector Calculus for Engineers and Linear Algebra and Partial Differential Equations for Engineers	
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]	2
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.		3-5
Engineering Fundamentals		
Two courses minimum (CS 106A or B recommended) [2]		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 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 & PHYSICS 121	Intermediate Electricity and Magnetism I and Intermediate Electricity and Magnetism II	
EE 142 & EE 242	Engineering Electromagnetics and Electromagnetic Waves	
Numerical Methods		
Select one of the following:		3-4
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
EE 101A	Circuits I	
EE 101B	Circuits II	
ENGR 40M	An Intro to Making: What is EE (or ENGR 40A+ENGR 40B; must take both [not offered 2019-20])	
PHYSICS 104	Electronics and Introduction to Experimental Methods (2020-21 only)	
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)	
ENGR 199W	Writing of Original Research for Engineers (for students pursuing an independent research project)	
BIOE 131	Ethics in Bioengineering (for Biophysics specialty only)	
CS 181W	Computers, Ethics, and Public Policy (for Computational Science specialty or other specialty with prereqs)	
CS 182W	Ethics, Public Policy, and Technological Change (for Computational Science specialty or other specialty with prereqs)	
EE 134	Introduction to Photonics (for Photonics specialty only. Not offered 2019-20)	
MATSCI 161	Energy Materials Laboratory (for Materials Science and Renewable Energy specialties)	
MATSCI 164	Electronic and Photonic Materials and Devices Laboratory (for Materials Science and Renewable Energy specialties)	
PHYSICS 107	Intermediate Physics Laboratory II: Experimental Techniques and Data Analysis (for Quantum Science & Engineering or other specialty)	
Quantum Mechanics		
Select one of the following sequences:		6-8
EE 222 & EE 223	Applied Quantum Mechanics I and Applied Quantum Mechanics II	
PHYSICS 130 & PHYSICS 131	Quantum Mechanics I and Quantum Mechanics II	
Thermodynamics and Statistical Mechanics		
PHYSICS 170 & PHYSICS 171	Thermodynamics, Kinetic Theory, and Statistical Mechanics I and Thermodynamics, Kinetic Theory, and Statistical Mechanics II	3-8
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:		9-12
Aerospace Physics:		
AA 203	Optimal and Learning-based Control	
AA 205	Rarefied and Ionized Gases	
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	
Biophysics:		
APPPHYS 205	Introduction to Biophysics	
BIO 132	Advanced Imaging Lab in Biophysics	
BIOE 42	Physical Biology	
BIOE 44	Fundamentals for Engineering Biology Lab	
BIOE 101	Systems Biology	
BIOE 103	Systems Physiology and Design	
BIOE 123	Bioengineering Systems Prototyping Lab	
BIOE 211	Biophysics of Multi-cellular Systems and Amorphous Computing	
BIOE 214	Representations and Algorithms for Computational Molecular Biology	
EE 169 or EE 369A	Introduction to Bioimaging 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 the Theory of Computation	
CS 161	Design and Analysis of Algorithms	
CS 205L	Continuous Mathematical Methods with an Emphasis on Machine Learning	
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	
Electromechanical System Design:		
ME 80	Mechanics of Materials	
ME 104	Mechanical Systems Design (formerly ME 112)	
ME 210 or EE 118	Introduction to Mechatronics Introduction to Mechatronics	
Materials Science:		
Any MATSCI courses numbered 151 to 199 (except 159Q) or PHYSICS 172		
Quantum Science & Engineering (See UGHB for further important details.)		
APPPHYS 203	Atoms, Fields and Photons	
APPPHYS 225	Probability and Quantum Mechanics	
APPPHYS 228	Quantum Hardware	
CS 254	Computational Complexity	
CS 269Q	Elements of Quantum Computer Programming	
EE 234	Photonics Laboratory	
EE 236C	Lasers	

EE 243	Semiconductor Optoelectronic Devices	
EE 340	Optical Micro- and Nano-Cavities	
PHYSICS 106	Experimental Methods in Quantum Physics	
PHYSICS 134	Advanced Topics in Quantum Mechanics	
PHYSICS 182	Quantum Gases	
PHYSICS 230	Graduate Quantum Mechanics I	
PHYSICS 231	Graduate Quantum Mechanics II	
STATS 376A	Information Theory	
Renewable Energy:		
CEE 176B	100% Clean, Renewable Energy and Storage for Everything	
EE 153	Power Electronics	
EE 155	Green Electronics	
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		
Total Units		93-119

[1] PHYSICS 67 Introduction to Laboratory Physics (2 units), recommended in place of PHYSICS 44 Electricity and Magnetism Lab

[2] The Engineering Fundamental courses are to be selected from the Basic Requirements 3 list. Fundamentals courses acceptable for the core program may also be used to satisfy the fundamentals requirement as long as 45 unduplicated units of Engineering are taken.

[3] Although not required, PHYSICS 59 (https://explorecourses.stanford.edu/search/?view=catalog&filter-coursestatus-Active=on&page=0&catalog=&academicYear=&q=physics59&collapse=) (Frontiers in Physics Research, 1 unit) and PHYSICS 91SI (https://explorecourses.stanford.edu/search/?view=catalog&filter-coursestatus-Active=on&page=0&catalog=&academicYear=&q=physics91si&collapse=) (Practical Computing for Scientists, 2 units) are highly recommended.

[4] A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

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

Honors Program

The School of Engineering offers a program leading to a Bachelor of Science in Engineering: Engineering Physics with Honors.

Honors Criteria

1. Minimum overall GPA of 3.5.
2. Independent research conducted at an advanced level with a faculty research adviser and documented in an honors thesis. The honors candidate must identify a faculty member who will serve as his or her honors research adviser and a second reader who will be asked to read the thesis and give feedback before endorsing the thesis. One of the two must be a member of the Academic Council and in the School of Engineering.

Application: The deadline to apply is November 1 in Autumn Quarter of the senior year. The application documents should be submitted to the Student Services Officer. Applications are reviewed by a subcommittee of the faculty advisers for Engineering Physics majors. Applicants and thesis advisers receive written notification when the application is approved. An application consists of three items:

1. One-page description of the research topic
2. The Honors Application form is available on Engineering Physics (https://ughb.stanford.edu/majors-minors/major-programs/engineering-physics-program/) page of the Undergraduate handbook. It must be signed by honors thesis adviser.
3. Unofficial Stanford transcript

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 November 1 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 199W Writing of Original Research for Engineers or in departmental courses such as AA 190 Directed Research and Writing in Aero/Astro or ME 191H Honors Research.
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 a pdf of the thesis, including the signature page signed by both readers, 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 somewhat more flexibility in the curriculum than the Civil Engineering degree program, and requires fewer units. 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.

Degree Requirements

		Units
Mathematics and Science		
See Basic Requirement 1 and 2 [1]		36
Technology in Society (TiS)		
One 3-5 unit course required, course chosen must be on the SoE Approved Courses list at <ughb.stanford.edu> the year taken; see Basic Requirement 4 [4]		3-5
Engineering Fundamentals		
Two courses minimum (see Basic Requirement 3), including:		
CS 106A	Programming Methodology	5
(or CS 106X)		
ENGR 14	Intro to Solid Mechanics	3
Fundamental Tools/Skills [2]		**9**
in visual, oral/written communication, and modeling/analysis		
Specialty Courses, in either		**40**
Coastal environments (see below)		
or Freshwater environments (see below)		
or Urban environments (see below)		
Total Units		**96-98**

1. Math must include CME 100 Vector Calculus for Engineers (or MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications), and either a Probability/Statistics course or CME 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 31M Chemical Principles: From Molecules to Solids (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, DESINST 270 Visual Design Fundamentals, 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, CEE 102W Technical and Professional Communication, ENGR 202W Technical Communication, CEE 151 Negotiation, EARTHSYS 191 Concepts in Environmental Communication or ORALCOMM 117 The Art of Effective Speaking;
    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 Modeling for Design & Construction (online only), CEE 146S Engineering Economics and Sustainability (online only), CEE 118X Shaping the Future of the Bay Area, 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 102 , EARTHSYS 140 , EARTHSYS 142 Remote Sensing of Land, EARTHSYS 144 Fundamentals of Geographic Information Science (GIS), or ESS 227 Decision Science for Environmental Threats
3. A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.
4. Basic Requirement 4: Technology in Society (TiS) requirement.

Urban Environments Focus Area (40 units)

		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
or		
CEE 176B	100% Clean, Renewable Energy and Storage for Everything	3-4
Electives (at least two of the 4 areas below must be included with at least 3 units from 2nd area)		
Building Systems		
CEE 102A	Legal / Ethical Principles in Design, Construction, Project Delivery	3
CEE 120B	Advanced Building Modeling Workshop	2-4
CEE 130	Architectural Design: 3-D Modeling, Methodology, and Process	5
or		
CEE 131C	How Buildings are Made -- Materiality and Construction Methods	4
CEE 156	Building Systems Design & Analysis	4
Energy Systems		
CEE 107A	Understanding Energy (or CEE 107S, Sum. 3-4 units)	4-5
CEE 176B	100% Clean, Renewable Energy and Storage for Everything ((if not counted as req'd course))	3-4
ENERGY 104	Sustainable Energy for 9 Billion	3
CEE 173S	Electricity Economics	3
or		
ENERGY 171	Energy Infrastructure, Technology and Economics	3
or		
ENERGY 191	Optimization of Energy Systems	3-4
Water Systems		
CEE 166A	Watershed Hydrologic Processes and Models	4
CEE 166B	Water Resources and Hazards	4
CEE 170	Aquatic and Organic Chemistry for Environmental Engineering	3
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 136	Planning Calif: the Intersection of Climate, Land Use, Transportation & the Economy	3
or		
CEE 275D	Environmental Policy Analysis	3-4
or		
CEE 273B	The Business of Water	2
CEE 177L	Smart Cities & Communities	3
URBANST 113	Introduction to Urban Design: Contemporary Urban Design in Theory and Practice	5
or		
URBANST 164	Sustainable Cities	4-5
or		
URBANST 165	(alt. years)	4-5
ME 267	Ethics and Equity in Transportation Systems	3
Capstone (one class required)		
CEE 131D	Urban Design Studio ((or CEE 131E))	5

CEE 141A	Infrastructure Project Development	3
CEE 141B	Infrastructure Project Delivery	3
CEE 226E	Techniques and Methods for Decarbonized and Energy Efficient Building Design	2-3
CEE 218Y	Shaping the Future of the Bay Area	3-5
CEE 218Z	Shaping the Future of the Bay Area	3-5
CEE 243	Intro to Urban Sys Engrg	3
CEE 265F	Environmental Governance and Climate Resilience	3
CEE 199	Undergraduate Research in Civil and Environmental Engineering	3-4

Freshwater Environments Focus Area (40 units)

		Units
Required		
CEE 70	Environmental Science and Technology	3
CEE 101B	Mechanics of Fluids	4
CEE 177	Aquatic Chemistry and Biology ((or CEE 170))	4
CEE 166A	Watershed Hydrologic Processes and Models	4
or		
CEE 174A	Providing Safe Water for the Developing and Developed World	3
or		
CEE 162E	Rivers, Streams, and Canals	3
Electives		
CEE 162E	Rivers, Streams, and Canals (if not counted as a required course)	3
CEE 162F	Coastal Processes	3
CEE 166A	Watershed Hydrologic Processes and Models (if not counted as a required course)	4
CEE 166B	Water Resources and Hazards	4
CEE 136	Planning Calif: the Intersection of Climate, Land Use, Transportation & the Economy	3
or		
CEE 275D	Environmental Policy Analysis	3-4
or		
CEE 273B	The Business of Water	2
CEE 174A	Providing Safe Water for the Developing and Developed World ((prereq: CHEM 31B) (if not counted as a req'd course))	3
CEE 174B	Wastewater Treatment: From Disposal to Resource Recovery ((prereq: CEE 174A))	3
CEE 177L	Smart Cities & Communities	3
or		
CEE 260D	Remote Sensing of Hydrology (prerequisite CS 106A)	3
CEE 265A	Resilience, Sustainability and Water Resources Development (offered occasionally)	3
CEE 265D	Water and Sanitation in Developing Countries	3
BIOHOPK 150H	Ecological Mechanics (alternate years)	3
Capstone (1 class required)		
CEE 141A	Infrastructure Project Development (recommended prerequisite: CEE 136)	3
CEE 218Y	Shaping the Future of the Bay Area	3-5
CEE 218Z	Shaping the Future of the Bay Area	3-5
CEE 199	Undergraduate Research in Civil and Environmental Engineering (must petition CEE UG Committee for approval, prior to enrollment; must have completed at least 6 focus area classes, excluding Breadth)	3-4

Coastal Environments Focus Area (40 units)

