MECHANICAL ENGINEERING

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

The programs in the Department of Mechanical Engineering (ME) emphasize a mix of applied mechanics, biomechanical engineering, computer simulations, design, and energy science and technology. Since mechanical engineering is a broad discipline, the undergraduate program can be a springboard for graduate study in business, law, medicine, political science, and other professions where understanding technology is important. Both undergraduate and graduate programs provide technical background for work in biomechanical engineering, environmental pollution control, ocean engineering, transportation, and other multidisciplinary problems that concern society. In all programs, emphasis is placed on developing systematic procedures for analysis, communication of work and ideas, practical and aesthetic aspects in design, and responsible use of technology.

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 intellectual and practical experiences that enable them to address a variety of societal needs. The curriculum encompasses elements from a wide array 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 another field where a broad engineering background is useful.

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:

1. an ability to apply knowledge of mathematics, science, and engineering.
2. an ability to design and conduct experiments, as well as to analyze and interpret data.
3. an ability to design a system, component, or process to meet desired needs.
4. an ability to function on multidisciplinary teams.
5. an ability to identify, formulate, and solve engineering problems.
6. an understanding of professional and ethical responsibility.
7. an ability to communicate effectively.
8. the broad education necessary to understand the impact of engineering solutions in a global and societal context.
9. a recognition of the need for and an ability to engage in life-long learning.
10. a knowledge of contemporary issues.
11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice..
12. the ability to apply advanced mathematics through multivariate calculus and differential equations.
13. the ability to work professionally in both thermal and mechanical systems areas including the design and realization of such systems.

Learning Outcomes (Graduate)

The purpose of the master's program is to provide students with the knowledge and skills necessary for a professional career or doctoral studies. This is done through course work providing depth in one area of specialization and breadth in complementary areas. Areas of specialization range from automatic controls, energy systems, fluid mechanics, heat transfer, and solid mechanics to biomechanical engineering, MEMS, and design.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research. Through course work and guided research, the program prepares students to make original contributions in Mechanical Engineering and related fields.

Graduate Programs in Mechanical Engineering

Admission and Financial Assistance

To be eligible for admission to the department, a student must have a B.S. degree in engineering, physics, or a comparable science program. To apply for the Ph.D. degree, applicants must have already completed an M.S. degree. PhD admission is based upon not only the admissions application, but faculty sponsorship within the department, which must be arranged prior to admission. Applications for Ph.D. and HCP (Honors Co-op) programs are accepted each quarter. M.S. applications must be received by the first Tuesday in December, and admitted students must matriculate in Autumn. The department annually awards, on a competitive basis, a limited number of fellowships, teaching assistantships, and research assistantships to incoming graduate students. Research assistantships are used primarily for post-master's degree students and are awarded by individual faculty research supervisors, not by the department.

Mechanical engineering is a varied profession, ranging from primarily aesthetic aspects of design to highly technical scientific research. Disciplinary areas of interest to mechanical engineers include biomechanics, energy conversion, fluid mechanics, materials, nuclear reactor engineering, propulsion, rigid and elastic body mechanics, systems engineering, scientific computing, and thermodynamics, to name a few. No mechanical engineer is expected to have a mastery of the entire spectrum.

A master's degree program leading to the M.S. is offered in Mechanical Engineering, and a master's degree program leading to the M.S. is offered in Engineering with a choice of the following fields of study: Biomechanical Engineering, Product Design, and an individually designed major.

Post-Master's Degree Programs

The department offers two post-master's degrees: Engineer and Doctor of Philosophy. Post-master's research generally requires some evidence that a student has research potential before a faculty member agrees to supervision and a research assistantship appointment. It is most efficient to carry out preliminary research during the M.S. degree program, if interested in a post-master's degree.

Departmental Groups

The department has five groups: Biomechanical Engineering; Design; Flow Physics and Computation; Mechanics and Computation; and Thermosciences. Each maintains its own labs, shops, and offices.

The Biomechanical Engineering (BME) Group has teaching and research activities which focus primarily on musculoskeletal biomechanics, neuromuscular biomechanics, cardiovascular biomechanics, and rehabilitation engineering. Research in other areas including hearing, ocean, plant, and vision biomechanics exists in collaboration with associated faculty in biology, engineering, and medicine. The group has strong research interactions with the Mechanics and Computation and the Design groups, and the departments of Neurology, Radiology, and Surgery in the School of Medicine.

The Design Group is devoted to the imaginative application of science, technology, and art to the conception, visualization, creation, analysis and realization of useful devices, products, and objects. Courses and research focus on topics such as kinematics, applied finite elements, microprocessors, medical devices, fatigue and fracture mechanics, dynamics and simulation, micro-electromechnical systems (MEMS), rehabilitation, optimization, high-speed devices, product design, vehicle dynamics, experimental mechanics, robotics, creativity, idea visualization, computer-aided design, manufacturing, design analysis, and engineering education.

The Flow Physics and Computational Engineering Group (FPCE) The Flow Physics and Computational Engineering Group (FPCE) blends research on flow physics and modeling with algorithm development, scientific computing, and numerical database construction. FPCE is contributing new theories, models and computational tools for accurate engineering design analysis and control of complex flows (including multi phase flows, micro-fluidics, chemical reactions, acoustics, plasmas, interactions with electromagnetic waves and other phenomena) in aerodynamics, propulsion and power systems, materials processing, electronics cooling, environmental engineering, and other areas. A significant emphasis of research is on modeling and analysis of physical phenomena in engineering systems.

The Mechanics and Computational Group covers biomechanics, continuum mechanics, dynamics, experimental and computational mechanics, finite element analysis, fluid dynamics, fracture mechanics, micromechanics, nanotechnology, and simulation based design. Qualified students can work as research project assistants, engaging in thesis research in association with the faculty director and fellow students. Projects include analysis, synthesis, and control of systems; biomechanics; flow dynamics of liquids and gases; fracture and micro-mechanics, vibrations, and nonlinear dynamics; and original theoretical, computational, and experimental investigations in the strength and deformability of elastic and inelastic elements of machines and structures.

The Thermosciences Group conducts experimental and analytical research on both fundamental and applied topics in the general area of thermal and fluid systems. Research strengths include high Reynolds number flows, microfluidics, combustion and reacting flows, multiphase flow and combustion, plasma sciences, gas physics and chemistry, laser diagnostics, microscale heat transfer, convective heat transfer, and energy systems. Research motivation comes from applications including air-breathing and space propulsion, bioanalytical systems, pollution control, electronics fabrication and cooling, stationary and mobile energy systems, biomedical systems, and materials processing. Emphasis is on fundamental experiments leading towards advances in modeling, optimization, and control of complex systems.

Facilities

The department groups maintain modern laboratories that support undergraduate and graduate instruction and graduate research work.

The Structures and Composites Laboratory, a joint activity with the Department of Aeronautics and Astronautics, studies structures made of fiber-reinforced composite materials. Equipment for fabricating structural elements includes autoclave, filament winder, and presses. X-ray, ultrasound, and an electron microscope are available for nondestructive testing. The lab also has environmental chambers, a high speed impactor, and mechanical testers. Lab projects include designing composite structures, developing novel manufacturing processes, and evaluating environmental effects on composites.

Experimental facilities are available through the interdepartmental Structures and Solid Mechanics Research Laboratory, which includes an electrohydraulic materials testing system, a vehicle crash simulator, and a shake table for earthquake engineering and related studies, together with highly sophisticated auxiliary instrumentation. Facilities to study the micromechanics of fracture areas are available in the Micromechanics/Fracture Laboratory, and include a computer-controlled materials testing system, a long distance microscope, an atomic force microscope, and other instrumentation. Additional facilities for evaluation of materials are available through the Center for Materials Research, Center for Integrated Circuits, and the Ginzton Laboratory. Laboratories for biological experimentation are accessible through the School of Medicine. Individual accommodation is available for the work of each research student.

Major experimental and computational laboratories engaged in bioengineering work are located in the Biomechanical Engineering Group. Other Biomechanical Engineering Group activities and resources are associated with the Rehabilitation Research and Development Center of the Veterans Administration Palo Alto Health Care System. This major national research center has computational and prototyping facilities. In addition, the Rehabilitation Research and Development Center houses the Electrophysiology Laboratory, Experimental Mechanics Laboratory, Human Motor Control Laboratory, Rehabilitation Device Design Laboratory, and Skeletal Biomechanics Laboratory. These facilities support graduate course work as well as Ph.D. student research activities.

Computational and experimental work is also conducted in various facilities throughout the School of Engineering and the School of Medicine, particularly the Advanced Biomaterials Testing Laboratory of the Department of Materials Science and Engineering, the Orthopaedic Research Laboratory in the Department of Functional Restoration, and the Vascular Research Laboratory in the Department of Surgery. In collaboration with the School of Medicine, facilities throughout the Stanford Medical Center and the Veterans Administration Palo Alto Health Care System conduct biological and clinical work.

The Design Group has facilities for lab work in experimental mechanics and experimental stress analysis. Additional facilities, including MTS electrohydraulic materials test systems, are available in the Solid Mechanics Research Laboratory. Design Group students also have access to Center for Integrated Systems (CIS) and Ginzton Lab microfabrication facilities.

The group also maintains the Product Realization Laboratory (PRL), a teaching facility offering students integrated experiences in market definition, product design, and prototype manufacturing. The PRL provides coaching, design manufacturing tools, and networking opportunities to students interested in product development. The ME 310 Design Project Laboratory has facilities for CAD, assembly, and testing of original designs by master's students in the engineering design program. A Smart Product Design Laboratory supports microprocessor application projects. The Center for Design Research (CDR) has an excellent facility for concurrent engineering research, development, and engineering curriculum creation and assessment. Resources include a network of high-performance workstations. For worldwide web mediated concurrent engineering by virtual, non-collocated, design development teams, see the CDR web site at http://cdr.stanford.edu . In addition, CDR has several industrial robots for student projects and research. These and several NC machines are part of the CDR Manufacturing Sciences Lab. The Manufacturing Modeling Laboratory (MML) addresses various models and methods that lead to competitive manufacturing. MML links design for manufacturing (dfM) research at the Department of Mechanical Engineering with supply chain management activities at the Department of Management Science and Engineering. The Rapid Prototyping Laboratory consists of seven processing stations including cleaning, CNC milling, grit blasting, laser deposition, low temperature deposition, plasma deposition, and shot peening. Students gain experience by using ACIS and Pro Engineer on Hewlett Packard workstations for process software development. The Design Group also has a Product Design Loft in which students in the Joint Program in Design develop graduate thesis projects.

The Flow Physics and Computation Group has a 32 processor Origin 2000, 48-node and 85-node Linux cluster with high performance interconnection and an array of powerful workstations for graphics and data analysis. Several software packages are available, including all the major commercial CFD codes. FPC is strongly allied with the Center for Turbulence Research (CTR), a research consortium between Stanford and NASA, and the Center for Integrated Turbulence Simulations (CITS), which is supported by the Department of Energy (DOE) under its Accelerated Strategic Computing Initiative (ASCI). The Center for Turbulence Research has direct access to major national computing facilities located at the nearby NASA-Ames Research Center, including massively parallel super computers. The Center for Integrated Turbulence Simulations has access to DOE's vast supercomputer resources. The intellectual atmosphere of the Flow Physics and Computation Group is greatly enhanced by the interactions among CTR's and CITS's postdoctoral researchers and distinguished visiting scientists.

The Mechanics and Computation Group has a Computational Mechanics Laboratory that provides an integrated computational environment for research and research-related education in computational mechanics and scientific computing. The laboratory houses Silicon Graphics, Sun, and HP workstations and servers, including an 8-processor SGI Origin2000 and a 16-processor networked cluster of Intel-architecture workstations for parallel and distributed computing solutions of computationally intensive problems. Software is available on the laboratory machines, including commercial packages for engineering analysis, parametric geometry and meshing, and computational mathematics. The laboratory supports basic research in computational mechanics as well as the development of related applications such as simulation-based design technology.

The Thermosciences Group has four major laboratory facilities. The Heat Transfer and Turbulence Mechanics Laboratory concentrates on fundamental research aimed at understanding and improved prediction of turbulent flows and high performance energy conversion systems. The laboratory includes two general-purpose wind tunnels, a pressurized high Reynolds number tunnel, two supersonic cascade flow facilities, three specialized boundary layer wind tunnels, and several other flow facilities. Extensive diagnostic equipment is available, including multiple particle-image velocimetry and laser-Doppler anemometry systems.

The High Temperature Gas Dynamics Laboratory includes research on sensors, plasma sciences, cool and biomass combustion and gas pollutant formation, and reactive and non-reactive gas dynamics. Research facilities include diagnostic devices for combustion gases, a spray combustion facility, laboratory combustors including a coal combustion facility and supersonic combustion facilities, several advanced laser systems, a variety of plasma facilities, a pulsed detonation facility, and four shock tubes and tunnels. The Thermosciences Group and the Design Group share the Microscale Thermal and Mechanical Characterization laboratory (MTMC). MTMC is dedicated to the measurement of thermal and mechanical properties in thin-film systems, including microfabricated sensors and actuators and integrated circuits, and features a nanosecond scanning laser thermometry facility, a laser interferometer, a near-field optical microscope, and an atomic force microscope. The activities at MTMC are closely linked to those at the Heat Transfer Teaching Laboratory (HTTL), where undergraduate and master's students use high-resolution probe stations to study thermal phenomena in integrated circuits and thermally-actuated microvalves. HTTL also provides macroscopic experiments in convection and radiative exchange.