		Units
Required		
CEE 70	Environmental Science and Technology	3
CEE 101B	Mechanics of Fluids	4
And two of the following 4 classes:		
CEE 162F	Coastal Processes	3
CEE 162D	Introduction to Physical Oceanography	4
CEE 162I	Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation	3
CEE 175A	California Coast: Science, Policy, and Law	3-4
Electives		
CEE 162D	Introduction to Physical Oceanography (if not counted as a required class)	4
CEE 162F	Coastal Processes (if not counted as a required class)	3
CEE 162I	Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation (if not counted as a req'd class)	3
CEE 166A	Watershed Hydrologic Processes and Models	4
CEE 136	Planning Calif: the Intersection of Climate, Land Use, Transportation & the Economy	3
or		
CEE 275D	Environmental Policy Analysis	3-4
or		
CEE 273B	The Business of Water	2
CEE 174A	Providing Safe Water for the Developing and Developed World	3
CEE 174B	Wastewater Treatment: From Disposal to Resource Recovery	3
CEE 175A	California Coast: Science, Policy, and Law	3-4
CEE 177	Aquatic Chemistry and Biology	4
or CEE 170	Aquatic and Organic Chemistry for Environmental Engineering	
CEE 272	Coastal Contaminants	3-4
BIOHOPK 150H	Ecological Mechanics	3
BIO 30	Ecology for Everyone	4
or		
BIO 81	Introduction to Ecology	4
or		
BIOHOPK 81	Introduction to Ecology	4
or		
EARTHSYS 116	Ecology of the Hawaiian Islands	4
or		
OSPAUSTL 32	Coastal Ecosystems	3
or		
OSPGEN 53		2
or		
OSPSANTG 85	Marine Ecology of Chile and the South Pacific	5
DESINST 250	Oceans by Design	3

ESS 8	The Oceans: An Introduction to the Marine Environment	4
or		
ESS 240	Advanced Oceanography	3
or		
BIOHOPK 182H	Stanford at Sea (Oceanography portion - only 4 units may count)	4
EARTHSYS 141	Remote Sensing of the Oceans	3-4
EARTHSYS 151	Biological Oceanography	3-4
to be taken concurrently with		
EARTHSYS 152	Marine Chemistry	3-4
Capstone (1 class required)		
CEE 141A	Infrastructure Project Development	3
CEE 218Y	Shaping the Future of the Bay Area	3-5
CEE 218Z	Shaping the Future of the Bay Area	3-5
CEE 199	Undergraduate Research in Civil and Environmental Engineering (must petition CEE UG Committee for approval, prior to enrollment; must have completed at least 6 focus area classes, excluding Breadth)	3-4

Honors Program

This program leads to a B.S. with honors for undergraduates majoring in Civil Engineering or in Environmental Systems Engineering. It is designed to encourage qualified students to undertake a more intensive study of civil and environmental engineering than is required for the normal majors through a substantial, independent research project.

The program involves an in-depth research study in an area proposed to and agreed to by a Department of Civil and Environmental Engineering faculty adviser and completion of a thesis of high quality. A written proposal for the research to be undertaken must be submitted and approved by the faculty advisor in the fourth quarter prior to graduation. At the time of application, the student must have an overall grade point average (GPA) of at least 3.3 for course work at Stanford; this GPA must be maintained to graduation. The thesis is supervised by a CEE faculty adviser and must involve input from the School of Engineering writing program by means of ENGR 202S Directed Writing Projects or ENGR 199W Writing of Original Research for Engineers. The written thesis must be approved by the thesis adviser. Students are encouraged to present their results in a seminar for faculty and students. Up to 10 units of CEE 199H Undergraduate Honors Thesis, may be taken to support the research and writing (not to duplicate ENGR 202S or ENGR 199W). These units are beyond the normal Civil Engineering or Environmental Systems Engineering major program requirements.

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

COVID-19-Related Degree Requirement Changes

The IDMEN Program counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that otherwise require a letter grade. Students are encouraged to enroll in the letter grade option for degree requirements whenever possible.

Individually Designed Major in Engineering (IDMEN)

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 under the Bachelor's tab); science (17 units minimum, see Basic Requirement 2); 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. Neither Introductory Seminar (IntroSem) nor Sophomore College (SC) courses may count toward the major. 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 an IDMEN 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 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 (Autumn, Winter, and Spring). Planning forms may be obtained from the Handbook for Undergraduate Engineering Programs at http://ughb.stanford.edu (http://ughb.stanford.edu/). Completed proposals should be submitted to Darlene Lazar in the Office of Student Affairs, Huang Engineering Center, Suite 135 or scan to dlazar@stanford.edu. An IDMEN cannot be a student's secondary major.

Honors in Individually Designed Major in Engineering

Qualified IDMEN students may pursue a Bachelor's degree with Honors (IDMEN-BSH) following the general guidelines outlined below, and consulting with advisers to set a topic and any further parameters regarding directed reading or research, special honors seminars, and the format of the honors work. The honors thesis, and any course work associated with the honors degree, is above and beyond the scope of the major itself and cannot be counted as part of the basic IDMEN-BS requirements.

1. The student must submit a letter applying for the honors option endorsed by the student' primary adviser and honors adviser; the letter should be submitted to the Office of Student Affairs in 135 Huang no later than mid-October of the senior year.
2. The IDMEN honors adviser may require course work beyond what is required for the BS without honors.
3. The student must maintain a GPA of at least 3.5.
4. The student must complete an honors thesis or project. The manner of evaluating the work will be set by the honors adviser and a second reader, one of whom must be a member of the Academic Council in the School of Engineering. The deadline to submit the thesis or project will be decided by the honors or program adviser but should be set by mid-May at latest.
5. 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 adviser.
6. A a pdf of the thesis, including the signature page signed by both readers, must be submitted to the Office of Student Affairs by the end of the second week of May. Students will be sent email instructions on how to archive a permanent electronic copy in the Terman Engineering library.

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

		Units
Mathematics and Science		**43**
Up to ten units of AP/IB Calculus, MATH 19, 20, and/or 21. [1]		10
All required; see SoE Basic Requirements 1 and 2		22
CME 100	Vector Calculus for Engineers	
or MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
ENGR 108	Introduction to Matrix Methods (formerly CME 103)	
MS&E 120	Introduction to Probability	
MS&E 121	Introduction to Stochastic Modeling	
MS&E 125	Introduction to Applied Statistics	
Select two of the following: [2]		8
CHEM 31B	Chemical Principles II	
CHEM 33	Structure and Reactivity of Organic Molecules	
PHYSICS 41	Mechanics	
or PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 43	Electricity and Magnetism	
or PHYSICS 23	Electricity, Magnetism, and Optics	
BIO 81	Introduction to Ecology	
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 85	Evolution	
BIO 86	Cell Biology	
Math, Science, or Statistics Elective from SoE approved lists. [3]		3
Technology in Society [4]		**3**
Select one of the following; see SoE Basic Requirement 4		
AA 252	Techniques of Failure Analysis	
BIOE 131	Ethics in Bioengineering	
COMM 120W	The Rise of Digital Culture	
CS 181	Computers, Ethics, and Public Policy	
CS 182	Ethics, Public Policy, and Technological Change	
ENGR 117	Expanding Engineering Limits: Culture, Diversity, and Equity	
ENGR 148	Principled Entrepreneurial Decisions	
ME 267	Ethics and Equity in Transportation Systems	
MS&E 193	Technology and National Security: Past, Present, and Future	
POLISCI 114S	International Security in a Changing World	
STS 1	The Public Life of Science and Technology	
Engineering Fundamentals [5]		**12**
Three required; see SoE Basic Requirement 3		
CS 106A	Programming Methodology [6]	
MS&E 111	Introduction to Optimization	
or MS&E 111X	Introduction to Optimization (Accelerated)	
Select one of the following:		
ENGR 10	Introduction to Engineering Analysis	
ENGR 14	Intro to Solid Mechanics	
ENGR 15	Dynamics	
ENGR 20	Introduction to Chemical Engineering	
ENGR 21	Engineering of Systems	
ENGR 40A	Introductory Electronics	
ENGR 40M	An Intro to Making: What is EE	

ENGR 42	Introduction to Electromagnetics and Its Applications	
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	
ENGR 50E	Introduction to Materials Science, Energy Emphasis	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	
ENGR 80	Introduction to Bioengineering (Engineering Living Matter)	
ENGR 90	Environmental Science and Technology	
Engineering Depth [5]		**52**
Core Courses (all six required)		28
CS 106B	Programming Abstractions	
ECON 1	Principles of Economics	
ECON 50	Economic Analysis I	
MS&E 108	Senior Project (WIM)	
MS&E 140	Accounting for Managers and Entrepreneurs	
MS&E 180	Organizations: Theory and Management	
Area Courses (eight required; see below)		24

Depth Areas

Choose eight courses; four courses from a primary area and two courses from each of the other two areas.

Finance and Decision Area	
Students choosing F&D as their primary area must take at least two of ECON 51 (or MS&E 241), MS&E 145 (or 245A), and MS&E 152 (or 252).	
Introductory (no prerequisites)	
ECON 143	Finance, Corporations, and Society
MS&E 152	Introduction to Decision Analysis
Intermediate (has prerequisites and/or appropriate for juniors and seniors)	
MS&E 145	Introduction to Finance and Investment
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 241	Economic Analysis
MS&E 245A	Investment Science
MS&E 245B	Advanced Investment Science
MS&E 246	Financial Risk Analytics
MS&E 250A	Engineering Risk Analysis
MS&E 250B	Project Course in Engineering Risk Analysis
Operations and Analytics Area	
Students choosing O&A as their primary area may also include one of CS 161, CS 229, or 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	Fundamentals of Data Science: Prediction, Inference, Causality
MS&E 231	Introduction to Computational Social Science
MS&E 251	Introduction to Stochastic Control with Applications
Applications	
MS&E 130	Information Networks and Services
MS&E 230	Incentives and Algorithms
MS&E 232	Introduction to Game Theory
MS&E 232H	Introduction to Game Theory
MS&E 234	Data Privacy and Ethics
MS&E 235	Network Structure and Epidemics
MS&E 260	Introduction to Operations Management
MS&E 263	Healthcare Operations Management
MS&E 267	Service Operations and the Design of Marketplaces
MS&E 330	Law, Order, & Algorithms
MS&E 463	Healthcare Systems Design
Organizations, Technology, and Policy Area	
Introductory (no prerequisites)	
ENGR 148	Principled Entrepreneurial Decisions
MS&E 193	Technology and National Security: Past, Present, and Future
Advanced (has prerequisites and/or appropriate for juniors and seniors)	
BIOE 177	Inventing the Future
ENGR 145	Technology Entrepreneurship
MS&E 175	Innovation, Creativity, and Change
MS&E 182A	Leading Organizational Change
MS&E 182B	Leading Organizational Change II
MS&E 184	Future of Work: Issues in Organizational Learning and Design
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

1. Students without AP/IB mathematics credit, who skip MATH 19, 20, and/or 21, may petition to waive up to 10 units of math.
2. AP/IB credit for Chemistry and Physics may be used.
3. Electives must come from the School of Engineering approved list or PSYCH 50 Introduction to Cognitive Neuroscience, may not repeat material from any other requirement, and may not be used to also satisfy an engineering fundamentals or depth requirement. AP/IB credit for Chemistry and Physics may be used if not used above.
4. A course may only be counted towards one requirement; courses used to satisfy the TiS requirement may not be used to also satisfy a depth area requirement.
5. Engineering fundamentals plus engineering depth must total a minimum of 60 units. Recommended engineering fundamentals are E25B, E25E, E40A, E40M, and E80. MS&E majors may not use E60, or E70B as engineering fundamentals.
6. Students may petition to waive CS 106A Programming Methodology after completion of CS 106B Programming Abstraction, and/or ECON 1 Principles of Economics after completion of ECON 50 Economic Analysis I.
7. All courses taken for the major must be taken for a letter grade. Minimum combined GPA for all courses in Engineering Topics (Engineering Fundamentals and Depth courses) is 2.0.

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

Bachelor of Science in Materials Science and Engineering (MSE/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.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to demonstrate the ability to:

1. Apply the knowledge of mathematics, science, and engineering to assess and synthesize scientific evidence, concepts, theories, and experimental data relating to the natural or physical world.
2. Extend students' knowledge of the natural or physical world beyond that obtained from secondary education by refining their powers of scientific observation, the essential process by which data is gained for subsequent analysis.
3. Design and conduct experiments, as well as understand and utilize the scientific method in formulating hypotheses and designing experiments to test hypotheses.
4. Function on multidisciplinary teams, while communicating effectively.
5. Identify, formulate, and solve engineering issues by applying conceptual thinking to solve certain problems, bypassing calculations or rote learning and relying on the fundamental meaning behind laws of nature.
6. Understand professional and ethical responsibility.
7. Understand the impact of engineering solutions in a global, economic, environmental, and societal context.
8. Demonstrate a working knowledge of contemporary issues.
9. Recognize the need for, and engage in, lifelong learning.
10. Apply the techniques, skills, and modern engineering tools necessary for engineering practice.
11. Transition from engineering concepts and theory to real engineering applications and understanding the distinction between scientific evidence and theory, inductive and deductive reasoning, and understanding the role of each in scientific inquiry.