The Energy Systems Laboratory is a teaching and research facility dedicated to the study of energy conversion systems. The lab includes three dynamometers for engine testing, a computer-controlled variable engine valve controller, a fuel-cell experimental station, a small rocket testing facility, and a small jet engine thrust stand.

The Guidance and Control Laboratory, a joint activity of the Department of Aeronautics and Astronautics and the Department of Mechanical Engineering, specializes in construction of electromechanical systems and instrumentation, particularly where high precision is a factor. Work ranges from robotics for manufacturing to feedback control of fuel injection systems for automotive emission control. The faculty and staff work in close cooperation with both the Design and Thermosciences Groups on device development projects of mutual interest.

Many computation facilities are available to department students. Three of the department's labs are equipped with super-minicomputers. Numerous smaller minicomputers and microcomputers are used in the research and teaching laboratories.

Library facilities at Stanford beyond the general library include Engineering, Mathematics, and Physics department libraries.

Mechanical Engineering Course Catalog Numbering System

The department uses the following course numbering system:

Number	Level
010-099	Freshman and Sophomore
100-199	Junior and Senior
200-299	Advanced Undergraduate and Beginning Graduate
300-399	Graduate
400-499	Advanced Graduate
500	Ph.D. Thesis

Bachelor of Science in Mechanical Engineering

Undergraduates seeking to major in Mechanical Engineering should see the curriculum outlined in the "Undergraduate Degree in Mechanical Engineering" section of this bulletin. The University's basic requirements for the bachelor's degree are discussed in the "Undergraduate Degrees" section of this bulletin. Courses taken for the departmental major (mathematics; science; science, technology, and society; engineering fundamentals; and engineering depth) must be taken for a letter grade if the instructor offers the option.

A Product Design program offered by the Design Group leads to the B.S. in Engineering (Product Design). A major in Biomechanical Engineering offered by the Biomechanical Engineering Group leads to the B.S. in Engineering (Biomechanical Engineering); this may be appropriate for students preparing for medical school or graduate bioengineering studies.

Grade Requirements

To be recommended by the department for a B.S. in Mechanical Engineering, a student must achieve the minimum grade point average (GPA) set by the School of Engineering (2.0 in engineering fundamentals and mechanical engineering depth).

Students interested in the minor should see the "Minor in Mechanical Engineering" section of this bulletin.

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.

Requirements

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		16
Science		
20 units minimum; see Basic Requirement 2 [1]		
CHEM 31X	Chemical Principles Accelerated	5
Plus addtional required courses [1]		15
Technology in Society		
One course required; must be on SoE Approved Courses list at <ughb.stanford.edu> the year taken.; see Basic Requirement 4		3-5
Engineering Fundamentals		
Three courses minimum; see Basic Requirement 3 [2]		
ENGR 40	Introductory Electronics	5
ENGR 70A	Programming Methodology (same as CS 106A)	5
Fundamentals Elective [2]		3-5
Engineering Depth		
Minimum of 68 Engineering Science and Design ABET units; see Basic Requirement 5		
ENGR 14	Intro to Solid Mechanics	4
ENGR 15	Dynamics	4
ENGR 30	Engineering Thermodynamics	3
ME 70	Introductory Fluids Engineering	4
ME 80	Mechanics of Materials	4
ME 101	Visual Thinking	4
ME 103D	Engineering Drawing and Design [3]	1
ME 112	Mechanical Systems Design [4]	4
ME 113	Mechanical Engineering Design	4
or ME 114	Consumer Analytical Product Design	
ME 131A	Heat Transfer	3-5
ME 131B	Fluid Mechanics: Compressible Flow and Turbomachinery	4
ME 140	Advanced Thermal Systems [4]	5
or ME 141	Alternative Energy Systems	
ME 161	Dynamic Systems, Vibrations and Control	4
ME 203	Design and Manufacturing [3]	4

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 31X Chemical Principles Accelerated but at a slower pace. CHEM 31X Chemical Principles Accelerated is recommended.
2. ME Fundamental elective may not be a course counted for other requirements. Students may opt to use ENGR 14 Intro to Solid Mechanics, ENGR 15 Dynamics, or ENGR 30 Engineering Thermodynamics from the required depth courses as the third fundamental class. However, total units for Engineering Topics (Fundamentals + Depth) must be a minimum of 68 units; additional options courses may be required to meet unit requirements. ENGR 70A (CS 106A) must be taken for 5 units.
3. Courses ME 103D and ME 203 must be taken concurrently .
4. ME 112, ME 131A, and ME 140 or ME 141, together fulfill the WIM requirement.

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

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

Honors Program

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 April 25. Further revisions and final endorsement by the adviser are to be finished by May 15, 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.

Mechanical Engineering (ME) Minor

The following courses fulfill the minor requirements:

		Units
General Minor *		
ENGR 14	Intro to Solid Mechanics	4
ENGR 15	Dynamics	4
ENGR 30	Engineering Thermodynamics	3
ME 70	Introductory Fluids Engineering	4
ME 101	Visual Thinking	4
Plus two of the following:		8-9
ME 80	Mechanics of Materials	
ME 131A	Heat Transfer	
ME 161	Dynamic Systems, Vibrations and Control	
ME 203	Design and Manufacturing	
Thermosciences Minor **		
ENGR 14	Intro to Solid Mechanics	4
ENGR 30	Engineering Thermodynamics	3
ME 70	Introductory Fluids Engineering	4
ME 131A	Heat Transfer	5
ME 131B	Fluid Mechanics: Compressible Flow and Turbomachinery	4
ME 140	Advanced Thermal Systems	5
Mechanical Design Minor ***		
ENGR 14	Intro to Solid Mechanics	4
ENGR 15	Dynamics	4
ME 80	Mechanics of Materials	4
ME 101	Visual Thinking	4
ME 112	Mechanical Systems Design	4
ME 203	Design and Manufacturing	4
Plus one of the following:		3-4
ME 113	Mechanical Engineering Design	
ME 210	Introduction to Mechatronics	
ME 220	Introduction to Sensors	
Total Units		79-81

* This minor aims to expose students to the breadth of ME in terms of topics and analytic and design activities. Prerequisites: MATH 41 Calculus, MATH 42 Calculus, and PHYSICS 41 Mechanics.

** Prerequisites: MATH 41 Calculus, MATH 42 Calculus, MATH 51 Linear Algebra and Differential Calculus of Several Variables (or CME 100 Vector Calculus for Engineers) and PHYSICS 41 Mechanics.

*** This minor aims to expose students to design activities supported by analysis. Prerequisites: MATH 41 Calculus, PHYSICS 42 Classical Mechanics Laboratory, and PHYSICS 41 Mechanics.

Coterminal Master of Science Program in Mechanical Engineering

Stanford undergraduates who wish to continue their studies for the master of science degree in the coterminal program must have earned a minimum of 120 units towards graduation. This includes allowable Advanced Placement (AP) and transfer credit. Applicants must submit he Application for Admission to Coterminal Masters' Program (http://registrar.stanford.edu/pdf/CotermApplic.pdf) no later than the quarter prior to the expected completion of their undergraduate degree. This is normally Winter Quarter (late January) prior to Spring Quarter graduation.

The application must provide evidence of potential for strong academic performance as a graduate student. The Mechanical Engineering department graduate admissions committee makes decisions on each application. Typically, a GPA of at least 3.5 in engineering, science, and math is expected. Applicants must have completed two of ME 80 Mechanics of Materials, ME 112 Mechanical Systems Design, ME 131A Heat Transfer, and ME 131B Fluid Mechanics: Compressible Flow and Turbomachinery, and must take the Graduate Record Examination (GRE) before action is taken on the application.

Coterminal information, applications deadlines, and forms can be obtained from the ME student services office.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/archive/2016-17/cotermdegrees) " section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/archive/2016-17/graduatedegrees/#masterstext) " section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken three quarters prior to the first graduate quarter, or later, are eligible for consideration for transfer to the graduate career. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Master of Science in Mechanical Engineering

The basic University requirements for the M.S. degree are discussed in the "Graduate Degrees (http://exploredegrees.stanford.edu/archive/2016-17/graduatedegrees) " section of this bulletin.

The master's program consists of 45 units of course work taken at Stanford. No thesis is required, although many students become involved in research projects during the master's program, particularly to explore their interests in working towards a Ph.D. degree. Students whose undergraduate backgrounds are entirely devoid of some of the major subject disciplines of engineering (for example, applied mechanics, applied thermodynamics, fluid mechanics, ordinary differential equations) may need to take some undergraduate courses to fill obvious gaps and prepare themselves to take graduate courses in these areas. Such students may require more than three quarters to fulfill the master's degree requirements, as the makeup courses may only be used as unrestricted electives (see item 4 below) in the M.S. degree program. However, it is not the policy to require fulfillment of mechanical engineering B.S. degree requirements to obtain an M.S. degree.

Mechanical Engineering

The master's degree program requires 45 units of course work taken as a graduate student at Stanford. No thesis is required. However, students who want some research experience during the master's program may participate in research through ME 391 Engineering Problems and ME 392 Experimental Investigation of Engineering Problems.

Students are encouraged to refer to the most recent *Mechanical Engineering Graduate Student Handbook* provided by the student services office. The department's requirements for the M.S. in Mechanical Engineering are as follows:

1. *Mathematical Fundamentals:* two mathematics courses for a total of at least 6 units from the following list are required: ME 300A, 300B, 300C, 408; CME 302; EE 261, 263; ENGR 155C/CME106. Only MATH courses with catalog numbers greater than 100 and CME courses with catalog numbers greater than 200 will count towards the math requirement. However, courses must cover two different areas out of the following choices: partial differential equations, linear algebra, numerical analysis and statistics. This excludes programming classes such as CS 106; CME 211, 212, 213, 214, 292. Those classes can counted towards the Approved Electives category. Courses taken for the math requirement must be taken for a letter grade.
2. *Depth in Mechanical Engineering:* a set of graduate-level courses in Mechanical Engineering to provide depth in one area. The faculty have approved these sets as providing depth in specific areas as well as a significant component of applications of the material in the context of engineering synthesis. These sets are outlined in the *Mechanical Engineering Graduate Student Handbook*. Depth courses must be taken for a letter grade.
3. *Breadth in Mechanical Engineering:* two additional graduate level courses (outside the depth) from the depth/breadth charts listed in the *Mechanical Engineering Graduate Handbook.* Breadth courses must be taken for a letter grade.
4. *Sufficient Mechanical Engineering Course Work:* students must take a minimum of 24 units of course work in mechanical engineering topics. For the purposes of determining mechanical engineering topics, any course on approved lists for the mathematics, depth, and breadth requirements counts towards these units. In addition, any graduate-level course with an ME course number is considered a mechanical engineering topic.
5. *Approved Electives* (to bring the total number of units to at least 39): electives must be approved by an adviser. Graduate engineering, mathematics, and science courses are normally approved. Approved electives must be taken for a letter grade. No more than 6 of the 39 units may come from ME 391/392 (or other independent study/research courses), and no more than 3 may come from seminars. Students planning a Ph.D. should discuss with their advisers the option of taking 391 or 392 during the master's program. ME 391/392 (and other independent study courses) may only be taken on a credit/no credit basis.
6. *Unrestricted electives* (to bring the total number of units submitted for the M.S. degree to 45): students are encouraged to take these units outside engineering, mathematics, or the sciences. Students should consult their advisers on course loads and on ways to use the unrestricted electives to make a manageable program. Unrestricted electives must have catalog numbers greater than 100. Unrestricted electives may be taken CR/NC.
7. Within the courses satisfying the requirements above, there must be at least one graduate-level course with a laboratory component. Courses which satisfy this requirement are:

		Units
ENGR 341	Micro/Nano Systems Design and Fabrication	3-5
ME 203	Design and Manufacturing	4
ME 210	Introduction to Mechatronics	4
ME 220	Introduction to Sensors	3-4
ME 218A	Smart Product Design Fundamentals	4-5
ME 218B	Smart Product Design Applications	4-5
ME 218C	Smart Product Design Practice	4-5
ME 218D	Smart Product Design: Projects	3-4
ME 250	Internal Combustion Engines	3-5
ME 310A	Product-Based Engineering Design, Innovation, and Development	4
ME 310B	Product-Based Engineering Design, Innovation, and Development	4
ME 310C	Project-Based Engineering Design, Innovation, and Development	4
ME 318	Computer-Aided Product Creation	4
ME 323	Modeling and Identification of Mechanical Systems for Control	3
ME 324	Precision Engineering	4
ME 348	Experimental Stress Analysis	3
ME 354	Experimental Methods in Fluid Mechanics	4
ME 367	Optical Diagnostics and Spectroscopy Laboratory	4
ME 385	Tissue Engineering Lab	1-2
ME 391/392	Engineering Problems	1-10

Or other independent study courses may satisfy this requirement if 3 units are taken for work involving laboratory experiments

Candidates for the M.S. in Mechanical Engineering are expected to have the approval of the faculty; they must maintain a minimum grade point average (GPA) of 3.0 in the 45 units presented for fulfillment of degree requirements (exclusive of independent study courses). All courses used to fulfill mathematics, depth, breadth, approved electives, and lab studies must be taken for a letter grade (excluding seminars, independent study, and courses for which a letter grade is not an option for any student).

Students falling below a GPA of 2.5 at the end of 20 units may be disqualified from further registration. Students failing to meet the complete degree requirements at the end of 60 units of graduate registration are disqualified from further registration. Courses used to fulfill deficiencies arising from inadequate undergraduate preparation for mechanical engineering graduate work may not be applied to the 45 units required for completion of the MS degree.

Engineering

As described in the "School of Engineering" section of this bulletin, each department in the school may sponsor students in a more general degree, the M.S. in Engineering. Sponsorship by the Department of Mechanical Engineering (ME) requires (1) filing a petition for admission to the program by no later than the day before instruction begins, and (2) that the center of gravity of the proposed program lies in ME. No more than 18 units used for the proposed program may have been previously completed. The program must include at least 9 units of graduate-level work in the department other than ME 300A,B,C, seminars, and independent study. The petition must be accompanied by a statement explaining the program objectives and how it is coherent, contains depth, and fulfills a well-defined career objective. The grade requirements are the same as for the M.S. in Mechanical Engineering.

Master of Science in Engineering, Biomechanical Engineering

The Master of Science in Engineering: Biomechanical Engineering (MSE:BME) promotes the integration of engineering mechanics and design with the life sciences. Applicants are expected to have additional exposure to biology and/or bioengineering in their undergraduate studies. Students planning for subsequent medical school studies are advised to contact Stanford's Premedical Advising Office in Sweet Hall.

Students wishing to pursue this program must complete the Graduate Program Authorization form and get approval from the Student Services Office. This form serves to officially add the field to the student's record. This form must be filled out electronically on Axess. The Mechanical Engineering Department does not have a coterminal Biomechanical Engineering Master's program.

Degree Requirements

1. Mathematical competence (minimum 6 units) in two of the following areas: partial differential equations, linear algebra, complex variables, or numerical analysis, as demonstrated by completion of two appropriate courses from the following list: ME300A,B,C; MATH106, 109, 113, 131M/P, 132; STATS110, or ENGR155C; CME108, 302. Students who have completed comparable graduate-level courses as an undergraduate, and who can demonstrate their competence to the satisfaction of the instructors of the Stanford courses, may be waived via petition from this requirement by their adviser and the Student Services Office. The approved equivalent courses should be placed in the approved electives category of the program proposal.
2. Graduate Level Engineering Courses (minimum 21 units), consisting of:
   a. Biomechanical engineering restricted electives (9 units) to be chosen from:

		Units
ME 239	Mechanics of the Cell	3
ME 280	Skeletal Development and Evolution	3
ME 281	Biomechanics of Movement	3
ME 287	Mechanics of Biological Tissues	3
ME 337	Mechanics of Growth	3
ME 381	Orthopaedic Bioengineering	3-4
ME 385	Tissue Engineering Lab	1-2
ME 387	Soft Tissue Mechanics	3

   b. Specialty in engineering (9-12 units): A set of three or four graduate level courses in engineering mechanics, materials, controls, or design (excluding bioengineering courses) selected to provide depth in one area. Such sets are approved by the Mechanical Engineering Faculty. Comparable specialty sets composed of graduate engineering courses outside the Mechanical Engineering Department can be used with the approval of the student's adviser. Examples can be obtained from the Biomechanical Engineering Group Office (Durand 223).
   c. Graduate engineering electives (to bring the total number of graduate level engineering units to at least 21). These electives must contribute to a cohesive degree program, and be approved by the student's adviser. No units may come from bioengineering courses, mathematics courses, or seminars.
3. Life science approved electives (minimum 6 units): Undergraduate or graduate biological/medical science/chemistry courses which contribute to a cohesive program.
4. Biomechanical engineering seminar ME 389 Biomechanical Research Symposium.
5. General approved electives (to bring the total number of units to 39): These courses must be approved by the student's adviser. Graduate level engineering, math, and physical science courses and upper division undergraduate or graduate life science courses are normally approved.
6. Unrestricted electives (to bring the total number of units to 45): Students without undergraduate biology are encouraged to use some of these unrestricted units to strengthen their biology background. Students should consult their adviser for recommendations on course loads and on ways to use the unrestricted electives to create a manageable program. Unrestrictive electives must have catalog numbers greater than 100.

All courses except unrestricted electives must be taken for a letter grade unless letter grades are not an option. A minimum cumulative GPA of 3.0 is required for degree conferral.

Master of Science in Engineering, Product Design

The master's program in Design focuses on the synthesis of technology with human needs and market viability (both profit and nonprofit models) to create innovative products, services and experiences. This program is offered by the Department of Mechanical Engineering. It provides a design thinking education that seeks to create design leaders who can transform organizations into cultures of creativity and innovation. Students completing the program will earn a Master of Science in Engineering degree with a concentration in Design (MSE-Design). Students complete the core product design courses in their first year of graduate study at Stanford before undertaking the master's project in their second year.

Degree Requirements

Please check with the Mechanical Engineering Department Student Services Office for updates on degree requirements.

Students must complete the following courses. Students making unsatisfactory degree progress by the end of the first year, at the faculty's discretion, may not advance to the second year (Masters Project Year). A minimum cumulative GPA of 3.0 and 54 units are required for degree conferral.

		Units
ME 203	Design and Manufacturing	4
ME 277	Graduate Design Research Techniques	3-4
ME 391	Engineering Problems (Instructor: Nicole Kahn)	3-4
ME 313	Human Values and Innovation in Design	3
ME 316A/316B/316C	Product Design Master's Project *	2-6
Approved Electives - including at least one d.School class **		24-34

* ME 316A Product Design Master's Project and B/C are taken sequentially for three quarters during the second year. ME316B & C are listed on the d.school website as Design Garage: A Deep Dive in Design Thinking. Students in the program take this sequence for 2-6 units (typically 4 unit) per quarter.

** Students may choose classes (at the 200 level or higher) from any of the schools at the University to fulfill their elective requirement. However, electives that are not already pre-approved must be approved by the student's adviser via petition prior to enrollment. Electives should be chosen to fulfill career objectives; students may focus their energy in engineering, entrepreneurship and business, psychology, or other areas relevant to design. Taking a coherent sequence of electives focused on a subject area is recommended. For example, the patent, negotiation, and licensing classes (ME 208 Patent Law and Strategy for Innovators and Entrepreneurs, ME 265 Technology Licensing and Commercialization) constitute a sequence most relevant to potential inventors. Students interested in social entrepreneurship should apply to the d.school course ME 206A Entrepreneurial Design for Extreme Affordability,B, Extreme Affordability.

Note: All required and approved electives must be taken for a letter grade, if offered, unless prior approval is granted to take a class CR/NC.

Pre-approved electives list

The following courses are pre-approved for fulfilling the elective requirement for the Masters Degree in Engineering - Design. Electives not on this list must be approved via petition prior to enrollment. Electives must be taken for a letter grade unless prior approval is obtained.

		Units
ME 218A/218B/218C	Smart Product Design Fundamentals *	4-5
ME 238	Patent Prosecution	2
ME 208	Patent Law and Strategy for Innovators and Entrepreneurs	2-3
ME 212	Calibrating the Instrument	1
ME 265	Technology Licensing and Commercialization	3
ME 297	Forecasting for Innovators:Technology, Tools & Social Change	3
ME 315	The Designer in Society	3
MS&E 273	Technology Venture Formation	3-4
STRAMGT 353	Entrepreneurship: Formation of New Ventures	4
STRAMGT 356/366	The Startup Garage: Design	4

* Students who opt to take ME 218A/B/C-Smart Products as one of their pre-approved electives should take the sequence during the first year.

Additional requirements

As part of their master's degree program, and in addition to Design Garage (ME316B/C), students are required to take at least one course offered by the Hasso Plattner Institute of Design (the d.School). All d.School courses require applications submitted the quarter prior to the start of class. All d.School classes (with the exception of 'pop-ups') count as pre-approved electives. Suggested classes are found below.

		Units
ME 206A/206B	Entrepreneurial Design for Extreme Affordability *	4
ENGR 231	Transformative Design	3-5
ENGR 280	From Play to Innovation	2-4
ENGR 281	d.media 4.0 - Designing Media that Matters	2-3
ME 301	LaunchPad:Design and Launch your Product or Service	4

* Students who opt to take ME 206A/B Entrepreneurial Design for Extreme Affordability as one of their pre-approved electives should take the sequence during the first year.

Engineer in Mechanical Engineering

The basic University requirements for the degree of Engineer are discussed in the "Graduate Degrees (http://exploredegrees.stanford.edu/archive/2016-17/graduatedegrees) " section of this bulletin.

This degree requires an additional year of study beyond the M.S. degree and includes a research thesis. The program is designed for students who wish to do professional engineering work upon graduation and who want to engage in more specialized study than is afforded by the master's degree alone.

Admission standards are substantially the same as indicated under the master's degree. However, since thesis supervision is required and the availability of thesis supervisors is limited, admission is not granted until the student has personally engaged a faculty member to supervise a research project. This most often involves a paid research assistantship awarded by individual faculty members (usually from the funds of sponsored research projects under their direction). Thus, individual arrangement between student and faculty is necessary. Students studying for the M.S. degree at Stanford who wish to continue to the Engineer degree ordinarily make such arrangements during the M.S. degree program. Students holding master's degrees from other universities are invited to apply and may be admitted providing they are sufficiently well qualified and have made thesis supervision and financial aid arrangements.

Department requirements for the degree include a thesis; up to 18 units of credit are allowed for thesis work (ME 400 Thesis). In addition to the thesis, 27 units of approved advanced course work in mathematics, science, and engineering are expected beyond the requirements for the M.S. degree; the choice of courses is subject to approval of the adviser. Students who have not fulfilled the Stanford M.S. degree requirements are required to do so, with allowance for approximate equivalence of courses taken elsewhere; up to 45 units may be transferable. A total of 90 units is required for degree conferral.

Candidates for the degree must have faculty approval and have a minimum grade point average (GPA) of 3.0 for all courses (exclusive of thesis credit and other independent study courses) taken beyond those required for the master's degree.

Doctor of Philosophy in Mechanical Engineering

The basic University requirements for the Ph.D. degree are discussed in the "Graduate Degree" section of this bulletin. The Ph.D. degree is intended primarily for students who desire a career in research, advanced development, or teaching; for this type of work, a broad background in mathematics and the engineering sciences, together with intensive study and research experience in a specialized area, are the necessary requisites.

Ph.D. students must have a master's degree from another institution, or must fulfill the requirements for the Stanford M.S. degree in Mechanical Engineering or another discipline.

In special situations dictated by compelling academic reasons, Academic Council members who are not members of the department's faculty may serve as the principal dissertation adviser when approved by the department. In such cases, a member of the department faculty must serve as program adviser and as a member of the reading committee, and agree to accept responsibility that department procedures are followed and standards maintained.

Admission involves much the same consideration described under the Engineer degree. Since thesis supervision is required, admission is not granted until the student has personally engaged a member of the faculty to supervise a research project. Once a student has obtained a research supervisor, this supervisor becomes thereafter the student's academic adviser. Research supervisors may require that the student pass the departmental qualifying examination before starting research and before receiving a paid research assistantship. Note that research assistantships are awarded by faculty research supervisors and not by the department.

Prior to being formally admitted to candidacy for the Ph.D. degree, the student must demonstrate knowledge of engineering fundamentals by passing a qualifying examination. The academic level and subject matter of the examination correspond approximately to the M.S. program described above. Typically, the exam is taken shortly after the student completes the M.S. degree requirements. The student is required to have a minimum graduate Stanford GPA of 3.5 to be eligible for the exam (grades from independent study courses are not included in the GPA calculation). Once the student's faculty sponsor has agreed that the exam should be scheduled, the student must submit an application folder containing several items including a curriculum vitae, research project abstract, and preliminary dissertation proposal. Information, examination dates, and deadlines may be obtained from the department's student services office.

Ph.D. candidates must complete a minimum of 21 units (taken for a letter grade) of approved formal course work (excluding research, directed study, and seminars) in advanced study beyond the M.S. degree. The courses should consist primarily of graduate courses in engineering and sciences, although the candidate's adviser may approve a limited number of upper-level undergraduate courses and courses outside of engineering and sciences, as long as such courses contribute to a strong and coherent program. In addition to this 21-unit requirement, all Ph.D. candidates must participate each quarter in one of the following (or equivalent) seminars:

		Units
ME 389	Biomechanical Research Symposium	1
ME 390	Thermosciences Research Project Seminar	1
ME 395	Seminar in Solid Mechanics	1
ME 397	Design Theory and Methodology Seminar	1-3
AA 297	Seminar in Guidance, Navigation, and Control	1
ENGR 298	Seminar in Fluid Mechanics	1
ENGR 311A/311B	Women's Perspectives	1

The department has a breadth requirement for the Ph.D. degree. This may be satisfied either by a formal minor in another department (generally 20 units) or by at least 9 units of course work (outside of the primary research topic) which are approved by the principal dissertation adviser. If a minor is taken, 9 units from the minor requirements can be counted towards the depth requirement.