Degree Requirements

		Units
Mathematics		
20 units minimum		
Select one of the following:		5
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
CME 100/ ENGR 154	Vector Calculus for Engineers	
Select one of the following:		5
MATH 52	Integral Calculus of Several Variables	
CME 104/ ENGR 155B	Linear Algebra and Partial Differential Equations for Engineers	
Select one of the following:		5
MATH 53	Ordinary Differential Equations with Linear Algebra	
CME 102/ ENGR 155A	Ordinary Differential Equations for Engineers	
One additional course [1]		5
Science		
20 units minimum		
Must include a full year (15 units) of calculus-based physics or chemistry, with one quarter of study (5 units) in the other subject. [2]		20
Technology in Society		
One course minimum [3]		3-5
Engineering Fundamentals		
Two courses minimum		
Select one of the following:		4
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis [4]	
ENGR 50E	Introduction to Materials Science, Energy Emphasis [4]	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis [4]	
At least one additional courses [4]		3-5
Department Requirements: MSE Fundamentals, Depth & Focus Areas		
Materials Science Fundamentals: All of the following courses:		16
MATSCI 142	Quantum Mechanics of Nanoscale Materials	
MATSCI 143	Materials Structure and Characterization	
MATSCI 144	Thermodynamic Evaluation of Green Energy Technologies	
MATSCI 145	Kinetics of Materials Synthesis	
Two of the following courses:		8
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	
Materials Science & Engineering Depth		**16**
Four laboratory courses for Sixteen units; Four units must be WIM		
MATSCI 160	Nanomaterials Laboratory	
MATSCI 161	Energy Materials Laboratory (WIM)	
MATSCI 162	X-Ray Diffraction Laboratory	
MATSCI 163	Mechanical Behavior Laboratory	
MATSCI 164	Electronic and Photonic Materials and Devices Laboratory (WIM)	
MATSCI 165	Nanoscale Materials Physics Computation Laboratory	
MATSCI 166	Data Science and Machine Learning Approaches in Chemical and Materials Engineering	
Focus Area Options [5, 6]		13
Total Units		103-107

1. See a list of approved math courses at ughb.stanford.edu (https://ughb.stanford.edu/courses-and-planning/approved-courses/). AP/IB Credit (https://ughb.stanford.edu/petitions/ap-credit/) may also be used to meet the 20 units minimum, but cannot replace the three required courses.
2. See a list of approved science courses at ughb.stanford.edu (https://ughb.stanford.edu/courses-and-planning/approved-courses/). AP/IB Credit (https://ughb.stanford.edu/petitions/ap-credit/)may also be used to meet the 20 units minimum in some cases; see the AP chart in the Bulletin or check with the School of Engineering in 135 Huang Engineering Center.
3. See a list of approved Technology in Society courses at ughb.stanford.edu (https://ughb.stanford.edu/courses-and-planning/approved-courses/). Course chosen must be on the approved list the year taken.
4. See a list of approved Engineering Fundamentals Courses at ugh.stanford.edu. Course chosen must be on the approved list the year taken.
5. Focus Area Options: 13 units from one of the following Focus Area Options below. If the focus area contains only 12 units, but the combined unit total in major (SoE Fundamentals, MSE Fundamentals, MSE Depth and the Focus Area) is at 60 or more, it will be allowed and no petition is necessary.
6. The self-defined focus area option requires additional approval; program deviation forms for this option can be found on the MSE website (https://mse.stanford.edu/student-resources/forms/undergraduate/).
7. A course may only be counted towards one requirement; it may not be double-counted. For the 2020-2021 academic year, all courses taken for the major may be taken for either a letter grade (if offered by the instructor) or for CR and count towards degree requirements. Minimum Combined GPA for all courses in Engineering Topics (Engineering Fundamentals and Depth courses) is 2.0.

Focus Area Options (Four courses for a minimum of 13 units; select from one of the ten Focus Areas.)

Bioengineering	
BIOE 80	Introduction to Bioengineering (Engineering Living Matter)
BIOE 220	Introduction to Imaging and Image-based Human Anatomy
BIOE 260	Tissue Engineering
BIOE 281	Biomechanics of Movement
BIOE 381	Orthopaedic Bioengineering
MATSCI 158	Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life
MATSCI 190	Organic and Biological Materials
MATSCI 225	Biochips and Medical Imaging
MATSCI 380	Nano-Biotechnology
MATSCI 381	Biomaterials in Regenerative Medicine
MATSCI 384	Materials Advances for Neurotechnology: Materials Meet the Mind
Chemical Engineering	
CHEM 171	Foundations of Physical Chemistry
CHEMENG 130	
CHEMENG 140	Micro and Nanoscale Fabrication Engineering
CHEMENG 150	Biochemical Engineering
MATSCI 158	Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life
Chemistry	
CHEM 151	Inorganic Chemistry I
CHEM 153	Inorganic Chemistry II
CHEM 171	Foundations of Physical Chemistry
CHEM 173	Physical Chemistry II
CHEM 175	Physical Chemistry III
CHEM 181	Biochemistry I
CHEM 183	Biochemistry II
CHEM 185	Biophysical Chemistry
Electronics & Photonics	
EE 101A	Circuits I
EE 101B	Circuits II
EE 102A	Signal Processing and Linear Systems I
EE 102B	Signal Processing and Linear Systems II
EE 116	Semiconductor Devices for Energy and Electronics
EE 134	Introduction to Photonics
EE 142	Engineering Electromagnetics (Formerly EE 141)
EE 155	Green Electronics
ME 210	Introduction to Mechatronics
MATSCI 343	Organic Semiconductors for Electronics and Photonics
MATSCI 346	Nanophotonics
Energy Technology	
EE 293B	Fundamentals of Energy Processes
EE 155	Green Electronics
CEE 107A	Understanding Energy
EE 293B	Fundamentals of Energy Processes
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution
MATSCI 302	Solar Cells
MATSCI 303	Principles, Materials and Devices of Batteries
ME 262	Physics of Wind Energy
Materials Characterization Techniques	
MATSCI 320	Nanocharacterization of Materials

MATSCI 321	Transmission Electron Microscopy
MATSCI 322	Transmission Electron Microscopy Laboratory
MATSCI 323	Thin Film and Interface Microanalysis
MATSCI 326	X-Ray Science and Techniques
CHEMENG 345	Fundamentals and Applications of Spectroscopy
BIO 232	Advanced Imaging Lab in Biophysics
APPPHYS 201	Electrons and Photons (PHOTON 201)
Mechanical Behavior & Design	
AA 240	Analysis of Structures
AA 256	Mechanics of Composites
MATSCI 198	Mechanical Properties of Materials
MATSCI 241	Mechanical Behavior of Nanomaterials
MATSCI 358	Fracture and Fatigue of Materials and Thin Film Structures
ME 80	Mechanics of Materials
or CEE 101A	Mechanics of Materials
ME 203	Design and Manufacturing
Nanoscience	
ENGR 240	Introduction to Micro and Nano Electromechanical Systems
MATSCI 241	Mechanical Behavior of Nanomaterials
MATSCI 316	Nanoscale Science, Engineering, and Technology
MATSCI 320	Nanocharacterization of Materials
MATSCI 346	Nanophotonics
MATSCI 347	Magnetic materials in nanotechnology, sensing, and energy
MATSCI 380	Nano-Biotechnology
Physics	
PHYSICS 70	Foundations of Modern Physics
PHYSICS 110	Advanced Mechanics
PHYSICS 120	Intermediate Electricity and Magnetism I
PHYSICS 121	Intermediate Electricity and Magnetism II
PHYSICS 130	Quantum Mechanics I
PHYSICS 131	Quantum Mechanics II
PHYSICS 134	Advanced Topics in Quantum Mechanics
PHYSICS 170	Thermodynamics, Kinetic Theory, and Statistical Mechanics I
PHYSICS 171	Thermodynamics, Kinetic Theory, and Statistical Mechanics II
PHYSICS 172	Solid State Physics
Self-Defined Option	
Petition for a self-defined cohesive program. [7]	

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

Honors Program

The Materials Science and Engineering honors program offers an opportunity for undergraduate Materials Science and Engineering majors with a GPA of 3.5 or higher to pursue independent research at an advanced level, supported by a faculty advisor and graduate student mentors. The main requirements are as follows:

1. Application to the honors program (must be pre-approved by faculty advisor)
2. Enrollment in MATSCI 150 Undergraduate Research and participation in an independent research project over three sequential full quarters
3. Completion of a faculty-approved thesis
4. Participation in either a poster or oral presentation of thesis work at a Stanford Symposium/event or, at your faculty advisor's discretion, in a comparable public event.

Since this requires three full quarters of research in addition to a final written thesis and presentation following completion of the work, students must apply to the program no less than four quarters prior to their planned graduation date. Materials Science and Engineering majors pursuing a typical four-year graduation timeline should meet with student services no later than the Winter Quarter of their junior year to receive information on the application process.

All requirements for the honors program are in addition to the normal undergraduate program requirements.

To apply to the MATSCI Honors program

- Have an overall GPA of 3.5 or higher (as calculated on the unofficial transcript) prior to application.
- Seek out a faculty research advisor and agree on a proposed research topic. If the research advisor is not a member of the MSE faculty or not a member of the School of Engineering Academic Council, students must have a second advisor who fulfills these requirements.
- Compose a brief (less than 1 page) summary of proposed research, including a proposed title, and submit along with unofficial transcript and signed application/faculty endorsement (https://mse.stanford.edu/student-resources/forms/undergraduate/).
- Submit application to MATSCI student services (Durand 113) at least four quarters prior to planned graduation.

To complete the MATSCI Honors program

- Overall GPA of 3.5 or higher (as calculated on the unofficial transcript) at graduation.
- Complete at least three quarters of research with a minimum of 9 units of MATSCI 150 (students may petition out of unit requirement with faculty adviser approval). All quarters must focus on the same topic. Maintain the same faculty adviser throughout, if possible.
- Present either a poster or oral presentation of thesis work at a Stanford event or, at the faculty advisor's discretion, in a comparable public event.
- Submit final drafts of an honors thesis to two faculty readers (one must be your research advisor, and one must be an MSE faculty member/SoE Academic Council member) at least one quarter prior to graduation. Both must approve the thesis by completing the signature page (https://mse.stanford.edu/student-resources/forms/undergraduate/).
- Submit to MATSCI student services (Durand 113) one copy of the honors thesis and signed signature page (in electronic or physical form) at least one quarter prior to graduation.

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, microelectromechanical systems, biomechanical engineering, energy science and technology, propulsion, sensing and control, nano- and micro- mechanics, 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.

Core Requirements

		Units
Mathematics		
24 units minimum; see Basic Requirement 1 [1]		
CME 102/ENGR 155A	Ordinary Differential Equations for Engineers	5
or MATH 53	Ordinary Differential Equations with Linear Algebra	
Select one of the following:		3-5
CME 106/ ENGR 155C	Introduction to Probability and Statistics for Engineers	
STATS 110	Statistical Methods in Engineering and the Physical Sciences	
STATS 116	Theory of Probability	
Plus additional courses to total min. 24		
Science		
20 units minimum; see Basic Requirement 2 [1]		
Plus addtional required courses [1]		
CHEM 31M	Chemical Principles: From Molecules to Solids	5
Technology in Society		
One course required; TIS courses should be selected from AA 252, BIOE 131, COMM 120W, CS 181, ENGR 131, HUMBIO 174, ME 267, or MSE 193.		3-5
Engineering Fundamentals		
Two courses minimum; see Basic Requirement 3		
ENGR 14	Intro to Solid Mechanics	3
CS 106A	Programming Methodology	5
or CS 106B	Programming Abstractions	
Engineering Core		
Minimum of 68 Engineering Science and Design ABET units; see Basic Requirement 5		
ME 1	Introduction to Mechanical Engineering	3
ENGR 15	Dynamics	3
ME 80	Mechanics of Materials	3
ME 30	Engineering Thermodynamics	3
ME 70	Introductory Fluids Engineering	3
ME 102	Foundations of Product Realization	3
ME 103	Product Realization: Design and Making	4
ME 104	Mechanical Systems Design	4
ME 131	Heat Transfer	4
ME 123	Computational Engineering	4
ME 170A	Mechanical Engineering Design- Integrating Context with Engineering [2,3]	4
ME 170B	Mechanical Engineering Design: Integrating Context with Engineering [2,3]	4

Core Concentrations and Concentration Electives

In addition to completing core requirements, students must choose one of the concentrations paths below. In addition to their concentration specific 3-courses, students select 2-3 additional courses such that the combination adds up to a minimum of 18 units. One of these additional courses must be from technical electives associated with the student's selected concentration. The other 1-2 courses could come from either technical electives from the student's selected concentration or any other concentration and its associated technical electives. Up to 3 units of ME 191 Engineering Problems and Experimental Investigation may be petitioned to count as technical elective.

For students choosing the Materials and Structures concentration path, in addition to the 2 concentration-specific courses, students must select at least 2 courses from the Materials and Structures electives, in addition to courses from other concentrations, as technical electives.

		Units
Dynamic Systems and Controls Concentration		
ME 161	Dynamic Systems, Vibrations and Control	3
ENGR 105	Feedback Control Design	3
Pick one of:		
ME 227	Vehicle Dynamics and Control	3
ME 327	Design and Control of Haptic Systems (not offered AY21)	3
Dynamic Systems and Controls Electives		
ENGR 205	Introduction to Control Design Techniques	3
ME 210	Introduction to Mechatronics (not offered AY21)	4
ME 220	Introduction to Sensors	4
ME 331A	Advanced Dynamics & Computation (not offered AY21)	3
ME 485	Modeling and Simulation of Human Movement	3
Pick one, if not used in concentration already:		
ME 227	Vehicle Dynamics and Control	3
ME 327	Design and Control of Haptic Systems (not offered AY21)	3

		Units
Materials and Structures Concentration		
ME 149	Mechanical Measurements	3
ME 152	Material Behaviors and Failure Prediction	3
Materials and Structures Electives		
(2 M&S electives required for students in M&S concentration)		
AA 240	Analysis of Structures	3
MATSCI 198	Mechanical Properties of Materials	3-4
ME 234	Introduction to Neuromechanics (not offered AY21)	3
ME 241	Mechanical Behavior of Nanomaterials (not offered AY21)	3
ME 281	Biomechanics of Movement	3
ME 283	Introduction to Biomechanics and Mechanobiology (not offered AY21)	3
ME 287	Mechanics of Biological Tissues (not offered AY21)	4
ME 331A	Advanced Dynamics & Computation (not offered AY21)	3
ME 335A	Finite Element Analysis	3
ME 338	Continuum Mechanics	3
ME 339	Introduction to parallel computing using MPI, openMP, and CUDA	3
ME 345	Fatigue Design and Analysis	3
ME 348	Experimental Stress Analysis	3

		Units
Product Realization Concentration		
ME 127	Design for Additive Manufacturing	3
ME 128	Computer-Aided Product Realization	3

ME 129	Manufacturing Processes and Design (offered AY 19-20)	3
Product Realization Electives		
ENGR 110	Perspectives in Assistive Technology (ENGR 110)	1-2
ENGR 240	Introduction to Micro and Nano Electromechanical Systems	3
ME 181	Deliverables: A Mechanical Engineering Design Practicum	3
CME 106	Introduction to Probability and Statistics for Engineers	4
ME 210	Introduction to Mechatronics (not offered AY21)	4
ME 263	The Chair	3-4
or ME 298	Silversmithing and Design	
ME 309	(not offered AY21)	3
ME 324	Precision Engineering	4

		Units
Thermo, Fluids, and Heat Transfer Concentration		
ME 149	Mechanical Measurements	3
ME 132	Intermediate Thermodynamics	4
ME 133	Intermediate Fluid Mechanics	3
Thermo, Fluids, and Heat Transfer Electives		
ME 257	Gas-Turbine Design Analysis (not offered AY21)	3
ME 351A	Fluid Mechanics	3
ME 351B	Fluid Mechanics	3
ME 352B	Fundamentals of Heat Conduction (not offered AY21)	3
ME 352C	Convective Heat Transfer (not offered AY21)	3
ME 352D	Nanoscale heat, mass and charge transport	3
ME 362A	Physical Gas Dynamics	3
ME 370A	Energy Systems I: Thermodynamics	3
ME 370B	Energy Systems II: Modeling and Advanced Concepts	4
ME 371	Combustion Fundamentals	3
AA 283	Aircraft and Rocket Propulsion	3

1 Math and science must total 45 units.

- Math: 24 units required and must include a course in differential equations (CME 102 Ordinary Differential Equations for Engineers or MATH 53 Ordinary Differential Equations with Linear Algebra; one of these required) and calculus-based Statistics (CME 106 Introduction to Probability and Statistics for Engineers or STATS 110 Statistical Methods in Engineering and the Physical Sciences or STATS 116 is required.
- Science: 20 units minimum and requires courses in calculus-based Physics and Chemistry, with at least a full year (3 courses) in one or the other. CHEM 31A Chemical Principles I/CHEM 31B Chemical Principles II are considered one course because they cover the same material as CHEM 31M but at a slower pace. CHEM 31M is recommended.

2 ME 170A and ME 170B fulfill the WIM requirement. In AY 2020-21, the same grading basis applies to both ME 170A and ME 170B, and cannot be changed after week 8 of enrollment in ME 170A.

3 ME 170A (http://exploredegrees.stanford.edu/search/?P=ME%20170A) and ME 170B (http://exploredegrees.stanford.edu/search/?P=ME%20170B) are a two quarter Capstone Design Sequence and must be taken in consecutive quarters.

4 A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum combined GPA for all courses in Engineering Topics (Engineering Fundamentals and Depth courses) is 2.0.

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

BSME 1.0 Notes

Those students (primarily seniors) who are completing BSME 1.0 from AY 2017-2018 or earlier should refer to bulletins from the academic year that corresponds with their program sheet.

Honors Program in Mechanical Engineering

The Department of Mechanical Engineering offers a program leading to a B.S. in Mechanical Engineering with honors. This program offers a unique opportunity for qualified undergraduate engineering majors to conduct independent study and research at an advanced level with a faculty mentor.

Mechanical Engineering majors who have a grade point average (GPA) of 3.5 or higher in the major may apply for the honors program. Students who meet the eligibility requirement and wish to be considered for the honors program must submit a written application to the Mechanical Engineering student services office no later than the second week of Autumn Quarter in the senior year. The application to enter the program can be obtained from the ME student services office, and must contain a one-page statement describing the research topic and include an unofficial Stanford transcript. In addition, the application must be approved by a Mechanical Engineering faculty member who agrees to serve as the thesis adviser for the project. Thesis advisers must be members of Stanford's Academic Council.

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

1. Maintain the 3.5 GPA required for admission to the honors program.
2. Submit a completed thesis draft to the adviser by the 3rd week of the quarter they intend to confer. Further revisions and final endorsement by the adviser are to be finished by week 6, when two bound copies are to be submitted to the Mechanical Engineering student services office.
3. Present the thesis at the Mechanical Engineering Poster Session held in mid-April. If the poster session is not offered or the student does not confer in the spring, an alternative presentation will be approved on a case by case basis with advisor and UGCC chair approval.

Note: Students may not use work completed towards an honors degree to satisfy the B.S. in ME course requirements.

COVID-19-Related Degree Requirement Changes

Grading

The Product Design Program counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that normally require a letter grade.

Other Undergraduate Policies

The Product Design Program encourages students to take courses for letter grades when possible in order to have complete records for use when seeking future opportunities, including employment in industry and students seeking to apply for graduate studies. Per University policy, students can change grading basis through the end of Week 8 in Autumn, Winter, and Spring, and Week 6 in Summer. Students are encouraged to reach out directly to Product Design Program Director, William Burnett <wburnett@stanford.edu>, for questions about petitions, especially in situations related to COVID-19 policies and grading basis.

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 designers 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

		Units
Mathematics and Science		**36 units minimum**
Mathematics [1,2]		**20 units minimum**
Recommended: one course in Statistics [1]		
Science [2,3]		**17 units minimum**
17 units minimum : Minimum of 9 units of SoE approved science and 8 units of Behavioral Science [2,3]		
PHYSICS 41	Mechanics	4
PSYCH 1	Introduction to Psychology	5
PSYCH or HUMBIO elective [3]		3-5
Technology in Society		**3-5 units**
One course required; must be on the SoE approved TiS courses list at <ughb.stanford.edu> the year it is taken..		
Engineering Fundamentals		**8 units minimum**
CS 106A	Programming Methodology (or CS 106B)	5
ENGR 40M	An Intro to Making: What is EE (or ENGR 40A)	3-5
or ENGR 40A	Introductory Electronics	
Product Design Engineering Depth		**54 units minimum**
ME 125 and ME 216M OR two Art Studio or Computer Science courses, 100 series or higher		6
ENGR 14	Intro to Solid Mechanics	3
ME 80	Mechanics of Materials	3
ME 101	Visual Thinking	4
ME 102	Foundations of Product Realization	3
ME 103	Product Realization: Design and Making	4
ME 104	Mechanical Systems Design	4
ME 110	Design Sketching	2
ME 115A	Introduction to Human Values in Design	3
ME 115B	Product Design Methods	4
ME 120	History and Ethics of Design	3
ME 115C	Designing Your Business	3
ME 125	Visual Frontiers (or ARTSTUDI or CS course)	3
ME 216A	Advanced Product Design: Needfinding [7]	4
ME 216B	Advanced Product Design: Implementation 1 [6]	4
ME 216C	Advanced Product Design: Implementation 2 [6]	4
ME 216M	Introduction to the Design of Smart Products (or ARTSTUDI or CS course)	3-4

1. Math requirements can be met with the Math 19, 20, 21 series, or up to 10 units AP or IB Calculus; and courses from the MATH 50 series and/or the CME 100 series; STATS 60 or STATS 160 are recommended
2. AP units can be applied; have these approved by SoE Dean's Office (email Darlene Lazar at dlazar@stanford.edu) prior to final quarter and before asking advisor to sign-off.
3. School of Engineering approved science list available at http://ughb.stanford.edu (http://ughb.stanford.edu/). PSYCH electives numbered 30-200 or HUMBIO 82A or HUMBIO 160 are pre-approved.
4. ME 216B & ME 216C will fulfill the Writing in the Major (WIM) requirement for Product Design beginning 2019-20.
5. ME 115C (not available 2020-21) is the only course that can be waived if a student takes a quarter overseas or at one of the BOSP campuses in New York or Washington DC. Students should plan their overseas quarter to take place in sophomore year, or Spring Quarter of the junior year only. If the student elects to go overseas junior year, the total depth units are reduced by 3; this is approved without petition.
6. You may substitute ME 216B and ME 216C with ME 206A and ME 206B Design for Extreme Affordability.
7. ME 216A must be taken for 4 units by all PD majors.

A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Topics (Engineering Fundamentals and Depth courses) is 2.0.

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

The joint major program (JMP) was discontinued at the end of the academic year 2018-19. Students may no longer declare this program. All students with declared joint majors are permitted to complete their degree; faculty and departments are committed to providing the necessary advising support.

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 (https://majors.stanford.edu/more-ways-explore/joint-majors-csx/) web site and its associated FAQs.

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

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.

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 one diploma separated by a hyphen. There will be 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."

See the "Undergraduate Majors and Minors (http://exploredegrees.stanford.edu/soe-ug-majors/)" menu item on the left side of this page for program-by-program descriptions of minor requirements. All programs are listed below to facilitate export as a pdf; use the Print option in the right hand menu of this page to create such a pdf for all the tabs in the School of Engineering.

Minor in the School of Engineering

An undergraduate minors 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.

Minors are offered in the following programs:

- Aeronautics and Astronautics (AA) Minor (http://exploredegrees.stanford.edu/schoolofengineering/aeronauticsandastronautics/#minortext)
- Chemical Engineering Minor (http://exploredegrees.stanford.edu/schoolofengineering/chemicalengineering/#minortext)
- Civil Engineering (CE) Minor (http://exploredegrees.stanford.edu/schoolofengineering/civilandenvironmentalengineering/#minortext)
- Computer Science (CS) Minor (http://exploredegrees.stanford.edu/schoolofengineering/computerscience/#minortext)
- Electrical Engineering (EE) Minor (http://exploredegrees.stanford.edu/schoolofengineering/electricalengineering/#minortext)
- Environmental Systems Engineering (EnvSE) Minor (http://exploredegrees.stanford.edu/schoolofengineering/civilandenvironmentalengineering/#minortext)
- Management Science and Engineering (MS&E) Minor (http://exploredegrees.stanford.edu/schoolofengineering/managementscienceandengineering/#minortext)
- Materials Science and Engineering (MATSCI) Minor (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering/#minortext)

- Mechanical Engineering (ME) Minor (http://exploredegrees.stanford.edu/schoolofengineering/mechanicalengineering/#minortext)

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 Aero/Astro adviser can help select substitute courses to fulfill the Aero/Astro 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		
12 Core Units, 24 Total Program Units		
ENGR 21	Engineering of Systems [1]	3
AA 100	Introduction to Aeronautics and Astronautics	3
AA 131	Space Flight	3
AA 141	Atmospheric Flight	3
AA Electives		
Choose 4 courses		
ENGR 105	Feedback Control Design	3
ME 70	Introductory Fluids Engineering	3
AA 102	Introduction to Applied Aerodynamics	3
AA 103	Air and Space Propulsion	3
AA 113	Aerospace Computational Science	3
AA 135	Introduction to Space Policy	3
AA 151	Lightweight Structures	3
AA 156	Mechanics of Composite Materials	3
AA 173	Flight Mechanics & Controls	3
AA 174A	Principles of Robot Autonomy I	5
AA 261	Building an Aerospace Startup from the Ground Up	3
AA 272	Global Positioning Systems	3
AA 279A	Space Mechanics	3

[1] 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:

		Units
ENGR 20	Introduction to Chemical Engineering	4
CHEMENG 100	Chemical Process Modeling, Dynamics, and Control	3
CHEMENG 110A	Introduction to Chemical Engineering Thermodynamics	3
CHEMENG 110B	Multi-Component and Multi-Phase Thermodynamics	3
CHEMENG 120A	Fluid Mechanics	4
CHEMENG 120B	Energy and Mass Transport	4
CHEMENG 130B	Introduction to kinetics and reactor design	3
CHEMENG 185A	Chemical Engineering Laboratory A	5
CHEMENG 180	Chemical Engineering Plant Design	4
Select one of the following:		3
CHEMENG 140	Micro and Nanoscale Fabrication Engineering	
CHEMENG 142	Basic Principles of Heterogeneous Catalysis with Applications in Energy Transformations	
CHEMENG 160	Polymer Science and Engineering	
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, Multivariable Calculus, and Modern Applications 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). 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.

Professor Anne Kiremidjian (kiremidjian@stanford.edu) is the CEE undergraduate minor adviser in Structural Engineering and Construction Engineering and Management. John Barton (jhbarton@stanford.edu (http://www.stanford.edu/dept/registrar/bulletin/jhbarton@stanford.edu)), Program Director for Architectural Design, is the undergraduate minor adviser in Architectural Design. Students must consult the appropriate adviser when developing their minor program, and obtain approval of the finalized study list from them.