The Ph.D. thesis normally represents at least one full year of research work and must be a substantial contribution to the field. Students may register for course credit for thesis work (ME 500) to help fulfill University academic unit requirements, but there is no minimum limit on registered dissertation units, as long as students are registered in at least 8 units (10 is recommended) per quarter prior to TGR. Candidates should note that only completed course units are counted toward the requirement, so ungraded courses or courses with an "N" grade must be cleared before going TGR. Questions should be directed to the department student services office.

The final University oral examination (dissertation defense) is conducted by a committee consisting of a chair from another department and four faculty members of the department or departments with related interests. Usually, the committee includes the candidate's adviser, reading committee members, plus two more faculty. The examination consists of two parts. The first is open to the public and is scheduled as a seminar talk, usually for one of the regular meetings of a seminar series. The second is conducted in private and covers subjects closely related to the dissertation topic.

Ph.D. Minor in Mechanical Engineering

Students who wish a Ph.D. minor in ME should consult with the ME student services office. A minor in ME may be obtained by completing 20 units of approved graduate-level ME courses. Courses approved for the minor must form a coherent program and must be chosen from those satisfying requirement 2 for the M.S. in Mechanical Engineering.

See the *Mechanical Engineering Graduate Student Handbook* produced by the Mechanical Engineering student services office for more information.

Emeriti: (Professors) James L. Adams, Peter Bradshaw*, Daniel B. DeBra, Robert H. Eustis, Thomas J. R. Hughes, James P. Johnston, Thomas R. Kane, William M. Kays, Joseph B. Keller, Charles H. Kruger, Robert H. McKim, Robert J. Moffat,* M. Godfrey Mungal*, J. David Powell, Charles R. Steele,* Douglass J. Wilde;* *(Professors, Research)* Richard M. Christensen, Sidney A. Self, Kenneth J. Waldron, Felix E. Zajac

Chair: Kenneth E. Goodson

Group Chairs: Mark R. Cutkosky (Design), Scott L. Delp (Biomechanical Engineering), Parviz Moin (Flow Physics and Computational Engineering), Peter M. Pinsky (Mechanics and Computation), Mark A. Cappelli (Thermosciences)

Professors: Thomas P. Andriacchi, David M. Barnett, Craig T. Bowman, Brian J. Cantwell, Mark A. Cappelli, Dennis R. Carter, Mark R. Cutkosky, Scott L. Delp, John K. Eaton, Christopher F. Edwards, Charbel Farhat, Kenneth E. Goodson, Ronald K. Hanson, David M. Kelley, Thomas W. Kenny, Larry J. Leifer, Sanjiva K. Lele, Arun Majumdar, Reginald E. Mitchell, Parviz Moin, Drew V. Nelson, Peter M. Pinsky, Friedrich B. Prinz, Bernard Roth, Juan G. Santiago, Eric S. G. Shaqfeh, Sheri D. Sheppard, Hai Wang

Associate Professors: Wei Cai, Eric F. Darve, J. Christian Gerdes, Gianluca Iaccarino, Ellen Kuhl, Marc E. Levenston, Adrian J. Lew, Allison M. Okamura, Beth L. Pruitt

Assistant Professors: Ovijit Chaudhuri, W. Matthias Ihme, David Lentink, Ali Mani, Sindy K.-Y. Tang, Xiaolin Zheng

Professor (Teaching): David W. Beach

Associate Professor (Teaching): Shilajeet S. Banerjee

Courtesy Professors: Fu-Kuo Chang, Reinhold Dauskardt, Oussama Khatib, Paul Yock

Courtesy Associate Professor: Margot G. Gerritsen, Nicholas Giori

Courtesy Professor (Research): J. Kenneth Salisbury

Courtesy Professor (Teaching): Shelley V. Goldman

Senior Lecturers: Vadim Khayms, J. Craig Milroy

Consulting Professors: Gary S. Beaupré, J. Edward Carryer, David M. Golden, Barry M. Katz, Paul Mitiguy, Johannes Schoonman, Edith Wilson

Consulting Associate Professors: Mehdi Asheghi, Rainer J. Fasching, John A. Howard, Gary O'Brien, R. Matthew Ohline, Sunil Puria, Paul L. Saffo III, Lester K. Su, Marc F. Theeuwes

Consulting Assistant Professors: Michael R. Barry, William R. Burnett, Jonathan Edelman

* Recalled to active duty.

Cognate Courses

		Units
CS 106A	Programming Methodology	3-5
CS 223A	Introduction to Robotics	3
ENGR 14	Intro to Solid Mechanics	4
ENGR 15	Dynamics	4
ENGR 30	Engineering Thermodynamics	3
ENGR 31		
ENGR 40	Introductory Electronics	5
ENGR 70A	Programming Methodology	3-5
ENGR 105	Feedback Control Design	3
ENGR 205	Introduction to Control Design Techniques	3
ENGR 209A	Analysis and Control of Nonlinear Systems	3
ENGR 240	Introduction to Micro and Nano Electromechanical Systems	3

ENGR 341	Micro/Nano Systems Design and Fabrication	3-5

Overseas Studies Courses in Mechanical Engineering

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

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

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

		Units
OSPBER 4	The Role of Technology in Modern Life: A Comparison between the U.S. and Germany	3
OSPBER 5	What is Engineering? A look at engineers and their work	3
OSPKYOTO 38	From Chashitsu to Muji: a Creative Introduction to the Roots of Contemporary Japanese Design	4

Courses

ME 10N. Form and Function of Animal Skeletons. 3 Units.
Preference to freshmen. The biomechanics and mechanobiology of the musculoskeletal system in human beings and other vertebrates on the level of the whole organism, organ systems, tissues, and cell biology. Field trips to labs.
Same as: BIOE 10N

ME 11SC. The Art and Science of Measuring Fluid Flows. 2 Units.
The roles of fluid flows in natural systems such as swimming protozoa and planet-forming nebulae, and technologies such as biomolecular assay devices and jet engines. The analytical background for fluid sciences. Phenomena such as shock waves and vortex formation that create flow patterns while challenging engineers. Visualization and measurement techniques to obtain full-field flow pattern information. The physics behind these technologies. Field trips; lab work. (Eaton).

ME 12N. The Jet Engine. 3 Units.
Preference to freshmen. This seminar describes how a jet engine works with examples given from modern commercial and military engines. We then explore the technologies and sciences required to understand them including thermodynamics, turbomachinery, combustion, advanced materials, cooling technologies, and testing methods. Visits to research laboratories, examination of a partially disassembled engine, and probable operation of a small jet engine. Prerequisites: high school physics and preferably calculus.

ME 12SC. Hands-on Jet Engines. 2 Units.
How jet engines transformed the world through intercontinental travel causing internationalization in daily life. Competition driving improvements in fuel economy, engine lifetime, noise, and emissions.

ME 13AX. Form & Space. 2 Units.
In this course students will explore the inherent order in 3-dimensional space that underlies and determines nature of form and structure, and then use that knowledge to inform the design and fabrication of original artworks. A survey of relevant artists and architects will suggest the rich potential for creative expression that results from a deep understanding of the nature of space. Topics will include: symmetry, pattern, tessellation, duality, transformation, polyhedra, space-filling.

The course will be conducted in Room 36, a state-of-the art maker space. Students will learn how to use a professional CAD program and a computer-controlled laser cutter to create models out of paper, plastic, and wood. Students will have access to 3D printers, and other digital and analog fabrication tools.

Students considering taking this course need not have any background in the visual arts, but should have a firm foundation and avid interest in geometry. Access to a Mac or Windows Laptops is required.

ME 13N. The Great Principle of Similitude. 3 Units.
Basic rules of dimensional analysis were proposed by Sir Isaac Newton. Lord Rayleigh called the method ¿The Great Principle of Similitude.¿ On its surface, it is a look at the relationships between physical quantities which uses their basic ¿units¿. In fact, it is a powerful and formalized method to analyze complex physical phenomena, including those for which we cannot pose, much less solve, governing equations. The method is also valuable to engineers and scientist as it helps perform back-of-the-envelope estimates and derive scaling laws for the design of machines and processes. The principle has been applied successfully to the study of complex phenomena in biology, aerodynamics, chemistry, sports, astrophysics, and forensics, among other areas. In this course, the students will be provided with the basic tools to perform such flexible and powerful analyses. We will then review particular example analyses. These will include estimating the running speed of a hungry tyrannosaurus rex, a comparison of the flights of mosquitos and jet airliners, the cost of submarines, and the energy released by an atomic weapon. We will then work together as a class to identify problems in everyday life and/or current world events to analyze with this powerful tool.

ME 14N. How Stuff Is Made. 3 Units.
The design and engineering of products and processes, such as machining, fabric, food, and electrical goods. Tradeoffs in choice of materials, features, and process selection. Final project: students research and redesign the engineering and manufacturing aspects of a product and its processes with an eye toward sustainability. Includes several field trips to manufacturing facilities.

ME 16N. Energy & The Industrial Revolution - Past, Present & Future. 3 Units.
When you flip a light switch, or drive to your neighborhood grocery store or do a Google search, it is easy to forget that we receive the benefit of 250 years of industrial revolution, which has been arguably the most remarkable period of human history. This revolution has resulted in exponential growth in the world¿s economy as well as unprecedented prosperity and improvements in our quality of life. The industrial revolution has been largely about how we sourced, distributed and used energy. It was and continues to be predominantly based on fossil energy. But the impact of our traditional energy sources on climate change is one of the most daunting issues of the 21st century because it will affect the world as a whole - the 7-10 billion people, businesses, nations, ecosystems. nnThe choice that our society is asked to make is often posed as follows: Should we continue our exponential economic growth based on fossil fuels and ignore the environment, or should we reduce our greenhouse gas emissions at the cost of our economic growth? This is a false choice because it is based on extrapolating the past. It does not account for the capacity for innovations in technology, finance and business to create sustainable energy future, one that allows the economy and our environment to be mutually inclusive. In short, we need a new industrial revolution. nnThis seminar course will: (a) provide a view of the current energy landscape and the magnitude of the challenge; (b) discuss some techno-economic trends that we are currently witnessing; and (c) identify opportunities to innovate in technology, finance and business that could create the foundations for a new industrial revolution.

ME 17. The Science of Flames. 3 Units.
This course is about what causes flames to look like they do and about what causes them to propagate. The physical and chemical phenomena that govern behaviors of flames will constitute the topics for discussion. The basic principles that govern flame phenomena include the conservation of mass, the first law of thermodynamics, and the momentum principle. Since flame processes are controlled by the rates of chemical reactions, these basic principles will be applied when account is made for the chemical transformations that occur when reactant bonds are broken and new bonds are formed, producing combustion products. In essence, this course serves as an introduction to combustion science.

ME 18Q. Teamology: Creative Teams and Individual Development. 3 Units.
Preference to sophomores. Roles on a problem solving team that best suit individual creative characteristics. Two teams are formed for teaching experientially how to develop less conscious abilities from teammates creative in those roles. Reinforcement teams have members with similar personalities; problem solving teams are composed of people with maximally different personalities.

ME 19. Pre-field Course for Alternative Spring Break: Design for Social Change. 1 Unit.
Focus is on applying design, technology and innovation to catalyze social change. Topics include identifying social needs, learning different brainstorming methods, developing an applicable service model or product, prototyping, implementation, and reiteration. Reading and service components, followed by week-long Alternative Spring Break trip. See http://d4sc.blogspot.com. Enrollment limited to 12. May be repeated for credit.

ME 20N. Haptics: Engineering Touch. 3 Units.
Students in this class will learn how to build, program, and control haptic devices, which are mechatronic devices that allow users to feel virtual or remote environments. In the process, students will gain an appreciation for the capabilities and limitations of human touch, develop an intuitive connection between equations that describe physical interactions and how they feel, and gain practical interdisciplinary engineering skills related to robotics, mechanical engineering, electrical engineering, bioengineering, and computer science. In-class laboratories will give students hands-on experience in assembling mechanical systems, making circuits, programming Arduino microcontrollers, testing their haptic creations, and using Stanford¿s student prototyping facilities. The final project for this class will involve creating a novel haptic device that could be used to enhance human interaction with computers, mobile devices, or remote-controlled robots.

ME 21N. Renaissance Machine Design. 3 Units.
Preference to freshmen. Technological innovations of the 1400s that accompanied the proliferation of monumental art and architecture by Brunelleschi, da Vinci, and others who designed machines and invented novel construction, fresco, and bronze-casting techniques. The social and political climate, from the perspective of a machine designer, that made possible and demanded engineering expertise from prominent artists. Hands-on projectsto provide a physical understanding of Renaissance-era engineering challenges and introduce the pleasure of creative engineering design. Technical background not required.

ME 22N. Smart Robots in our Mix: Collaborating in High Tech Environments of Tomorrow. 3 Units.
This course invites students to explore rules of engagement in a global digitally interconnected world they will create with the robots in their society. The material will be taught in the context of ubiquitous integrated technology that will be part of their future reality. Human-robot interactions will be an integral part of future diverse teams. Students will explore what form will this interaction take as an emerging element of tomorrow's society, be it medical implanted technology or the implications of military use of robots and social media in future society. Students will learn to foster their creative confidence to explore collaboration by differences for social innovation in a digitally networked world.

ME 23Q. The Worldly Engineer. 3 Units.
Preference given to sophomores. Engineering, its practice and products placed in multi-disciplinary context. Topics include the history of the engineering profession and engineering education; cultural influences on design; the role of national and international public policy and economics; dependence on natural resources; environmental impact; contemporary workforce development. Emphasis is on cultivating an appreciation of these issues to enrich the educational and professional pursuit of engineering.