Computer Science (CS) Minor

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

		Units
Introductory Programming (AP Credit may be used to fulfill this requirement):		
CS 106B	Programming Abstractions	5
or CS 106X	Programming Abstractions	
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	Data Management and Data Systems	4
CS 148	Introduction to Computer Graphics and Imaging	4
Theory—		
CS 154	Introduction to the Theory of Computation	4
CS 157	Computational Logic	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:

		Units
Select one:		5
EE 42	Introduction to Electromagnetics and Its Applications	
EE 65	Modern Physics for Engineers	
ENGR 40A & ENGR 40B	Introductory Electronics and Introductory Electronics Part II	
ENGR 40M	An Intro to Making: What is EE	
Select one:		8
Option I:		
EE 101A	Circuits I	
EE 101B	Circuits II	
Option II:		
EE 102A	Signal Processing and Linear Systems I	
EE 102B	Signal Processing and Linear Systems II	
Option III:		
EE 102A	Signal Processing and Linear Systems I	
ENGR 108	Introduction to Matrix Methods	
Option IV:		
EE 108	Digital System Design	
EE 180	Digital Systems Architecture	
In addition, four letter-graded EE courses at the 100-level or higher must be taken (12 units minimum). CS 107 is required as a prerequisite for EE 180, but can count as one of the four classes.		12

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, Multivariable Calculus, and Modern Applications 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 adviser 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:

		Units
Prerequisites (two courses; letter-graded or CR/NC)		
CME 100	Vector Calculus for Engineers	5
or MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
CS 106A	Programming Methodology	5
Minor requirements (seven courses; all letter-graded)		
MS&E 111	Introduction to Optimization	3-4
or MS&E 111X	Introduction to Optimization (Accelerated)	
MS&E 120	Introduction to Probability [1]	4
MS&E 121	Introduction to Stochastic Modeling	4
MS&E 125	Introduction to Applied Statistics	4
MS&E 180	Organizations: Theory and Management	4
Electives (select any two 100- or 200-level MS&E courses)		6
Recommended courses		
In addition to the required prerequisite and minor courses, it is recommended that students also take the following courses.		
ECON 50	Economic Analysis I	5
MS&E 140	Accounting for Managers and Entrepreneurs (may be used as one of the required electives above)	3-4

[1] Students completing a calculus-based probability course such as CS 109 or STATS 116 for their major, may substitute another MS&E course for MS&E 120.

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:

		Units
Engineering Fundamentals		
Select one of the following:		4
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	
ENGR 50E	Introduction to Materials Science, Energy Emphasis	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	
Materials Science Fundamentals and Engineering Depth		
Select six of the following:		24
MATSCI 142	Quantum Mechanics of Nanoscale Materials	
MATSCI 143	Materials Structure and Characterization	
MATSCI 144	Thermodynamic Evaluation of Green Energy Technologies	
MATSCI 145	Kinetics of Materials Synthesis	
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 160	Nanomaterials Laboratory	
MATSCI 161	Energy Materials Laboratory	
MATSCI 162	X-Ray Diffraction Laboratory	
MATSCI 163	Mechanical Behavior Laboratory	
MATSCI 164	Electronic and Photonic Materials and Devices Laboratory	
MATSCI 165	Nanoscale Materials Physics Computation Laboratory	
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	
Total Units		28

Mechanical Engineering (ME) Minor

The following courses fulfill the minor requirements:

		Units
General Minor *		
ENGR 14	Intro to Solid Mechanics	3
ENGR 15	Dynamics	3
ME 1	Introduction to Mechanical Engineering	3
ME 30	Engineering Thermodynamics	3
ME 70	Introductory Fluids Engineering	3
Plus two of the following:		
ME 80	Mechanics of Materials	3
ME 102	Foundations of Product Realization	3
ME 131	Heat Transfer	4
ME 161	Dynamic Systems, Vibrations and Control	3
Total Units: 21		
Thermosciences Minor **		
ENGR 14	Intro to Solid Mechanics	3
ME 30	Engineering Thermodynamics	3
ME 70	Introductory Fluids Engineering	3
ME 131	Heat Transfer	4
ME 132	Intermediate Thermodynamics	4

ME 133	Intermediate Fluid Mechanics (offered SPR 18-19; more information to come)	3
ME 149	Mechanical Measurements	3
Total units: 23		
Mechanical Design Minor ***		
ENGR 14	Intro to Solid Mechanics	3
ME 80	Mechanics of Materials	3
ME 1	Introduction to Mechanical Engineering	3
ME 102	Foundations of Product Realization	3
ME 103	Product Realization: Design and Making	4
ME 104	Mechanical Systems Design	4
Plus one of the following:		
ME 127	Design for Additive Manufacturing	3
ME 128	Computer-Aided Product Realization	3-4
ME 129	Manufacturing Processes and Design	3
ME 210	Introduction to Mechatronics	4
ME 220	Introduction to Sensors	3-4
Total units: 23		

* 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 or PHYSICS 41E Mechanics, Concepts, Calculations, and Context.

** Prerequisites: MATH 19 Calculus, MATH 20 Calculus, MATH 21 Calculus , MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications (or CME 100 Vector Calculus for Engineers) and PHYSICS 41 Mechanics or PHYSICS 41E Mechanics, Concepts, Calculations, and Context.

*** 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 or PHYSICS 41E Mechanics, Concepts, Calculations, and Context.

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 or handbooks.

The M.S. in Engineering is rarely pursued as a coterminal program, and potential coterms 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 the Application for Admission to Coterminal Masters' Program (http://registrar.stanford.edu/pdf/CotermApplic.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 the SCPD website (http://scpd.stanford.edu); call (650) 204-3984; fax (650) 725-2868; or email scpd-gradstudents@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.

COVID-19 Policies

On July 30, the Academic Senate adopted grading policies effective for all undergraduate and graduate programs, excepting the professional Graduate School of Business, School of Law, and the School of Medicine M.D. Program. For a complete list of those and other academic policies relating to the pandemic, see the "COVID-19 and Academic Continuity (http://exploredegrees.stanford.edu/covid-19-policy-changes/#tempdepttemplatetabtext)" section of this bulletin.

The Senate decided that all undergraduate and graduate courses offered for a letter grade must also offer students the option of taking the course for a “credit” or “no credit” grade and recommended that deans, departments, and programs consider adopting local policies to count courses taken for a “credit” or “satisfactory” grade toward the fulfillment of degree-program requirements and/or alter program requirements as appropriate.

Undergraduate and graduate grading in the School of Engineering is determined by the department or program. Refer to the COVID-19 tab within each of the departmental sections, or check the Undergraduate Majors and Minors (http://exploredegrees.stanford.edu/soe-ug-majors/) pages for policy on undergraduate school-sponsored majors and minors.

Dean: Jennifer Widom

Senior Associate Deans: Ken Goodson (Faculty and Academic Affairs), Scott Calvert (Administration), Thomas Kenny (Student Affairs)

Associate Dean: Kirsti Copeland (Student Affairs)

Assistant Dean: Sally Gressens (Graduate Student Affairs)

Overseas Studies Courses in Engineering

The Bing Overseas Studies Program (http://bosp.stanford.edu) (BOSP) manages Stanford international and domestic study away 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 BOSP 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).

Due to COVID-19, all BOSP programs have been suspended for Autumn Quarter 2020-21. All courses and quarters of operation are subject to change.

		Units
OSPBER 40M	An Intro to Making: What is EE	5
OSPBER 50M	Introductory Science of Materials	4
OSPFLOR 50M	Introductory Science of Materials	4
OSPPARIS 40M	An Intro to Making: What is EE	5
OSPPARIS 50M	Introductory Science of Materials	4

Courses

ENGR 1. Want to Be an Engineer?. 1 Unit.
This course is designed for you if you are a new student who has a hypothesis that you want to be a scientist, mathematician, or engineer but don't yet know what you want to major in. As a scientist, you know that you need data to test your hypothesis. As a design thinker, you know that there is no way forward except to be exposed to different things and weigh the results. As a potential engineer, you know that you need lots of information to make a decision. Each week a panel of faculty from STEM majors in the School of Engineering, the School of Humanities & Sciences, and Stanford Earth will present with the goal of helping you discover if their field is right for you.

ENGR 2A. SSEA Seminar: Developing Your Leadership Toolkit. 1 Unit.
In this weekly seminar, SSEA students will learn practical leadership skills so they can successfully navigate academic and professional opportunities while at Stanford and achieve meaningful results. Mentorship and career exploration will also be delivered through an inspiring line up of guest speakers and interactive activities.

ENGR 10. Introduction to Engineering Analysis. 4 Units.
Integrated approach to the fundamental scientific principles that are the cornerstones of engineering analysis: conservation of mass, atomic species, charge, momentum, angular momentum, energy, production of entropy expressed in the form of balance equations on carefully defined systems, and incorporating simple physical models. Emphasis is on setting up analysis problems arising in engineering. Topics: simple analytical solutions, numerical solutions of linear algebraic equations, and laboratory experiences. Provides the foundation and tools for subsequent engineering courses. Prerequisite: AP Physics and AP Calculus or equivalent.

ENGR 14. Intro to Solid Mechanics. 3 Units.
Introduction to engineering analysis using the principles of engineering solid mechanics. Builds on the math and physical reasoning concepts in Physics 41 to develop skills in evaluation of engineered systems across a variety of fields. Foundational ideas for more advanced solid mechanics courses such as ME80 or CEE101A. Interactive lecture sessions focused on mathematical application of key concepts, with weekly complementary lab session on testing and designing systems that embody these concepts. Limited enrollment, subject to instructor approval. Pre-requisite: Physics 41. When signing up for this course make sure to sign up both for the lecture and for a Discussion Section.

ENGR 15. Dynamics. 3 Units.
The application of Newton's Laws to solve 2-D and 3-D static and dynamic problems, particle and rigid body dynamics, freebody diagrams, and equations of motion, with application to mechanical, biomechanical, and aerospace systems. Computer numerical solution and dynamic response. Prerequisites: Calculus (differentiation and integration) such as Math 19, 20; and ENGR 14 (statics and strength) or a mechanics course in physics such as PHYSICS 41.

ENGR 20. Introduction to Chemical Engineering. 4 Units.
Overview of chemical engineering through discussion and engineering analysis of physical and chemical processes. Topics: overall staged separations, material and energy balances, concepts of rate processes, energy and mass transport, and kinetics of chemical reactions. Applications of these concepts to areas of current technological importance: biotechnology, energy, production of chemicals, materials processing, and purification. Prerequisite: CHEM 31.
Same as: CHEMENG 20

ENGR 21. Engineering of Systems. 3 Units.
A high-level look at techniques for analyzing and designing complex, multidisciplinary engineering systems, such as aircraft, spacecraft, automobiles, power plants, cellphones, robots, biomedical devices, and many others. The need for multi-level design, modeling and simulation approaches, computation-based design, and hardware and software-in-the-loop simulations will be demonstrated through a variety of examples and case studies. Several aspects of system engineering will be applied to the design of large-scale interacting systems and contrasted with subsystems such as hydraulic systems, electrical systems, and brake systems. The use of design-thinking, story-boarding, mockups, sensitivity analysis, simulation, team-based design, and the development of presentation skills will be fostered through several realistic examples in several fields of engineering.

ENGR 40A. Introductory Electronics. 3 Units.
Instruction will be completed in the first seven weeks of the quarter. Students not majoring in Electrical Engineering may choose to take only ENGR 40A; Electrical Engineering majors should take both ENGR 40A and ENGR 40B. Overview of electronic circuits and applications. Electrical quantities and their measurement, including operation of the oscilloscope. Basic models of electronic components including resistors, capacitors, inductors, and operational amplifiers. Lab. Lab assignments. Enrollment limited to 300.

ENGR 40B. Introductory Electronics Part II. 2 Units.
Instruction will be completed in the final three weeks of the quarter. Students should not enroll in ENGR 40B without having taken (or enrolling concurrently in) ENGR 40A. Project on digital hardware and software implementations of a robotic car. Lab. Lab assignments. Pre- or co-requisite: ENGR 40A. Enrollment limited to 300.

ENGR 40M. An Intro to Making: What is EE. 5 Units.
Is a hands-on class where students learn to make stuff. Through the process of building, you are introduced to the basic areas of EE. Students build a "useless box" and learn about circuits, feedback, and programming hardware, a light display for your desk and bike and learn about coding, transforms, and LEDs, a solar charger and an EKG machine and learn about power, noise, feedback, more circuits, and safety. And you get to keep the toys you build. Prerequisite: CS 106A.

ENGR 42. Introduction to Electromagnetics and Its Applications. 5 Units.
Electricity and magnetism and its essential role in modern electrical engineering devices and systems, such as sensors, displays, DVD players, and optical communication systems. The topics that will be covered include electrostatics, magnetostatics, Maxwell's equations, one-dimensional wave equation, electromagnetic waves, transmission lines, and one-dimensional resonators. Pre-requisites: none.
Same as: EE 42

ENGR 50. Introduction to Materials Science, Nanotechnology Emphasis. 4 Units.
The structure, bonding, and atomic arrangements in materials leading to their properties and applications. Topics include electronic and mechanical behavior, emphasizing nanotechnology, solid state devices, and advanced structural and composite materials.

ENGR 50E. Introduction to Materials Science, Energy Emphasis. 4 Units.
Materials structure, bonding and atomic arrangements leading to their properties and applications. Topics include electronic, thermal and mechanical behavior; emphasizing energy related materials and challenges.

ENGR 50M. Introduction to Materials Science, Biomaterials Emphasis. 4 Units.
Topics include: the relationship between atomic structure and macroscopic properties of man-made and natural materials; mechanical and thermodynamic behavior of surgical implants including alloys, ceramics, and polymers; and materials selection for biotechnology applications such as contact lenses, artificial joints, and cardiovascular stents. No prerequisite.

ENGR 60. Engineering Economics and Sustainability. 3 Units.
Engineering Economics is a subset of the field of economics that draws upon the logic of economics, but adds that analytical power of mathematics and statistics. The concepts developed in this course are broadly applicable to many professional and personal decisions, including making purchasing decisions, deciding between project alternatives, evaluating different processes, and balancing environmental and social costs against economic costs. The concepts taught in this course will be increasingly valuable as students climb the carrier ladder in private industry, a non-governmental organization, a public agency, or in founding their own startup. Eventually, the ability to make informed decisions that are based in fundamental analysis of alternatives is a part of every career. As such, this course is recommended for engineering and non-engineering students alike. This course is taught exclusively online in every quarter it is offered. (Prerequisites: MATH 19 or 20 or approved equivalent.).
Same as: CEE 146S

ENGR 62. Introduction to Optimization. 3-4 Units.
Formulation and computational analysis of linear, quadratic, and other convex optimization problems. Applications in machine learning, operations, marketing, finance, and economics. Prerequisite: CME 100 or MATH 51.
Same as: MS&E 111, MS&E 211

ENGR 62X. Introduction to Optimization (Accelerated). 3-4 Units.
Optimization theory and modeling. The role of prices, duality, optimality conditions, and algorithms in finding and recognizing solutions. Perspectives: problem formulation, analytical theory, computational methods, and recent applications in engineering, finance, and economics. Theories: finite dimensional derivatives, convexity, optimality, duality, and sensitivity. Methods: simplex and interior-point, gradient, Newton, and barrier. Prerequisite: CME 100 or MATH 51 or equivalent.
Same as: MS&E 111X, MS&E 211X

ENGR 76. Information Science and Engineering. 4 Units.
What is information? How can we measure and efficiently represent it? How can we reliably communicate and store it over media prone to noise and errors? How can we make sound decisions based on partial and noisy information? This course introduces the basic notions required to address these questions, as well as the principles and techniques underlying the design of modern information, communication, and decision-making systems with relations to and applications in machine-learning, through genomics, to neuroscience. Students will get a hands-on appreciation of the concepts via projects in small groups, where they will develop their own systems for streaming of multi-media data under human-centric performance criteria. Prerequisite: CS 106A.

ENGR 80. Introduction to Bioengineering (Engineering Living Matter). 4 Units.
Students completing BIOE.80 should have a working understanding for how to approach the systematic engineering of living systems to benefit all people and the planet. Our main goals are (1) to help students learn ways of thinking about engineering living matter and (2) to empower students to explore the broader ramifications of engineering life. Specific concepts and skills covered include but are not limited to: capacities of natural life on Earth; scope of the existing human-directed bioeconomy; deconstructing complicated problems; reaction & diffusion systems; microbial human anatomy; conceptualizing the engineering of biology; how atoms can be organized to make molecules; how to print DNA from scratch; programming genetic sensors, logic, & actuators; biology beyond molecules (photons, electrons, etc.); what constraints limit what life can do?; what will be the major health challenges in 2030?; how does what we want shape bioengineering?; who should choose and realize various competing bioengineering futures?.
Same as: BIOE 80

ENGR 90. Environmental Science and Technology. 3 Units.
Introduction to environmental quality and the technical background necessary for understanding environmental issues, controlling environmental degradation, and preserving air and water quality. Material balance concepts for tracking substances in the environmental and engineering systems.
Same as: CEE 70

ENGR 100. Teaching Public Speaking. 3 Units.
The theory and practice of teaching public speaking and presentation development. Lectures/discussions on developing an instructional plan, using audiovisual equipment for instruction, devising tutoring techniques, and teaching delivery, organization, audience analysis, visual aids, and unique speaking situations. Weekly practice speaking. Students serve as apprentice speech tutors. Those completing course may become paid speech instructors in the Technical Communications Program. Prerequisite: consent of instructor.

ENGR 102W. Technical and Professional Communication. 3 Units.
Effective communication skills will help you advance quickly. Learn the best technical and professional techniques in writing and speaking. Group workshops and individual conferences with instructors. Designed for undergraduates going into industry. Allowed to fulfill WIM for Atmosphere/Energy and Environmental Systems Engineering majors only.
Same as: CEE 102W

ENGR 103. Public Speaking. 3 Units.
Priority to Engineering students. Introduction to speaking activities, from impromptu talks to carefully rehearsed formal professional presentations. How to organize and write speeches, analyze audiences, create and use visual aids, combat nervousness, and deliver informative and persuasive speeches effectively. Weekly class practice, rehearsals in one-on-one tutorials, videotaped feedback. Limited enrollment.
Same as: ENGR 203

ENGR 105. Feedback Control Design. 3 Units.
Design of linear feedback control systems for command-following error, stability, and dynamic response specifications. Root-locus and frequency response design techniques. Examples from a variety of fields. Some use of computer aided design with MATLAB. Prerequisites: Dynamics systems (EE 102B or ME 161), and ordinary differential equations (CME 102 or Math 53). This course will include synchronous teaching sessions, but will be recorded to allow asynchronous participation.

ENGR 108. Introduction to Matrix Methods. 3-5 Units.
Formerly EE 103/CME 103. Introduction to applied linear algebra with emphasis on applications. Vectors, norm, and angle; linear independence and orthonormal sets; applications to document analysis. Clustering and the k-means algorithm. Matrices, left and right inverses, QR factorization. Least-squares and model fitting, regularization and cross-validation. Constrained and nonlinear least-squares. Applications include time-series prediction, tomography, optimal control, and portfolio optimization. Undergraduate students should enroll for 5 units, and graduate students should enroll for 3 units. Prerequisites:MATH 51 or CME 100, and basic knowledge of computing (CS 106A is more than enough, and can be taken concurrently). ENGR 108 and Math 104 cover complementary topics in applied linear algebra. The focus of ENGR 108 is on a few linear algebra concepts, and many applications; the focus of Math 104 is on algorithms and concepts.

ENGR 110. Perspectives in Assistive Technology (ENGR 110). 1-2 Unit.
Online seminar and student project course that explores the personal, medical, social, ethical, and technical challenges surrounding the design, development, and use of technologies that improve the lives of people with disabilities and older adults. Guest lecturers include engineers, clinicians, researchers, and individuals with disabilities. Students from any discipline are welcome to enroll. Two credit units for students who pursue an individual assistive technology project (letter grade or S/NC) with a community partner. One credit unit for seminar attendance only (S/NC). See course website http://engr110.stanford.edu for more information. Designated a Cardinal Course by the Haas Center for Public Service.
Same as: ENGR 210

ENGR 113A. Solar Decathlon 2015. 3 Units.
Open to all majors. Seminar / Lab format course facilitates the student-led administration, conception, development, and execution of the Solar Decathlon 2015 competition entry sponsored by the US Department of Energy. (http://www.solardecathlon.gov/) Students shall learn best practices in creating design teams to address multi-disciplinary design problems. Students shall work both as individuals and in teams across multiple Stanford SD2015 phases of project management, research, fundraising, design, engineering, contracting, construction administration, and competitive testing in Irvine CA.
Same as: ENGR 213A

ENGR 113B. Solar Decathlon 2015. 3 Units.
Open to all majors. Seminar / Lab format course facilitates the student-led administration, conception, development, and execution of the Solar Decathlon 2015 competition entry sponsored by the US Department of Energy. (http://www.solardecathlon.gov/) Students shall learn best practices in creating design teams to address multi-disciplinary design problems. Students shall work both as individuals and in teams across multiple Stanford SD2015 phases of project management, research, fundraising, design, engineering, contracting, construction administration, and competitive testing in Irvine CA.
Same as: ENGR 213B

ENGR 113C. Solar Decathlon 2015. 3 Units.
Open to all majors. Seminar / Lab format course facilitates the student-led administration, conception, development, and execution of the Solar Decathlon 2015 competition entry sponsored by the US Department of Energy. (http://www.solardecathlon.gov/) Students shall learn best practices in creating design teams to address multi-disciplinary design problems. Students shall work both as individuals and in teams across multiple Stanford SD2015 phases of project management, research, fundraising, design, engineering, contracting, construction administration, and competitive testing in Irvine CA.
Same as: ENGR 213C

ENGR 113D. SOLAR DECATHLON 2015. 3 Units.
Open to all majors. Seminar / Lab format course facilitates the student-led administration, conception, development, and execution of the Solar Decathlon 2015 competition entry sponsored by the US Department of Energy. (http://www.solardecathlon.gov/) Students shall learn best practices in creating design teams to address multi-disciplinary design problems. Students shall work both as individuals and in teams across multiple Stanford SD2015 phases of project management, research, fundraising, design, engineering, contracting, construction administration, and competitive testing in Irvine CA.
Same as: ENGR 213D

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

ENGR 117. Expanding Engineering Limits: Culture, Diversity, and Equity. 3 Units.
This course investigates how culture and diversity shape who becomes an engineer, what problems get solved, and the quality of designs, technology, and products. As a course community, we consider how cultural beliefs about race, ethnicity, gender, sexuality, abilities, socioeconomic status, and other intersectional aspects of identity interact with beliefs about engineering, influence diversity in the field, and affect equity in engineering education and practice. We also explore how engineering cultures and environments respond to and change with individual and institutional agency. The course involves weekly presentations by scholars and engineers, readings, short writing assignments, small-group discussion, and hands-on, student-driven projects. Students can enroll in the course for 1 unit (lectures only), or 3 units (lectures+discussion+project). For 1 unit, students should sign up for Section 1 and Credit/No Credit grading, and for 3 units students should sign up for Section 2 and either the C/NC or Grade option.
Same as: CSRE 117, CSRE 217, ENGR 217, FEMGEN 117, FEMGEN 217

ENGR 119. Community Engagement Preparation Seminar. 1 Unit.
This seminar is designed for engineering students who have already committed to an experiential learning program working directly with a community partner on a project of mutual benefit. This seminar is targeted at students participating in the Summer Service Learning Program offered through Stanford¿s Global Engineering Program.
Same as: ENGR 219

ENGR 120. Fundamentals of Petroleum Engineering. 3 Units.
Lectures, problems, field trip. Engineering topics in petroleum recovery; origin, discovery, and development of oil and gas. Chemical, physical, and thermodynamic properties of oil and natural gas. Material balance equations and reserve estimates using volumetric calculations. Gas laws. Single phase and multiphase flow through porous media.
Same as: ENERGY 120

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

ENGR 140B. Leadership of Technology Ventures. 1-2 Unit.
Open to Mayfield Fellows only; taken during the summer internship at a technology startup. Students exchange experiences and continue the formal learning process. Activities journal. Credit given following quarter.

ENGR 140C. Leadership of Technology Ventures. 2-3 Units.
Open to Mayfield Fellows only. Capstone to the 140 sequence. Students, faculty, employers, and venture capitalists share recent internship experiences and analytical frameworks. Students develop living case studies and integrative project reports.

ENGR 145. Technology Entrepreneurship. 4 Units.
How does the entrepreneurship process enable the creation and growth of high-impact enterprises? Why does entrepreneurial leadership matter even in a large organization or a non-profit venture? What are the differences between just an idea and true opportunity? How do entrepreneurs form teams and gather the resources necessary to create a successful startup? Mentor-guided projects focus on analyzing students' ideas, case studies allow for examining the nuances of innovation, research examines the entrepreneurial process, and expert guests allow for networking with Silicon Valley's world-class entrepreneurs and venture capitalists. For undergraduates of all majors with interest in startups the leverage breakthrough information, energy, medical and consumer technologies. No prerequisites. Limited enrollment.
Same as: ENGR 145S

ENGR 145S. Technology Entrepreneurship. 4 Units.
How does the entrepreneurship process enable the creation and growth of high-impact enterprises? Why does entrepreneurial leadership matter even in a large organization or a non-profit venture? What are the differences between just an idea and true opportunity? How do entrepreneurs form teams and gather the resources necessary to create a successful startup? Mentor-guided projects focus on analyzing students' ideas, case studies allow for examining the nuances of innovation, research examines the entrepreneurial process, and expert guests allow for networking with Silicon Valley's world-class entrepreneurs and venture capitalists. For undergraduates of all majors with interest in startups the leverage breakthrough information, energy, medical and consumer technologies. No prerequisites. Limited enrollment.
Same as: ENGR 145

ENGR 148. Principled Entrepreneurial Decisions. 3 Units.
Examines how leaders tackle significant events that occur in high-growth entrepreneurial companies. Students prepare their minds for the difficult entrepreneurial situations that they will encounter in their lives in whatever their chosen career. Cases and guest speakers discuss not only the business rationale for the decisions taken but also how their principles affected those decisions. The teaching team brings its wealth of experience in both entrepreneurship and VC investing to the class. Previous entrepreneurship coursework or experience preferred. Limited enrollment. Admission by application: http://web.stanford.edu/class/engr248/apply.
Same as: ENGR 248

ENGR 150. Data Challenge Lab. 3-5 Units.
In this lab, students develop the practical skills of data science by solving a series of increasingly difficult, real problems. Skills developed include: data manipulation, data visualization, exploratory data analysis, and basic modeling. The data challenges each student undertakes are based upon their current skills. Students receive one-on-one coaching and see how expert practitioners solve the same challenges. Limited enrollment; application required. See http://datalab.stanford.edu for more information.
Same as: COMM 173E