ME 24N. Designing the Car of the Future. 3 Units.
Preference to freshmen. Automotive design drawing from all areas of mechanical engineering. The state of the art in automotive design and the engineering principles to understand vehicle performance. Future technologies for vehicles. Topics include vehicle emissions and fuel consumption, possibilities of hydrogen, drive-by-wire systems, active safety and collision avoidance, and human-machine interface issues.

ME 25N. Energy Sustainability and Climate Change. 3 Units.
One of the primary global challenges of the 21st century is providing the energy required to meet increasing demands due to population growth and economic development. A related challenge is mitigation of the effect of this energy growth on climate. This seminar will examine various scenarios for the energy resources required to meet future demand and the potential consequences on climate. The scientific issues underlying climate change and the coupling of energy use with changes in the global atmosphere that impact climate will be discussed.

ME 26N. Think Like a Designer. 3 Units.
Introduces students to techniques designers use to create highly innovative solutions across domains. The project-based class will emphasize approaches to problem identification and problem solving. Topics include need-finding, structured brainstorming, synthesis, rapid prototyping, and visual communication; field trips to a local design firm, a robotics lab, and a machining lab. A secondary goal of the seminar is to introduce students to the pleasures of creative design and hands-on development of tangible solutions.

ME 27SI. Needfinding for Underserved Populations. 2 Units.
The heart of any design process resides in empathy with users and their needs. Working in the realm of public service may engage a population to which the designer might not have been exposed. How different needfinding techniques can help designers to understand users from underserved populations and inspire them to create products and services that serve user needs.

ME 28SI. Professional Design Practices. 1 Unit.
Lab. Professional skills are developed through web-based portfolio and resume building. Additionally, visits to local design consulting firms and in house design groups will help solidify students understanding of the designer in the professional workplace.May be repeated for credit.

ME 29SI. Cars: A Crash Course. 1 Unit.
Focus is on the basic mechanics and significance of cars. Topics include a basic, real-world understanding of automobile workings, histories, industries, cultural impact, and related media. Field trips to Tesla Motors and Go-Kart Racer will be organized, and there will be guest appearances by local automotive historians and enthusiasts. Students will get hands on experience with maintaining real cars, see high performance engines run, and have the opportunity to learn how to drive a manual transmission.

ME 52SI. Scan, Model, Print! Designing with 3D Technology. 2 Units.
Think 3D scanning, modeling, and printing technology is just about plastic widgets? Think again! Immerse yourself in a world of custom prosthetics, manufacturing in space, autonomous cars, and much more. This hands-on engineering design course teaches advanced 3D imaging and computational modeling skills in order to leverage the unique benefits of additive manufacturing to solve complex problems. Students will connect the theory behind these tools to direct experience with the equipment and software. Short assignments at the start of the quarter will build students' core competencies and prepare them for a team-based, open-ended project. Class time will be a mixture of lecture, lab, guest speakers, and field trips. Recommended: basic CAD, fabrication, and programming experience (e.g. ME103D, 203, CS106A or equivalents).

ME 66SI. Machine Dissection. 2 Units.
This course is designed to help engineering students build their physical intuition through a series of mini-lectures, mechanical ¿dissection¿ activities, student presentations, and a final project. Some of the mechanisms students will dissect include a wind-up toy, fishing reel, and car transmission. Through these activities, students learn the process and value of reverse engineering, develop a better understanding of the design choices made by engineers, become familiar with historically significant mechanisms, and develop both oral and graphical communication skills necessary for working in a technical team. This course is intended for freshman/sophomore engineering students with some knowledge of physics, but little ¿hands on¿ experience.

ME 70. Introductory Fluids Engineering. 4 Units.
Elements of fluid mechanics as applied to engineering problems. Equations of motion for incompressible ideal flow. Hydrostatics. Control volume laws for mass, momentum, and energy. Bernoulli equation. Dimensional analysis and similarity. Flow in ducts. Boundary layer flows. Lift and drag. Lab experiment demonstrations. Prerequisites: ENGR 14 and 30.

ME 80. Mechanics of Materials. 4 Units.
Mechanics of materials and deformation of structural members. Topics include stress and deformation analysis under axial loading, torsion and bending, column buckling and pressure vessels. Introduction to stress transformation and multiaxial loading. Prerequisite: ENGR 14.

ME 101. Visual Thinking. 4 Units.
Lecture/lab. Visual thinking and language skills are developed and exercised in the context of solving design problems. Exercises for the mind's eye. Rapid visualization and prototyping with emphasis on fluent and flexible idea production. The relationship between visual thinking and the creative process. Limited enrollment, attendance at first class required.

ME 103D. Engineering Drawing and Design. 1 Unit.
Designed to accompany 203. The fundamentals of engineering drawing including orthographic projection, dimensioning, sectioning, exploded and auxiliary views, assembly drawings, and SolidWorks. Homework drawings are of parts fabricated by the student in the lab. Assignments in 203 supported by material in 103D and sequenced on the assumption that the student is enrolled in both courses simultaneously.

ME 103Q. Product Realization: Making is Thinking. 3 Units.
Product Realization encompasses those processes required to transform a concept into the creation of a functional, useful, and beautiful product. In this project-based seminar, students develop product realization confidence and intuition using the rich array of tools available in the Product Realization Lab as well as industry-standard design engineering software programs and course readings in design/realization philosophy. Interactions with the Stanford design engineering community as well as field trips to iconic Bay area design engineering firms round out students' experience. Learning Goals: Build confidence in transforming concepts into products through foundational texts and rigorous exercises, master integrated design/realization software and tools through hands-on learning and practice, and engage with the Stanford design engineering community on campus and well beyond.

ME 104. The Designer's Voice. 1 Unit.
Course helps students develop a point of view about their design career that will enable them to articulate their design vision, inspire a design studio, or infect a business with a culture of design-thinking. Focus on the integration of work and worldview, professional values, design language, and the development of the designer's voice. Includes seminar-style discussions, role-playing, short writing assignments, guest speakers, and individual mentoring and coaching. Participants will be required to keep a journal.

ME 104B. Designing Your Life. 2 Units.
The course employs a design thinking approach to help students develop a point of view about their career. The course focuses on an introduction to design thinking, the integration of work and worldview, and practices that support vocation formation. Includes seminar-style discussions, role-playing, short writing assignments, guest speakers, and individual mentoring and coaching. Open to juniors, seniors and 5th year coterms, all majors. Additional course information at http://www.designingyourlife.org.

ME 104S. Designing Your Stanford. 2 Units.
DYS uses a Design Thinking approach to help Freshmen and Sophomores learn practical tools and ideas to make the most of their Stanford experience. Topics include the purpose of college, major selection, educational wayfinding, and innovating college outcomes - all applied through an introduction to Design Thinking. This seminar class incorporates small group discussion, in-class activities, field exercises, personal reflection, and individual coaching. Admission to be confirmed by email to Axess registered students prior to first class session.
Same as: EDUC 118S

ME 105. Designing for Impact. 3 Units.
This course will introduce the design thinking process and skills, and explore unique challenges of solving problems and initiating action for public good. Design skills such as need-finding, insight development, and prototyping will be learned through project work, with a particular emphasis on the elements required to be effective in the social sector. Prerequisite: ME101.

ME 110. Design Sketching. 2 Units.
Freehand sketching, rendering, and design development. Students develop a design sketching portfolio for review by program faculty. May be repeated for credit.

ME 110B. Digital Design Principles and Applications. 2 Units.
Building upon foundation design principles, project-based individual / group exploration and critique facilitates a self-guided learning process, where analytical problem-solving approaches are cultivated through real-time implementation in digital tools. A series of diverse projects are brought together in conjunction with related student project portfolio development. Class Prerequisites: Students must have completed ME110 with high levels of understanding, engagement. May be repeat for credit.

ME 112. Mechanical Systems Design. 4 Units.
Lecture/lab. Characteristics of machine elements including gears, bearings, and shafts. Design for fatigue life. Electric motor fundamentals. Transmission design for maximizing output power or efficiency. Mechanism types, linkage analysis and kinematic synthesis. Team-based design projects emphasizing the balance of physical with virtual prototyping based on engineering analysis. Lab for dissection of mechanical systems and project design reviews. Prerequisites: 80, 101. Recommended: 203, ENGR 15.

ME 113. Mechanical Engineering Design. 4 Units.
Capstone course. Mechanical engineering design is experienced by students as they work on team projects. Prerequisites: 80, 101, 112, 203. Enrollment limited to ME majors. One of two available capstone design courses.

ME 114. Consumer Analytical Product Design. 4 Units.
Holistic design experience for consumer product. Integration of models of engineering function, environmental impact, manufacturing costs, and market conditions. Introduction to life-cycle-analysis to capture environmental impact. Introduction to modeling micro economics, market models, and consumer surveying as applied in product design. Introduction to consumer product cost modeling. Draw from past coursework to build engineering function model. Student teams build and link these models in an optimization framework to maximize profitability and minimize environmental impact. Build prototypes for engineering function and form expression. ME Design Capstone Experience option. Same as: CAPD

ME 115A. Introduction to Human Values in Design. 3 Units.
An intensive project-based class that introduces the central philosophy of the product design program. Students learn how to use the lens of human needs to innovate at the intersection of technical factors (feasibility), business factors (viability), and human values (desirability). Students work toward mastery of the human-centered design methodology through several real-world, team-based projects. Students gain fluency in designing solutions ranging from physical products, to digital interfaces, to services and experiences. Students are immersed in building their individual and team capacities around core design process and methods, and emerge with a strong foundation in needfinding, synthesis, ideation, rapid prototyping, user testing, iteration, and storytelling.

ME 115B. Product Design Methods. 3 Units.
Problem-finding, problem-solving, intermediate creativity methods and effective techniques for researching and presenting product concepts. Individual- and team-based design projects emphasizing advanced visual thinking and prototyping skills. Prerequisite: ME115A.

ME 115C. Design and Business Factors. 3 Units.
Design and Business Factors: Introduces business concepts critical to determining the success of new products and services. Students will learn to estimate the cost of R&D for new product development. Using financial analysis, ROI, and tollgates to reduce development risk will be explored using case studies and simulations. Students will develop a bill of materials and a profit and loss statement for a sample product concept, prototype a design consultancy, and create a business proposal for a proposed new product company.

ME 120. History and Philosophy of Design. 3 Units.
Major schools of 19th- and 20th-century design (Arts and Crafts movement, Bauhaus, Industrial Design, and postmodernism) are analyzed in terms of their continuing cultural relevance. The relation of design to art, technology, and politics; readings from principal theorists, practitioners, and critics; recent controversies in industrial and graphic design, architecture, and urbanism. Enrollment limited to 65.

ME 123. Computational Engineering. 4 Units.
The design of wind turbines, biomedical devices, jet engines, electronic units, and almost every other engineering system, require the analysis of its flow and thermal characteristics to ensure optimal performance and safety. The continuing growth ofcomputer power and the emergence of general-purpose engineering software has fostered the use of computational analysis as a complement to experimental testing. Virtual prototyping is a staple of modern engineering practice. This course is an introduction to Computational Engineering using commercial analysis codes, covering both theory and applications. Assuming limited knowledge of computational methods, the course starts with introductory training on the software, using a nseries of lectures and hands-on tutorials. We utilize the ANSYS software suite, which is used across a variety of engineering fields. Herein, the emphasis is on geometry modeling, mesh generation, solution strategy and post-processing for diverse applications. Using classical flow/thermal problems, the course develops the essential concepts of Verification and Validation for engineering simulations, nproviding the basis for assessing the accuracy of the results. Advanced concepts such as the use of turbulence models, user programming and automation for design are also introduced. The course is concluded by a project, in which the students apply the software to solve a industry-inspired problem.

ME 124. Visual Expressions. 3 Units.
Visual Expressions: Visual Expressions explores the practice of art in any of a number of areas directly concerned with utility or communication. It is a hands-on exploration of the grammar of imagery through the study of the elements (line, shape, space, texture, color) and principles (balance, unity, contrast, proportion, rhythm) of visual design.

ME 125. Visual Frontiers. 3 Units.
Visual Frontiers: A survey across contemporary communications platforms. Students will juxtapose emerging tools, services, and applications with historic means of communications and produce works that bridge the past with the future. Fundamentals of visual communications will be applied to familiar platforms, enabling students to enhance their profiles, visualize information, and make convincing presentations.

ME 131A. Heat Transfer. 3-5 Units.
The principles of heat transfer by conduction, convection, and radiation with examples from the engineering of practical devices and systems. Topics include transient and steady conduction, conduction by extended surfaces, boundary layer theory for forced and natural convection, boiling, heat exchangers, and graybody radiative exchange. Prerequisites: 70, ENGR 30. Recommended: intermediate calculus, ordinary differential equations.

ME 131B. Fluid Mechanics: Compressible Flow and Turbomachinery. 4 Units.
Engineering applications involving compressible flow: aircraft and rocket propulsion, power generation; application of mass, momentum, energy and entropy balance to compressible flows; variable area isentropic flow, normal shock waves, adiabatic flow with friction, flow with heat addition. Operation of flow systems: the propulsion system. Turbomachinery: pumps, compressors, turbines. Angular momentum analysis of turbomachine performance, centrifugal and axial flow machines, effect of blade geometry, dimensionless performance of turbomachines; hydraulic turbines; steam turbines; wind turbines. Compressible flow turbomachinery: the aircraft engine. Prerequisites: 70, ENGR 30.

ME 137. 3D Printing for Non-Technical Innovators. 1-3 Unit.
3D Printing is a method of creation that requires only some basic computer skills and a few rules of thumb. This class will allow students to discover for themselves the potential and limitations of 3D Printing through a build intensive design project. This course is an excellent option for anyone who ever wanted to prototype an invention, create a work of art, customize a product or just make something cool -- and yet lacked the skills or a fully equipped workshop. Students may enroll for 1 unit to attend the lectures or 3 units for the complete project course. No prior technical knowledge needed.nNote: Course material is targeted toward non-ME Design and non-PD majors. An application is required for the 3-unit course option. Please complete the online application by Friday, March 25th. The application is available on the course website: web.stanford.edu/class/me137.
Same as: ME 237

ME 139. Educating Young STEM Thinkers. 3-5 Units.
The course introduces students to the design thinking process, the national conversations about the future of STEM careers, and opportunities to work with middle school students and K-12 teachers in STEM-based after-school activities and intercession camps. The course is both theory and practice focused. The purpose is twofold; to provide reflection and mentoring opportunities for students to learn about pathways to STEM careers and to introduce mentoring opportunities with young STEM thinkers.
Same as: EDUC 139, EDUC 239, ME 231

ME 140. Advanced Thermal Systems. 5 Units.
Capstone course. Thermal analysis and engineering emphasizing integrating heat transfer, fluid mechanics, and thermodynamics into a unified approach to treating complex systems. Mixtures, humidity, chemical and phase equilibrium, and availability. Labs apply principles through hands-on experience with a turbojet engine, PEM fuel cell, and hybrid solid/oxygen rocket motor. Use of MATLAB as a computational tool. Prerequisites: ENGR 30, ME 70, and 131A,B.

ME 141. Alternative Energy Systems. 5 Units.
Capstone course. Energy analysis, diagnostics and engineering of selected alternative energy systems with an integrated thermodynamic, heat transfer, and fluid mechanic approach. Mixtures, transport, reactions, electrochemical processes and photovoltaic effects. Labs apply principles through hands-on experience with selected alternative energy systems and their components. Use of MATLAB as an analysis tool.

ME 161. Dynamic Systems, Vibrations and Control. 3-4 Units.
(Graduate students only enroll in 261.) Modeling, analysis, and measurement of mechanical and electromechanical systems. Numerical and closed form solutions of ordinary differential equations governing the behavior of single and multiple degree of freedom systems. Stability, resonance, amplification and attenuation, and control system design. Demonstrations and laboratory experiments. Prerequisite: Calculus (differentiation and integration), ordinary differential equations (e.g., CME 102 or MATH53), basic linear algebra (determinants and solving linear equations), and familiarity with basic dynamics (F=m*a) and electronics (v=i*R). ME undergraduates must enroll for 4 units with lab. All others should enroll for 3 units without lab.
Same as: ME 261

ME 166. Introduction to Physiology and Biomechanics of Hearing. 3 Units.
Hearing is fundamental to our ability to communicate, yet in the US alone over 30 million people suffer some form of hearing impairment. As engineers and scientists, it is important for us to understand the underlying principles of the auditory system if we are to devise better ways of helping those with hearing loss. The goal of this course is to introduce undergraduate and graduate students to the anatomy, physiology, and biomechanics of hearing. Principles from acoustics, mechanics, and hydrodynamics will be used to build a foundational understanding of one of the most complex, interdisciplinary, and fascinating areas of biology. Topics include the evolution of hearing, computational modeling approaches, fluid-structure interactions, ion-channel transduction, psychoacoustics, diagnostic tools, and micrometer to millimeter scale imaging methods. We will also study current technologies for mitigating hearing loss via passive and active prostheses, as well as future regenerative therapies.
Same as: BIOE 287, ME 266

ME 177. Global Engineers' Education. 3 Units.
A project based course for those who would like to use their engineering backgrounds to address real world challenges faced by underserved communities globally. In direct collaboration with an underserved community from a rural village in India, students will develop engineering solutions to the challenge of sanitation and hygiene. Focus will be on working with the community rather than for them. Concepts covered will include designing with what designers care about at the center, articulating and realizing individual and community aspirations, ethics of engaging with underserved communities, and methodology of working sustainably with an underserved community.

ME 181. Deliverables: A Mechanical Engineering Design Practicum. 3 Units.
The goal of this course is to enable students to solve industry design challenges using modern mechanical design methods. Each week a new practical skill is introduced. These skills have been identified by recently graduated Stanford engineers as being critical to their work. Students then build their command of each skill by completing a simplified yet representative project and submitting deliverables similar to those required in industry. For example, students will learn about how to properly design parts with O-rings and then will be required to design a water-tight enclosure and submit CAD, mechanical drawings, and a bill of materials. Several of the classes feature recent Stanford graduates as guest lecturers. In addition to teaching applicable skills from their job and providing examples from industry, these engineers will also expose students to the range of responsibilities and daily activities that makeup professional mechanical design work. Prerequisites: ME203, ME103d and ME112 OR consent of instructor. Enrollment limited, students complete application on first day of class.

ME 182. Electric Transportation. 3 Units.
Transportation accounts for nearly one-third of American energy use and greenhouse gas emissions and three-quarters of American oil consumption. It has crucial impacts on climate change, air pollution, resource depletion, and national security. Students wishing to address these issues reconsider how we move, finding sustainable transportation solutions. An introduction to the issue, covering the past and present of transportation and its impacts; examining alternative fuel proposals; and digging deeper into the most promising option: battery electric vehicles. Energy requirements of air, ground, and maritime transportation; design of electric motors, power control systems, drive trains, and batteries; and technologies for generating renewable energy. Students will also have a fun opportunity for a hands-on experience with an electric car. Prerequisites: Introduction to calculus and Physics AP or elementary mechanics.

ME 185. Electric Vehicle Design. 3 Units.
This project based class focuses on the design and prototyping of electric vehicles. Students learn the fundamentals of vehicle design in class and apply the knowledge as they form teams and work on projects involving concept, specifications, structure, systems, integration, assembly, testing, etc. The class meets once a week to learn about the fundamentals, exchange their experiences, and coordinate between projects. The teams of 3-5 will work on their projects independently.

ME 190. Ethical Issues in Mechanical Engineering. 4 Units.
Moral rights and responsibilities of engineers in relation to society, employers, colleagues, and clients; cost-benefit-risk analysis, safety, and informed consent; whistle blowing; engineers as expert witnesses, consultants, and managers; ethical issues in engineering design, manufacturing, and operations, and engineering work in foreign countries; and ethical implications of the social and environmental contexts of contemporary engineering. Case studies and field research. Enrollment limited to 25 Mechanical Engineering majors.

ME 191. Engineering Problems and Experimental Investigation. 1-5 Unit.
Directed study and research for undergraduates on a subject of mutual interest to student and staff member. Student must find faculty sponsor and have approval of adviser.

ME 191H. Honors Research. 1-5 Unit.
Student must find faculty honors adviser and apply for admission to the honors program.nn (Staff).

ME 199A. Practical Training. 1 Unit.
For undergraduate students. Educational opportunities in high technology research and development labs in industry. Students engage in internship work and integrate that work into their academic program. Following internship work, students complete a research report outlining work activity, problems investigated, key results, and follow-up projects they expect to perform. Meets the requirements for curricular practical training for students on F-1 visas. Student is responsible for arranging own internship/employment and faculty sponsorship. Register under faculty sponsor's section number. All paperwork must be completed by student and faculty sponsor, as the Student Services Office does not sponsor CPT. Students are allowed only two quarters of CPT per degree program. Course may be repeated twice.

ME 200. Judging Historical Significance Through the Automobile. 1 Unit.
This seminar is for students to learn how to assess the impact of historical importance through the lens of the automobile. Students will participate in discussions about measuring and judging historical importance from a number of perspectives - engineering, aesthetic, historical, etc. They will then decide on criteria and use these to be a part of a judging team at the Pebble Beach Concours d'Elegance. The Pebble Beach event is the leading concours for automobiles in the United States. Using the criteria established by the students, the judging team, including the students, will decide the recipient of the Stanford/Revs Automotive History Trophy for 2017 and have the opportunity to present it on the lawn at Pebble Beach Lodge in August. Must apply using this application: http://revs.stanford.edu/course/703. Must attend first class to be considered for acceptance, no exceptions.

ME 201. Dim Sum of Mechanical Engineering. 1 Unit.
Introduction to research in mechanical engineering for M.S. students and upper-division undergraduates. Weekly presentations by current ME Ph.D. and second-year fellowship students to show research opportunities across the department. Strategies for getting involved in a research project.

ME 202. Mechaphonics: Smart Phone-Enabled Mechatronic Systems. 3 Units.
Explore the use of smartphones and tablets as enabling components within modern mechatronic systems. Emphasis on leveraging Android resources (user interface, communications, sensors) in combination with the Arduino microcontroller platform to design and build complex mechatronic devices. Topics include: basic Android application development, Android communications, sensors, Arduino, Arduino peripherals. Large, open-ended team project. Android device and programming hardware required. Limited enrollment. Prerequisites: ME210, ME218, or permission of instructor.

ME 203. Design and Manufacturing. 4 Units.
Integrated experience involving need finding, product definition, conceptual design, detail design, prototype manufacture, public presentation of outcomes, archiving and intrepreting the product realization process and its results. Presents an overview of manufacturing processes crucial to the practice of design. Corequisite: 103D or CAD experience. Recommended: 101.

ME 203X. Prototyping and Process Capture. 1 Unit.
Concepts and methods for low resolution prototyping as an integral activity in engineering design process. Class meetings include presentations by faculty and design oriented exercises by students. Assignments will be Blog Posts. ME203X is designed to work in phase with ME203 and offers greater depth in protoyping strategy, technique, and resultant insights. Concurrent enrollment in ME203 is required. Enrollment is optional and capped at 6 students.

ME 204A. Bicycle Design and Frame-Building. 1 Unit.
Lecture/lab. The engineering and artistic execution of designing and building a bicycle frame. Fundamentals of bicycle dynamics, handling, and sizing. Manufacturing processes. Films, guest lecturers, field trips. Each student designs and fabricates a custom bicycle frame. This course is now a two part course series ME204A&B. Limited enrollment. Prerequisite: 203 or equivalent.

ME 204B. Bicycle Design and Frame-Building. 3 Units.
The engineering and artistic execution of designing and building a bicycle frame. The fundamentals of bicycle dynamics, handling, and sizing. Manufacturing processes. Films, guest lecturers, field trips. Each student designs a custom bicycle frame that they continue from ME204A in winter quarter. Limited enrollment, admission by consent of instructors. Attendance at first lecture is required. Both ME204A and ME204B must be taken. Prerequisite: 203 or equivalent.

ME 205. Flexible Part Design. 3 Units.
Project based course. Students design and fabricate tooling to create and refine elastomeric parts using RTV silicone rubber. Focus is on the development of elastomeric part design intuition through iteration. Fabrication techniques include manual/CNC machining and additive manufacturing, and molding liquid silicone. Prerequisites: ME203 or instructor consent. Recommended: ME318. Admission is by consent of the instructor. Class size limited to 10, must attend first lecture.

ME 206A. Entrepreneurial Design for Extreme Affordability. 4 Units.
Project course jointly offered by School of Engineering and Graduate School of Business. Students apply engineering and business skills to design product prototypes, distribution systems, and business plans for entrepreneurial ventures in developing countries for a specified challenge faced by the world's poor. Topics include user empathy, appropriate technology design, rapid prototype engineering and testing, social technology entrepreneurship, business modeling, and project management. Weekly design reviews; final course presentation. Industry and adviser interaction. Limited enrollment via application; see extreme.stanford.edu.

ME 206B. Entrepreneurial Design for Extreme Affordability. 4 Units.
Part two of two-quarter project course jointly offered by School of Engineering and Graduate School of Business. Second quarter emphasizes prototyping and implementation of specific projects identified in first quarter. Students work in cross-disciplinary project teams. Industry and adviser interaction, weekly design reviews; final course presentation. Prerequisite: 206A.n(Jointly offered as GSB OIT333B) Design Institute class; see http://dschool.stanford.edu.

ME 207. Movie Design. 2 Units.
Learn the ins and outs of high-speed filmmaking in the digital age; writing, directing, shooting, and editing. We¿ll do it through a rapid prototyping approach to filmmaking. Whether you have tons of experience or none, you¿ll leave with new tactics that will up your storytelling, filmmaking, and design chops simultaneously. These techniques are useful whether you plan to move to Hollywood or create a video for the web.n Project-based: students will design, write, shoot, edit, and screen a short film in the span of one week. It¿s going to be quick but intense, kind of like cross-fit for your storytelling and video creating muscles. You¿ll sweat a bit, but you¿ll feel confident afterwards. Students should be prepared to spend significant amount of out of class work-time creating movies: for one week + one weekend, see "Notes" for specific dates. Admission by application. See dschool.stanford.edu/classes for more information.