ENGR 154. Vector Calculus for Engineers. 5 Units.
Computation and visualization using MATLAB. Differential vector calculus: vector-valued functions, analytic geometry in space, functions of several variables, partial derivatives, gradient, linearization, unconstrained maxima and minima, Lagrange multipliers and applications to trajectory simulation, least squares, and numerical optimization. Introduction to linear algebra: matrix operations, systems of algebraic equations with applications to coordinate transformations and equilibrium problems. Integral vector calculus: multiple integrals in Cartesian, cylindrical, and spherical coordinates, line integrals, scalar potential, surface integrals, Green's, divergence, and Stokes' theorems. Numerous examples and applications drawn from classical mechanics, fluid dynamics and electromagnetism. Prerequisites: knowledge of single-variable calculus equivalent to the content of Math 19-21 (e.g., 5 on Calc BC, 4 on Calc BC with Math 21, 5 on Calc AB with Math 21). Placement diagnostic (recommendation non-binding) at: https://exploredegrees.stanford.edu/undergraduatedegreesandprograms/#aptext.
Same as: CME 100

ENGR 155A. Ordinary Differential Equations for Engineers. 5 Units.
Analytical and numerical methods for solving ordinary differential equations arising in engineering applications are presented. For analytical methods students learn to solve linear and non-linear first order ODEs; linear second order ODEs; and Laplace transforms. Numerical methods using MATLAB programming tool kit are also introduced to solve various types of ODEs including: first and second order ODEs, higher order ODEs, systems of ODEs, initial and boundary value problems, finite differences, and multi-step methods. This also includes accuracy and linear stability analyses of various numerical algorithms which are essential tools for the modern engineer. This class is foundational for professional careers in engineering and as a preparation for more advanced classes at the undergraduate and graduate levels. Prerequisites: knowledge of single-variable calculus equivalent to the content of Math 19-21 (e.g., 5 on Calc BC, 4 on Calc BC with Math 21, 5 on Calc AB with Math 21). Placement diagnostic (recommendation non-binding) at: https://exploredegrees.stanford.edu/undergraduatedegreesandprograms/#aptext.
Same as: CME 102

ENGR 155B. Linear Algebra and Partial Differential Equations for Engineers. 5 Units.
Linear algebra: systems of algebraic equations, Gaussian elimination, undetermined and overdetermined systems, coupled systems of ordinary differential equations, LU factorization, eigensystem analysis, normal modes. Linear independence, vector spaces, subspaces and basis. Numerical analysis applied to structural equilibrium problems, electrical networks, and dynamic systems. Fourier series with applications, partial differential equations arising in science and engineering, analytical solutions of partial differential equations. Applications in heat and mass transport, mechanical vibration and acoustic waves, transmission lines, and fluid mechanics. Numerical methods for solution of partial differential equations: iterative techniques, stability and convergence, time advancement, implicit methods, von Neumann stability analysis. Examples and applications drawn from a variety of engineering fields. Prerequisite: CME102/ENGR155A.
Same as: CME 104

ENGR 155C. Introduction to Probability and Statistics for Engineers. 4 Units.
Probability: random variables, independence, and conditional probability; discrete and continuous distributions, moments, distributions of several random variables. Numerical simulation using Monte Carlo techniques. Topics in mathematical statistics: random sampling, point estimation, confidence intervals, hypothesis testing, non-parametric tests, regression and correlation analyses. Numerous applications in engineering, manufacturing, reliability and quality assurance, medicine, biology, and other fields. Prerequisite: CME100/ENGR154 or Math 51 or 52.
Same as: CME 106

ENGR 159Q. Japanese Companies and Japanese Society. 3 Units.
Preference to sophomores. The structure of a Japanese company from the point of view of Japanese society. Visiting researchers from Japanese companies give presentations on their research enterprise. The Japanese research ethic. The home campus equivalent of a Kyoto SCTI course.
Same as: MATSCI 159Q

ENGR 177A. Engineering and Sustainable Development: Toolkit. 1-3 Unit.
The first of a two-quarter, project-based course sequence that address cultural, sociopolitical, organizational, technical, and ethical issues at the heart of implementing sustainable engineering projects in a developing world. Students work in interdisciplinary project teams to tackle real-world design challenges in partnership with social entrepreneurs, local communities, and/or NGOs. While students must have the skills and aptitude necessary to make meaningful contributions to technical product designs, the course is open to all backgrounds and majors. The first quarter focuses on cultural awareness, ethical implications, user requirements, conceptual design, feasibility analysis, and implementation planning. Admission is by application. Students should plan to enroll in CEE 177S/277S (ENGR 177B/277B) Engineering & Sustainable Development: Implementation following successful completion of this course. Designated a Cardinal Course by the Haas Center for Public Service. To satisfy a Ways requirement, students must register for an undergraduate course number (CEE 177S or ENGR 177A) and this course must be taken for at least 3 units. In AY 2020-21, a letter grade or `CR' grade satisfies the Ways requirement.
Same as: CEE 177X, CEE 277X, ENGR 277A

ENGR 177B. Engineering and Sustainable Development. 1-3 Unit.
The second of a two-quarter, project-based course sequence that address cultural, political, organizational, technical and business issues at the heart of implementing sustainable engineering projects in the developing world. Students work in interdisciplinary project teams to tackle real-world design challenges in partnership with social entrepreneurs and/or NGOs. This quarter focuses on implementation, evaluation, and deployment of the designs developed in the winter quarter. Designated a Cardinal Course by the Haas Center for Public Service.
Same as: CEE 177S, CEE 277S, ENGR 277B

ENGR 192. Engineering Public Service Project. 1-2 Unit.
Volunteer work on a public service project with a technical engineering component. Project requires a faculty sponsor and a community partner such as a nonprofit organization, school, or individual. Required report. See http://soe.stanford.edu/publicservice. May be repeated for credit. Prerequisite: consent of instructor.

ENGR 193. Discover Engineering: How to Aim High, Embrace Uncertainty, and Achieve Impact. 1 Unit.
This weekly seminar will provide students of all engineering majors with practical leadership skills training (e.g. how to network, advocate for yourself, assert influence) in order to make innovative and meaningful contributions in their fields. Career exploration and mentorship opportunities will be delivered through an inspiring line up of guest speakers and interactive activities, demonstrations and tours. May be repeat for credit.

ENGR 199. Special Studies in Engineering. 1-15 Unit.
Special studies, lab work, or reading under the direction of a faculty member. Often research experience opportunities exist in ongoing research projects. Students make arrangements with individual faculty and enroll in the section number corresponding to the particular faculty member. May be repeated for credit. Prerequisite: consent of instructor.

ENGR 199A. Additional Calculus for Engineers. 1 Unit.
Additional problem solving practice for the calculus courses. Sections are designed to allow students to acquire a deeper understanding of calculus and its applications, work collaboratively, and develop a mastery of the material. Limited enrollment, permission of instructor required. Concurrent enrollment in MATH 19, 20, 52, or 53 required.

ENGR 199W. Writing of Original Research for Engineers. 1-3 Unit.
Technical writing in science and engineering. Students produce a substantial document describing their research, methods, and results. Prerequisite: completion of freshman writing requirements; prior or concurrent in 2 units of research in the major department; and consent of instructor. WIM for select School of Engineering majors with permission from advisor.

ENGR 202C. Technical Communication for CEE SDC Students. 3 Units.
Students learn how to write and present technical information clearly, with a focus on how to draft and revise reader-centered professional documents. The course includes elements of effective oral communication and presentation.This offering for CEE SDC students only.

ENGR 202S. Directed Writing Projects. 1 Unit.
Individualized writing instruction for students working on writing projects such as dissertations, proposals, grant applications, theses, journal articles, conference papers, and teaching and research statements. Weekly one-on-one conferences with writing instructors from the Technical Communication Program. Students receive close attention to and detailed feedback on their writing. TCP Director assigns each student to an instructor. No prerequisite. Grading: Satisfactory/No Credit. This course may be repeated for credit.

ENGR 202W. Technical Communication. 3 Units.
This course focuses on how to write clear, concise, and organized technical writing. Through interactive presentations, group workshops, and individual conferences, students learn best practices for communicating to academic and professional audiences for a range of purposes.

ENGR 203. Public Speaking. 3 Units.
Priority to Engineering students. Introduction to speaking activities, from impromptu talks to carefully rehearsed formal professional presentations. How to organize and write speeches, analyze audiences, create and use visual aids, combat nervousness, and deliver informative and persuasive speeches effectively. Weekly class practice, rehearsals in one-on-one tutorials, videotaped feedback. Limited enrollment.
Same as: ENGR 103

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

ENGR 207A. Linear Control Systems I. 3 Units.
Introduction to control of discrete-time linear systems. State-space models. Controllability and observability. The linear quadratic regulator. Prerequisite: 105 or 205.

ENGR 207B. Linear Control Systems II. 3 Units.
Probabilistic methods for control and estimation. Statistical inference for discrete and continuous random variables. Linear estimation with Gaussian noise. The Kalman filter. Prerequisite: EE 263.

ENGR 209A. Analysis and Control of Nonlinear Systems. 3 Units.
Introduction to nonlinear phenomena: multiple equilibria, limit cycles, bifurcations, complex dynamical behavior. Planar dynamical systems, analysis using phase plane techniques. Describing functions. Lyapunov stability theory. SISO feedback linearization, sliding mode control. Design examples. Prerequisite: 205.

ENGR 210. Perspectives in Assistive Technology (ENGR 110). 1-2 Unit.
Online seminar and student project course that explores the personal, medical, social, ethical, and technical challenges surrounding the design, development, and use of technologies that improve the lives of people with disabilities and older adults. Guest lecturers include engineers, clinicians, researchers, and individuals with disabilities. Students from any discipline are welcome to enroll. Two credit units for students who pursue an individual assistive technology project (letter grade or S/NC) with a community partner. One credit unit for seminar attendance only (S/NC). See course website http://engr110.stanford.edu for more information. Designated a Cardinal Course by the Haas Center for Public Service.
Same as: ENGR 110

ENGR 213. Solar Decathlon. 1-4 Unit.
Open to all engineering majors. Project studio for all work related to the Solar Decathlon 2013 competition. Each student will develop a personal work plan for the quarter with his or her advisor and perform multidisciplinary collaboration on designing systems for the home or pre-construction planning. Work may continue through the summer as a paid internship, as well as through the next academic year. For more information about the team and the competition, please visit solardecathlon.stanford.edu.

ENGR 213A. Solar Decathlon 2015. 3 Units.
Open to all majors. Seminar / Lab format course facilitates the student-led administration, conception, development, and execution of the Solar Decathlon 2015 competition entry sponsored by the US Department of Energy. (http://www.solardecathlon.gov/) Students shall learn best practices in creating design teams to address multi-disciplinary design problems. Students shall work both as individuals and in teams across multiple Stanford SD2015 phases of project management, research, fundraising, design, engineering, contracting, construction administration, and competitive testing in Irvine CA.
Same as: ENGR 113A

ENGR 213B. Solar Decathlon 2015. 3 Units.
Open to all majors. Seminar / Lab format course facilitates the student-led administration, conception, development, and execution of the Solar Decathlon 2015 competition entry sponsored by the US Department of Energy. (http://www.solardecathlon.gov/) Students shall learn best practices in creating design teams to address multi-disciplinary design problems. Students shall work both as individuals and in teams across multiple Stanford SD2015 phases of project management, research, fundraising, design, engineering, contracting, construction administration, and competitive testing in Irvine CA.
Same as: ENGR 113B

ENGR 213C. Solar Decathlon 2015. 3 Units.
Open to all majors. Seminar / Lab format course facilitates the student-led administration, conception, development, and execution of the Solar Decathlon 2015 competition entry sponsored by the US Department of Energy. (http://www.solardecathlon.gov/) Students shall learn best practices in creating design teams to address multi-disciplinary design problems. Students shall work both as individuals and in teams across multiple Stanford SD2015 phases of project management, research, fundraising, design, engineering, contracting, construction administration, and competitive testing in Irvine CA.
Same as: ENGR 113C

ENGR 213D. SOLAR DECATHLON 2015. 3 Units.
Open to all majors. Seminar / Lab format course facilitates the student-led administration, conception, development, and execution of the Solar Decathlon 2015 competition entry sponsored by the US Department of Energy. (http://www.solardecathlon.gov/) Students shall learn best practices in creating design teams to address multi-disciplinary design problems. Students shall work both as individuals and in teams across multiple Stanford SD2015 phases of project management, research, fundraising, design, engineering, contracting, construction administration, and competitive testing in Irvine CA.
Same as: ENGR 113D

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

ENGR 217. Expanding Engineering Limits: Culture, Diversity, and Equity. 3 Units.
This course investigates how culture and diversity shape who becomes an engineer, what problems get solved, and the quality of designs, technology, and products. As a course community, we consider how cultural beliefs about race, ethnicity, gender, sexuality, abilities, socioeconomic status, and other intersectional aspects of identity interact with beliefs about engineering, influence diversity in the field, and affect equity in engineering education and practice. We also explore how engineering cultures and environments respond to and change with individual and institutional agency. The course involves weekly presentations by scholars and engineers, readings, short writing assignments, small-group discussion, and hands-on, student-driven projects. Students can enroll in the course for 1 unit (lectures only), or 3 units (lectures+discussion+project). For 1 unit, students should sign up for Section 1 and Credit/No Credit grading, and for 3 units students should sign up for Section 2 and either the C/NC or Grade option.
Same as: CSRE 117, CSRE 217, ENGR 117, FEMGEN 117, FEMGEN 217

ENGR 219. Community Engagement Preparation Seminar. 1 Unit.
This seminar is designed for engineering students who have already committed to an experiential learning program working directly with a community partner on a project of mutual benefit. This seminar is targeted at students participating in the Summer Service Learning Program offered through Stanford¿s Global Engineering Program.
Same as: ENGR 119

ENGR 231. Transformative Design. 3 Units.
Too many alums are doing what they've always been told they're good at, and are living with regret and a sense that they're just resigned to doing this thing for the rest of their lives. Capabilities displaced their values as the primary decision driver in their lives. Our ultimate goal is to restore a sense of agency and passion into the lives of current Stanford students by creating the space to explore and experiment with the greatest design project possible: YOUR LIFE. We will turn d.school tools and mindsets onto the topic of our lives -- not in theory, but in reality -- and will prototype changes to make your life and career more fulfilling and rewarding. We will actively empathize and experiment in your life and work, so if you don't want to do that kind of self-examination, this class will not be a good fit for you.