ME 208. Patent Law and Strategy for Innovators and Entrepreneurs. 2-3 Units.
This course teaches the essentials for a startup to build a valuable patent portfolio and avoid a patent infringement lawsuit. Jeffrey Schox, who is the top recommended patent attorney for Y Combinator, built the patent portfolio for Twilio (IPO), Cruise ($1B acquisition), and 250 startups that have collectively raised over $2B in venture capital. This course is equally applicable to EE, CS, and Bioengineering students. For those students who are interested in a career in Patent Law, please note that this course is a prerequisite for ME238 Patent Prosecution.
Same as: MS&E 278

ME 209. Imperfections in Crystalline Solids. 3 Units.
To develop a basic quantitative understanding of the behavior of point, line and planar defects in crystalline solids. Particular attention is focused on those defects that control the thermodynamic, structural and mechanical properties of crystalline materials.

ME 210. Introduction to Mechatronics. 4 Units.
Technologies involved in mechatronics (intelligent electro-mechanical systems), and techniques to apply this technology to mecatronic system design. Topics include: electronics (A/D, D/A converters, op-amps, filters, power devices); software program design, event-driven programming; hardware and DC stepper motors, solenoids, and robust sensing. Large, open-ended team project. Prerequisites: ENGR 40, CS 106, or equivalents.
Same as: EE 118

ME 211. ReMake: Design Lessons from Restoration. 1 Unit.
Focus is on the restoration of the 1962 Cadillac DeVille project car as a design investigation. Topics include: What makes a car a classic? How does this car express luxury, and how is that different from contemporary luxury products? What does the car say about the American identity, and how has that changed over the past half-century? Every student can expect to get their hands dirty; prior automotive experience is not required. Goal is to have the car operational again by the end of Autumn Quarter. Preference to early graduate and advanced undergraduate students. Enrollment limited to 15.

ME 212. Calibrating the Instrument. 1 Unit.
For first-year graduate students in the Joint Program in Design. Means for calibrating the designer's mind/body instrument through tools including improvisation, brainstorming, creative imaging, educational kinesiology, and Brain Gym. Current design issues; guest speakers; shared stories; and goal setting.

ME 215. From Maps to Meaning. 3 Units.
One of the oldest visual tools created by humans to make sense of the complexities of our world, maps are unique in their ability to synthesize data, convey meaning through spatial logic, and deliver information at high resolution. They are also incredible tools for communication, data sorting and insight finding.n n This is an intensive, hands-on course that uses mapping techniques to navigate the intersection of data and design. Students will tackle three main projects and several shorter assignments over 10 weeks. Perfect attendance and completion of projects is absolutely mandatory. You will:n -collect, sort and organize quantitative and qualitative datan -create maps to synthesize complex informationn -use mapping as a tool to work on design problemsn -explore biases in map-makingn -create design interventions based on data and mapsn n While no specific prior experience is necessary, this class is for you if you are comfortable with the ambiguity of learning new skills on and off the computer, if you geek out about design and data, and if you are not intimidated by the idea of creating analog and digital maps. Admission by application. See dschool.stanford.edu/classes for more information.

ME 216A. Advanced Product Design: Needfinding. 3-4 Units.
Human needs that lead to the conceptualization of future products, environments, systems, and services. Field work in public and private settings; appraisal of personal values; readings on social ethnographic issues; and needfinding for a corporate client. Emphasis is on developing the flexible thinking skills that enable the designer to navigate the future. Prerequisites for undergraduates: ME115A, ME115B and ME203, or consent of the instructor.

ME 216B. Advanced Product Design: Implementation 1. 4 Units.
Summary project using knowledge, methodology, and skills obtained in Product Design major. Students implement an original design concept and present it to a professional jury. Prerequisite: 216A.

ME 216C. Advanced Product Design: Implementation 2. 4 Units.
ME216C: Implementation II is a continuation of ME216B. Students would develop project from ME216B to a further state of completion. Design will be completed, details about manufacturing, cost and production will be developed. Students will validate their projects by making them real in the world. Prerequisites for class are ME216A and ME216B.Prerequisite: 216A and 216B.

ME 216M. Introduction to the Design of Smart Products. 4 Units.
This course will focus on the technical mechatronic skills as well as the human factors and interaction design considerations required for the design of smart products and devices. Students will learn techniques for rapid prototyping of smart devices, best practices for physical interaction design, fundamentals of affordances and signifiers, and interaction across networked devices. Students will be introduced to design guidelines for integrating electrical components such as PCBs into mechanical assemblies and consider the physical form of devices, not just as enclosures but also as a central component of the smart product. Prerequisites include: CS106A, E40, and ME 210, or instructor approval.

ME 217. Design & Construction in Wood. 3 Units.
Exploration of the design and construction of objects using wood including the rich history and current trends for furniture. Taught in the Product Realization Lab. Limited enrollment via application; see stanford.edu/class/me217.

ME 218A. Smart Product Design Fundamentals. 4-5 Units.
Lecture/Lab. Team design project series on programmable electromechanical systems design. Topics: transistors as switches, basic digital and analog circuits, operational amplifiers, comparators, software design, state machines, programming in C. Lab fee. Limited enrollment.

ME 218B. Smart Product Design Applications. 4-5 Units.
Lecture/lab. Second in team design project series on programmable electromechanical systems design. Topics: user I/O, timer systems, interrupts, signal conditioning, software design for embedded systems, statecharts, sensors, actuators, noise, and power supplies. Lab fee. Limited enrollment. Prerequisite: 218A or passing the smart product design fundamentals proficiency examination.

ME 218C. Smart Product Design Practice. 4-5 Units.
Lecture/lab. Advanced level in series on programmable electromechanical systems design. Topics: inter-processor communication, system design with multiple microprocessors, architecture and assembly language programming for the PIC microcontroller, controlling the embedded software tool chain, A/D and D/A techniques, electronic manufacturing technology. Team project. Lab fee. Limited enrollment. Prerequisite: 218B.

ME 218D. Smart Product Design: Projects. 3-4 Units.
Lecture/lab. Industrially sponsored project is the culmination of the Smart Product Design sequence. Student teams take on an industrial project requiring application and extension of knowledge gained in the prior three quarters, including prototyping of a final solution with hardware, software, and professional documentation and presentation. Lectures extend the students' knowledge of electronic and software design, and electronic manufacturing techniques. Topics: chip level design of microprocessor systems, real time operating systems, alternate microprocessor architectures, and PCB layout and fabrication. Prerequisite: 218C.

ME 219. The Magic of Materials and Manufacturing. 3 Units.
Intended for design-oriented students who anticipate imagining and then creating new products with a focus on materiality and brand or design and business. Assumes basic knowledge of materials and manufacturing processes which results from taking ENGR 50, ME 203, or equivalent course/life experience. Goal is to acquire professional foundation information about materials and materiality from a product design point-of-view, manufacturing processes and business systems inside a factory, and story-telling by book authorship, essay writing, and multimedia presentation. Goal is for students to exhibit a deep and life-long love of materials and manufacturing in order to make great products and tell a good story about each one.

ME 220. Introduction to Sensors. 3-4 Units.
Sensors are widely used in scientific research and as an integral part of commercial products and automated systems. The basic principles for sensing displacement, force, pressure, acceleration, temperature, optical radiation, nuclear radiation, and other physical parameters. Performance, cost, and operating requirements of available sensors. Elementary electronic circuits which are typically used with sensors. Lecture demonstration of a representative sensor from each category elucidates operating principles and typical performance. Lab experiments with off-the-shelf devices. Recommended Pre-requisites or equivalent knowledge: Physics 43 electromagnetism, Physics 41 mechanics, Math 53 Taylor series approximation, 2nd order Ordinary Diff Eqns, ENGR40A/Engr40 or ME210, i.e. some exposure to building basic circuits.

ME 221. Green Design Strategies and Metrics. 2 Units.
Foundation in sustainable product design principles, reinforced by conceptual design projects. Discuss what aspects of sustainability matter most for different products. Application of dozens of strategies to improve product sustainability. Frameworks, measurements, and decision-making tools to navigate the complexities of designing greener products. Life-cycle analysis, materials, energy use, biomimicry, product-service systems, persuasive design, design for end-of-life, and systems thinking.

ME 222. Design for Sustainability. 2-3 Units.
Lecture/lab. Role of design in building a sustainable world. How to include sustainability in the design process considering environmental, cultural, and social impacts. Focus is on a proactive design approach, and the tools and techniques needed to translate theory into artifact.

ME 224. The Consumer Mind and Behavior Design. 3 Units.
This course will introduce new theories and research concerning neuroscience and behavioral psychology to examine models for designing user habits. Students will learn how to use the latest behavior change methodologies from industry-leading experts to design or re-design a customer experience. Course topics will be taught in the context of design thinking: empathize-define-ideate-prototype-test. Students will leave the class having prototyped, tested, and improved a user behavior.

ME 225. Mystery of Manufacturing. 3 Units.
Mystery of Manufacturing is intended for design- and engineering-oriented students who anticipate or have an interest in launching products. Where the cousin of this class, ME219, is an overview of fabrication and factory systems, this course will look at manufacturing systems more holistically: what does it take to get a product from your idea into peoples' hands? We'll look at factors that drive location, distribution, and supply chain decisions, and we'll look closely at the inner workings of factories. nnnThis course assumes basic knowledge of materials and manufacturing processes resulting from ENGR 50, ME 203, ME 219 or equivalent course/life experience. The goal is to acquire a professional foundation in factory manufacturing systems and the business of manufacturing through story-telling, essay writing, and multimedia presentation. We hope students will exhibit a deep and life-long love of the complexity and flexibility of manufacturing systems in order to launch great products into the world.

ME 226. Designing Sustainable Behavior. 1 Unit.
How do you design a product so people will use it in the most sustainable way? Through practical design exercises you experience how selected design tools can help you affect the behavior of your target group. The course consists of an 8-hour workshop on Saturday April 6th in Studio2 at the d.school, followed by a group project finishing April 24th. Students may request to only audit the workshop by emailing jdaae@stanford.edu. The course builds upon and contributes to an ongoing research project. Prerequisite: training in product design.

ME 227. Vehicle Dynamics and Control. 3 Units.
The application of dynamics, kinematics, and control theory to the analysis and design of ground vehicle behavior. Simplified models of ride, handling, and braking, their role in developing intuition, and limitations in engineering design. Suspension design fundamentals. Performance and safety enhancement through automatic control systems. In-car laboratory assignments for model validation and kinesthetic understanding of dynamics. Limited enrollment. Prerequisites: ENGR 105, consent of instructor.

ME 228. The Future of Mechanical Engineering. 1 Unit.
This seminar series provides an overview of current research in mechanical engineering and of its interface with other engineering and non-engineering disciplines. The seminar is targeted at senior mechanical engineering undergraduates and mechanical engineering graduate students. Presenters will be selected external speakers who feature exciting, cutting-edge applications of mechanical engineering.

ME 229. Design Evangelism. 1-2 Unit.
Students work with Ambidextrous staff and magazine professionals to edit and produce Ambidextrous, Stanford University's Journal of Design. Topics include design processes and innovation, storytelling, writing and editing for an audience, magazine production and project leadership. Hands-on projects, in-class exercises, and guest lectures.

ME 230. Principles of Mechanical Measurements. 3 Units.
A lecture-based introduction to experiment design and implementation. Topics include measurement methods, transducer fundamentals, instrumentation, optical systems, signal processing, noise theory, analog and digital electronic fundamentals, data acquisition and processing systems. May be repeat for credit.

ME 231. Educating Young STEM Thinkers. 3-5 Units.
The course introduces students to the design thinking process, the national conversations about the future of STEM careers, and opportunities to work with middle school students and K-12 teachers in STEM-based after-school activities and intercession camps. The course is both theory and practice focused. The purpose is twofold; to provide reflection and mentoring opportunities for students to learn about pathways to STEM careers and to introduce mentoring opportunities with young STEM thinkers.
Same as: EDUC 139, EDUC 239, ME 139

ME 232. Additive Manufacturing- From Fundamentals to Applications. 3 Units.
Additive manufacturing (AM) is an emerging technique for direct conversion of 3D computer aided designs into physical objects using a variety of approaches. AM technologies are simple and flexible processes that allow for the creation of very complex and customizable 3D objects in just a few process steps. This lecture gives an overview of available processes and current research in additive manufacturing. Students will get to know how AM can change the way we prototype and manufacture products in the future.

ME 234. Introduction to Neuromechanics. 3 Units.
Understanding the role of mechanics in brain development, physiology, and pathology. Mechanics of brain cells: neurons, mechanobiology, mechanotransduction. Mechanics of brain tissue: experimental testing, constitutive modeling, computational modeling. Mechanics of brain development: gyrification, cortical folding, axon elongation, lissencephaly, polymicrogyria. Mechanics of traumatic brain injury: high impact loading, neural injury. Mechanics of brain tumors, brain cancer, tumor growth, altered cytoskeletal mechanics. Mechanics of neurological disorders: autism, dementia, schizophrenia. Mechanics of brain surgery.

ME 235. Understanding Superfans and their Heroes. 2-3 Units.
Harness the power of the hero coefficient through a radical team-based, hands-on, multidisciplinary class. Students will learn and utilize the principles of Empathy-Define-Ideate-Prototype-Test components of the d.thinking process. Why do superfans love their heroes? You'll get to prototype and explore how superfans connect with their heroes, understanding this connective tissue works will give your own ideas a boost. We'll be studying heroes the likes of Dale Earnhardt, Michael Jordan and Stephen Colbert. Expect to leave this class ready to spread the word about heroes and superfans and make everyone at your company or on your team feel like one. You will hear from special guests and take a field trip to a racetrack. Sponsored by the Revs Program. Limited enrollment. FAQ and apply here: http://revs.stanford.edu/course/693.