ENGR 240. Introduction to Micro and Nano Electromechanical Systems. 3 Units.
Miniaturization technologies now have important roles in materials, mechanical, and biomedical engineering practice, in addition to being the foundation for information technology. This course will target an audience of first-year engineering graduate students and motivated senior-level undergraduates, with the goal of providing an introduction to M/NEMS fabrication techniques, selected device applications, and the design tradeoffs in developing systems. The course has no specific prerequisites, other than graduate or senior standing in engineering; otherwise, students will require permission of the instructors.

ENGR 241. Advanced Micro and Nano Fabrication Laboratory. 3 Units.
This project course focuses on developing processes for ExFab, a shared facility that supports flexible lithography, heterogeneous integration, and rapid micro prototyping. Team projects are approved by the instructor and are mentored by an ExFab staff member. Students will plan and execute experiments and document them in a final presentation and report, to be made available on the lab's Wiki for the benefit of the Stanford research community. This year's offering of ENGR241 will span two quarters: students interested in taking this course must sign up for both fall and winter courses, and will be researching a single project over that time. Students must consult with Prof. Fan or the SNF staff before signing up. For Autumn 18-19, the course will meet from 4:00pm-5:50pm in Allen 101X (note the start time).

ENGR 243. LAW, TECHNOLOGY, AND LIBERTY. 2 Units.
New technologies from gene editing to networked computing have already transformed our economic and social structures and are increasingly changing what it means to be human. What role has law played in regulating and shaping these technologies? And what role can and should it play in the future? This seminar will consider these and related questions, focusing on new forms of networked production, the new landscape of security and scarcity, and the meaning of human nature and ecology in an era of rapid technological change. Readings will be drawn from a range of disciplines, including science and engineering, political economy, and law. The course will feature several guest speakers. There are no formal prerequisites in either engineering or law, but students should be committed to pursuing novel questions in an interdisciplinary context. The enrollment goal is to balance the class composition between law and non-law students. Elements used in grading: Attendance, Class Participation, Written Assignments. CONSENT APPLICATION: To apply for this course, students must complete and submit a Consent Application Form available on the SLS website (Click Courses at the bottom of the homepage and then click Consent of Instructor Forms). See Consent Application Form for instructions and submission deadline. This course is cross-listed with the School of Engineering (TBA). May be repeat for credit.
Same as: BIOE 242

ENGR 245. The Lean LaunchPad: Getting Your Lean Startup Off the Ground. 3-4 Units.
Learn how to turn a technical idea from a lab, research, or vision into a successful business using the Lean Launchpad process (business model canvas, customer development, running experiments, and agile engineering.) Hands-on experiential class. 15+ hours per week talking to customers, regulators and partners outside the classroom, plus time building minimal viable products. This class is the basis of the National Science Foundation I-Corps ¿ with a focus on understanding all the components to build for deep technology and life science applications. Team applications required in March. Proposals may be software, hardware, or service of any kind. See course website http://leanlaunchpad.stanford.edu/. Prerequisite: interest in and passion for exploring whether your technology idea can become a real company. Limited enrollment.

ENGR 248. Principled Entrepreneurial Decisions. 3 Units.
Examines how leaders tackle significant events that occur in high-growth entrepreneurial companies. Students prepare their minds for the difficult entrepreneurial situations that they will encounter in their lives in whatever their chosen career. Cases and guest speakers discuss not only the business rationale for the decisions taken but also how their principles affected those decisions. The teaching team brings its wealth of experience in both entrepreneurship and VC investing to the class. Previous entrepreneurship coursework or experience preferred. Limited enrollment. Admission by application: http://web.stanford.edu/class/engr248/apply.
Same as: ENGR 148

ENGR 250. Data Challenge Lab. 1-6 Unit.
In this lab, students develop the practical skills of data science by solving a series of increasingly difficult, real problems. Skills developed include: data manipulation, exploratory data analysis, data visualization, and predictive modeling. The data challenges each student undertakes are based upon their current skills. Students receive one-on-one coaching and see how expert practitioners solve the same challenges. Prerequisite: ENGR150. Limited enrollment; application required. May be repeated for credit. See http://datalab.stanford.edu for more information.

ENGR 277A. Engineering and Sustainable Development: Toolkit. 1-3 Unit.
The first of a two-quarter, project-based course sequence that address cultural, sociopolitical, organizational, technical, and ethical issues at the heart of implementing sustainable engineering projects in a developing world. Students work in interdisciplinary project teams to tackle real-world design challenges in partnership with social entrepreneurs, local communities, and/or NGOs. While students must have the skills and aptitude necessary to make meaningful contributions to technical product designs, the course is open to all backgrounds and majors. The first quarter focuses on cultural awareness, ethical implications, user requirements, conceptual design, feasibility analysis, and implementation planning. Admission is by application. Students should plan to enroll in CEE 177S/277S (ENGR 177B/277B) Engineering & Sustainable Development: Implementation following successful completion of this course. Designated a Cardinal Course by the Haas Center for Public Service. To satisfy a Ways requirement, students must register for an undergraduate course number (CEE 177S or ENGR 177A) and this course must be taken for at least 3 units. In AY 2020-21, a letter grade or `CR' grade satisfies the Ways requirement.
Same as: CEE 177X, CEE 277X, ENGR 177A

ENGR 277B. Engineering and Sustainable Development. 1-3 Unit.
The second of a two-quarter, project-based course sequence that address cultural, political, organizational, technical and business issues at the heart of implementing sustainable engineering projects in the developing world. Students work in interdisciplinary project teams to tackle real-world design challenges in partnership with social entrepreneurs and/or NGOs. This quarter focuses on implementation, evaluation, and deployment of the designs developed in the winter quarter. Designated a Cardinal Course by the Haas Center for Public Service.
Same as: CEE 177S, CEE 277S, ENGR 177B

ENGR 280. From Play to Innovation. 2-4 Units.
Focus is on enhancing the innovation process with playfulness. The class will be project-based and team-centered. We will investigate the human "state of play" to reach an understanding of its principal attributes and how important it is to creative thinking. We will explore play behavior, its development, and its biological basis. We will then apply those principles through design thinking to promote innovation in the corporate world. Students will work with real-world partners on design projects with widespread application. This course requires an application. You can find the application here: dschool.stanford.edu/classes.

ENGR 281. d.media - Designing Media that Matters. 2-3 Units.
The combination of always-on smartphones, instant access to information and global social sharing is changing behavior and shifting cultural norms. How can we design digital experiences that make this change positive? Join the d.media team and find out! This course is project-based and hands-on. Three projects will explore visual design, interaction design and behavioral design all in the context of today's technology landscape and in service of a socially positive user experience. See http://dmedia.stanford.edu, Admission by application. See dschool.stanford.edu/classes for more information.

ENGR 295. Learning & Teaching of Science. 3 Units.
This course will provide students with a basic knowledge of the relevant research in cognitive psychology and science education and the ability to apply that knowledge to enhance their ability to learn and teach science, particularly at the undergraduate level. Course will involve readings, discussion, and application of the ideas through creation of learning activities. It is suitable for advanced undergraduates and graduate students with some science background.
Same as: EDUC 280, MED 270, PHYSICS 295, VPTL 280

ENGR 298. Seminar in Fluid Mechanics. 1 Unit.
Interdepartmental. Problems in all branches of fluid mechanics, with talks by visitors, faculty, and students. Graduate students may register for 1 unit, without letter grade; a letter grade is given for talks. May be repeated for credit.

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

ENGR 311A. Women's Perspectives. 1 Unit.
Graduate seminar series, driven by student interests, with guest speakers from academia and industry. Previous themes have included Finding your North, Becoming Fearless, Daydreams to Reality, and Letters to My Younger Self. Discussion is encouraged as graduate students share experiences and learn with speakers and each other. Possible topics of discussion range from time management and career choices to diversity, health, and family. Several optional informal dinners are hosted after the seminar to continue conversation with the speakers. May be repeated for credit.

ENGR 311B. Designing the Professional. 1 Unit.
Wondering how to weave together what really fits you, is doable, and will be satisfying and meaningful? Have more questions than answers? Have too many ideas for your career, or not enough? This course applies the mindsets and innovation principles of design thinking to the "wicked problem" of designing your life and vocation. Students gain awareness and empathy, define areas of life and work on which they want to work, ideate about ways to move forward, try small prototypes, and test their assumptions. The course is highly interactive. It will conclude with creation of 3 versions of the next 5 years and prototype ideas to begin making those futures a reality. The course will include brief readings, writing, reflections, and in-class exercises. Expect to practice ideation and prototyping methodologies, decision making practices and to participate in interactive activities in pairs, trios, and small groups. Seminar open to all graduate students and Postdocs in all 7 schools.

ENGR 311D. Portfolio to Professional: Supporting the Development of Digital Presence Through ePortfolios. 1 Unit.
This course guides graduate students in creating a professional ePortfolio and establishing an online presence. The course includes seminar-style presentations and discussions, opportunities for feedback with career mentors, classmates, alumni, employers, and other community members using think-aloud protocols and peer review approaches. Curriculum modules focus on strategies for telling your story in the digital environment, platform considerations, evidence and architecture, visual design and user experience. Open to all graduate students and majors.

ENGR 312. Science and Engineering Course Design. 2-3 Units.
For students interested in an academic career and who anticipate designing science or engineering courses at the undergraduate or graduate level. Goal is to apply research on science and engineering learning to the design of effective course materials. Topics include syllabus design, course content and format decisions, assessment planning and grading, and strategies for teaching improvement.
Same as: CTL 312

ENGR 313. Topics in Engineering and Science Education. 1-2 Unit.
This seminar series focuses on topics related to teaching science, technology, engineering, and math (STEM) courses based on education research. Each year focuses on a different topic related to STEM education. This course may be repeated for credit each year. This year we will explore problem-based learning in STEM courses, particularly focusing on design and evaluation of problem-based learning activities. The course will involve in-class discussions, small group activities, and guest lectures. Throughout the quarter, there will be several opportunities for directly practicing and applying STEM education strategies to specific teaching goals in your field.

ENGR 341. Micro/Nano Systems Design and Fabrication. 3-5 Units.
Laboratory course in micro and nano fabrication technology that combines lectures on theory and fundamentals with hands-on training in the Stanford Nanofabrication Facility. Prerequisite: ENGR 240 or equivalent.

ENGR 342. MEMS Laboratory II. 3-4 Units.
Emphasis is on tools and methodologies for designing and fabricating N/MEMS-based solutions. Student interdisciplinary teams collaborate to invent, develop, and integrate N/MEMS solutions. Design alternatives fabricated and tested with emphasis on manufacturability, assembly, test, and design. Limited enrollment. Prerequisite: ENGR 341.

ENGR 350. Data Impact Lab. 1-6 Unit.
In this lab, multi-disciplinary teams of students tackle high-impact, unsolved problems for social sector partners. Teams receive mentorship and coaching from Stanford faculty, domain experts, and data science experts from industry. Sample projects include innovations for: poverty alleviation in the developing world, local government services, education, and healthcare. Limited enrollment; application required. May be repeated for credit. See http://datalab.stanford.edu for more information.

ENGR 391. Engineering Education and Online Learning. 3 Units.
A project based introduction to web-based learning design. In this course we will explore the evidence and theory behind principles of learning design and game design thinking. In addition to gaining a broad understanding of the emerging field of the science and engineering of learning, students will experiment with a variety of educational technologies, pedagogical techniques, game design principles, and assessment methods. Over the course of the quarter, interdisciplinary teams will create a prototype or a functioning piece of educational technology.
Same as: EDUC 391

ENGR 395. Summer Opportunities in Engineering Research & Leadership. 1 Unit.
Summer First provides Fellows from a range of engineering disciplines the opportunity to gain exposure to the wealth of resources on campus, and explore the research environment(s) in their own doctoral programs. This experience effectively serves as a supplementary research rotation for these graduate students, enabling them to explore research options over an additional quarter. Fellows also engage in small literature discussion groups, professional development workshops, excursions, mentoring opportunities, and social activities as a mechanism for fostering a sense of belonging and community. Fellows are incoming first year PhD students nominated by their departments. Instructor permission required.