ME 236. Tales to Design Cars By. 1-3 Unit.
Students learn to tell personal narratives and prototype connections between popular and historic media using the automobile. Explores the meaning and impact of personal and preserved car histories. Storytelling techniques serve to make sense of car experiences through engineering design principles and social learning, Replay memories, examine engagement and understand user interviews, to design for the mobility experience of the future. This course celebrates car fascination, and leads the student through finding and telling a car story through the REVS photographic archives, ethnographic research, interviews, and diverse individual and collaborative narrative methods-verbal, non-verbal, and film. Methods draw from socio-cognitive psychology design thinking, and fine art; applied to car storytelling. Course culminates in a final story presentation and showcase. Restricted to co-term and graduate students. Class Size limited to 18.

ME 237. 3D Printing for Non-Technical Innovators. 1-3 Unit.
3D Printing is a method of creation that requires only some basic computer skills and a few rules of thumb. This class will allow students to discover for themselves the potential and limitations of 3D Printing through a build intensive design project. This course is an excellent option for anyone who ever wanted to prototype an invention, create a work of art, customize a product or just make something cool -- and yet lacked the skills or a fully equipped workshop. Students may enroll for 1 unit to attend the lectures or 3 units for the complete project course. No prior technical knowledge needed.nNote: Course material is targeted toward non-ME Design and non-PD majors. An application is required for the 3-unit course option. Please complete the online application by Friday, March 25th. The application is available on the course website: web.stanford.edu/class/me137.
Same as: ME 137

ME 238. Patent Prosecution. 2 Units.
The course follows the patent application process through the important stages: inventor interviews, patentability analysis, drafting claims, drafting a specification, filing a patent application, and responding to an office action. The subject matter and practical instruction relevant to each stage are addressed in the context of current rules and case law. The course includes four written assignments: an invention capture, a claim set, a full patent application, and an Office Action response.Pre-requisites: Law 326 (IP:Patents), Law 409 (Intro IP), ME 208, or MS&E 278.

ME 239. Mechanics of the Cell. 3 Units.
Understanding cells as the fundamental building blocks of life. Cell biomechanics: understanding how cell biology and biochemistry influence the mechanical properties of the cell. Cell mechanobiology: understanding how the mechanical environment, load, pressure, stress or strain can influence the cell's shape and integrity, and eventually its biology and biochemistry. Characterizing, modeling, and simulating cell behavior: energy and entropy of biopolymers and biomembranes. Characterizing mechanotransduction.

ME 240. Introduction to Nanotechnology. 3 Units.
Nanotechnology as multidisciplinary with contributions from physical sciences, engineering, and industry. Current topics in nanotechnology research; developments in nanomaterials, mechanics, electronics, and sensors; and applications. Nanoscale materials building blocks, fabrication and assembly processes, characterization and properties, and novel system architectures. Implications for future development.

ME 242B. Mechanical Vibrations. 3 Units.
For M.S.-level graduate students. Covers the vibrations of discrete systems and continuous structures. Introduction to the computational dynamics of linear engineering systems. Review of analytical dynamics of discrete systems; undamped and damped vibrations of N-degree-of-freedom systems; continuous systems; approximation of continuous systems by displacement methods; solution methods for the Eigenvalue problem; direct time-integration methods. Prerequisites: AA 242A or equivalent (recommended but not required); basic knowledge of linear algebra and ODEs; no prior knowledge of structural dynamics is assumed.
Same as: AA 242B

ME 243. Designing Emotion-Reactive Car Interfaces. 1-3 Unit.
How to design in car interfaces that take into account the emotional state of the driver in the moment of driving? Participants will be prototyping and testing interfaces for an industry partner. The challenge is to take real time responsive data to infer the emotional state of a driver and to lever these to improve the driving experience. We will cover topics on design methodology, psychology of emotions, and human machine interaction to reflect and work on the emotionally charged car experience of today to imagine the car of tomorrow. Class meetings will include: prototyping, discussions and presentations. Participants will have access to tools, prototyping materials, and a car. Students from all ENG majors but also beyond are encouraged to join. Bring your drivers license, if you have one. May be repeat for credit.

ME 244. Mechanotransduction in Cells and Tissues. 3 Units.
Mechanical cues play a critical role in development, normal functioning of cells and tissues, and various diseases. This course will cover what is known about cellular mechanotransduction, or the processes by which living cells sense and respond to physical cues such as physiological forces or mechanical properties of the tissue microenvironment. Experimental techniques and current areas of active investigation will be highlighted.
Same as: BIOE 283, BIOPHYS 244

ME 250. Internal Combustion Engines. 1-5 Unit.
Internal combustion engines including conventional and turbocharged spark ignition, and diesel engines. Lectures: basic engine cycles, engine components, methods of analysis of engine performance, pollutant emissions, and methods of engine testing. Lab involves hands-on experience with engines and test hardware. Limited enrollment. Prerequisites: 140.

ME 257. Turbine and Internal Combustion Engines. 3 Units.
Principles of design analysis for aircraft gas turbines and automotive piston engines. Analysis for aircraft engines performed for Airbus A380 type aircraft. Design parameters determined considering aircraft aerodynamics, gas turbine thermodynamics, compressible flow physics, and material limitations. Additional topics include characteristics of main engine components, off-design analysis, and component matching. Performance of automotive piston engines including novel engine concepts in terms of engine thermodynamics, intake and exhaust flows, and in-cylinder flow.
Same as: ME 357

ME 260. Fuel Cell Science and Technology. 3 Units.
Emphasis on proton exchange membrane (PEM) and solid oxide fuel cells (SOFC), and principles of electrochemical energy conversion. Topics in materials science, thermodynamics, and fluid mechanics. Prerequisites: MATH 43, PHYSICS 55, and ENGR 30 or ME 140, or equivalents.

ME 261. Dynamic Systems, Vibrations and Control. 3-4 Units.
(Graduate students only enroll in 261.) Modeling, analysis, and measurement of mechanical and electromechanical systems. Numerical and closed form solutions of ordinary differential equations governing the behavior of single and multiple degree of freedom systems. Stability, resonance, amplification and attenuation, and control system design. Demonstrations and laboratory experiments. Prerequisite: Calculus (differentiation and integration), ordinary differential equations (e.g., CME 102 or MATH53), basic linear algebra (determinants and solving linear equations), and familiarity with basic dynamics (F=m*a) and electronics (v=i*R). ME undergraduates must enroll for 4 units with lab. All others should enroll for 3 units without lab.
Same as: ME 161

ME 262. Physics of Wind Energy. 3 Units.
Formerly CEE 261. An introduction to the analysis and modeling of wind energy resources and their extraction. Topics include the physical origins of atmospheric winds; vertical profiles of wind speed and turbulence over land and sea; the wind energy spectrum and its modification by natural topography and built environments; theoretical limits on wind energy extraction by wind turbines and wind farms; modeling of wind turbine aerodynamics and wind farm performance. Final project will focus on development of a new wind energy technology concept. Prerequisites: CEE 262A or ME 351A.
Same as: CEE 261B

ME 263. The Chair. 4 Units.
Students design and fabricate a highly refined chair. The process is informed and supported by historical reference, anthropometrics, form studies, user testing, material investigations, and workshops in wood steam-bending, plywood forming, metal tube bending, TIG & MIG welding, upholstery & sewing. Pre-req: ME 203 Design and Manufacturing. May be repeat for credit.

ME 264. d.science: Design for Science. 3-4 Units.
Where does design fit into scientific research? In this class, we will design for how data are collected, how data are communicated, and how to apply scientific insights to community-based projects. This year's projects are inspired by the Citizen Science movement and The Year of the Bay. We will use human-centered design methods to understand the needs of bay area citizens through hands-on data collection, public data exploration and collaboration with local industry, government and research partners.nWith guest lectures from the design and science community, research mentors, and skills workshops, you will develop an actionable understanding of the challenges of collecting good data, the complexities of creating engaging stories with quantitative data, and the challenges of balancing insights from both human-centered design research and scientific research. One of the three class projects will involve visualizing and mapping big data. No prior programming or statistics experience required.nEnrollment limited to 24. This course is open to graduate students from all schools and departments. Apply the first day of class.

ME 265. Technology Licensing and Commercialization. 3 Units.
Course focuses on how to bridge the gap between creation and commercialization with new ideas, inventions, and technology (not limited to mechanical engineering). Covers business strategies and legal aspects of determining what can be owned and licensed, how to determine commercial value, and what agreements and other paperwork is necessary. Discussion includes aspects of Contract and Intellectual Property law as well as provisions of license agreements and their negotiation. All materials provided including many sample documents.

ME 266. Introduction to Physiology and Biomechanics of Hearing. 3 Units.
Hearing is fundamental to our ability to communicate, yet in the US alone over 30 million people suffer some form of hearing impairment. As engineers and scientists, it is important for us to understand the underlying principles of the auditory system if we are to devise better ways of helping those with hearing loss. The goal of this course is to introduce undergraduate and graduate students to the anatomy, physiology, and biomechanics of hearing. Principles from acoustics, mechanics, and hydrodynamics will be used to build a foundational understanding of one of the most complex, interdisciplinary, and fascinating areas of biology. Topics include the evolution of hearing, computational modeling approaches, fluid-structure interactions, ion-channel transduction, psychoacoustics, diagnostic tools, and micrometer to millimeter scale imaging methods. We will also study current technologies for mitigating hearing loss via passive and active prostheses, as well as future regenerative therapies.
Same as: BIOE 287, ME 166

ME 271. Aerial Robot Design. 3 Units.
An introduction to the aerodynamic design of rotor-based drones, for students with a background in robotics, aerospace, or fluids. Focus is on rotor-based drones operating at low Reynolds numbers, but material is applicable to drones, aviation and wind energy in general. Topics include: airfoil simulation, fundamentals of rotor aerodynamics, blade element analysis, rotor simulation and performance (e.g. mission duration, distance, maneuverability, and reliability). Midterm is the design of an airfoil for a drone, final is the aerodynamic design of a rotor for a drone; these projects will be peer-reviewed by students in the class. Prereqs: background in fluid mechanics or aerodynamics; fluency with MATLAB. Recommended: take ME202 or AA241X before or after ME271, for practical applications in drone prototyping and control theory.

ME 277. Graduate Design Research Techniques. 3-4 Units.
Students from different backgrounds work on real-world design challenges. The Design Thinking process with emphasis on: ethnographic techniques, need finding, framing and concept generation. The Design Thinking process as a lens to explore ways to better understand people and their culture. Cultural differences as a source of design inspiration, with the understanding that design itself is a culturally embedded practice.

ME 280. Skeletal Development and Evolution. 3 Units.
The mechanobiology of skeletal growth, adaptation, regeneration, and aging is considered from developmental and evolutionary perspectives. Emphasis is on the interactions between mechanical and chemical factors in the regulation of connective tissue biology. Prerequisites: BIO 42, and ME 80 or BIOE 42.
Same as: BIOE 280

ME 281. Biomechanics of Movement. 3 Units.
Experimental techniques to study human and animal movement including motion capture systems, EMG, force plates, medical imaging, and animation. The mechanical properties of muscle and tendon, and quantitative analysis of musculoskeletal geometry. Projects and demonstrations emphasize applications of mechanics in sports, orthopedics, and rehabilitation.
Same as: BIOE 281

ME 283. Introduction to Biomechanics and Mechanobiology. 3 Units.
Introduction to the application of mechanical engineering analysis to understand human physiology and disease. Topics include basics of musculoskeletal force analysis, cell mechanics, blood flow, and mechanical behaviors of tissues. Undergraduates should have taken ME 70 and ME 80 or equivalents.

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

ME 285. Computational Modeling in the Cardiovascular System. 3 Units.
This course introduces computational modeling methods for cardiovascular blood flow and physiology. Topics in this course include analytical and computational methods for solutions of flow in deformable vessels, one-dimensional equations of blood flow, cardiovascular anatomy, lumped parameter models, vascular trees, scaling laws, biomechanics of the circulatory system, and 3D patient specific modeling with finite elements; course will provide an overview of the diagnosis and treatment of adult and congenital cardiovascular diseases and review recent research in the literature in a journal club format. Students will use SimVascular software to do clinically-oriented projects in patient specific blood flow simulations.
Same as: BIOE 285, CME 285

ME 287. Mechanics of Biological Tissues. 4 Units.
Introduction to the mechanical behaviors of biological tissues in health and disease. Overview of experimental approaches to evaluating tissue properties and mathematical constitutive models. Elastic behaviors of hard tissues, nonlinear elastic and viscoelastic models for soft tissues.

ME 289A. Interactive Art / Performance Design. 2 Units.
This class is for those who want the experience of designing and creating interactive art and performance pieces for public audiences, using design thinking as the method, and supported by guest speakers, artist studio visits and needfinding trips to music festivals, museums and performances.nnDrawing on the fields of design, art, performance, and engineering, each student will ideate, design, plan and lead a team to build an interactive art and/or performance piece to be showcased to audience of 5000 at the Frost Music and Art Festival held on the Stanford campus on May 17th 2014. Projects can range from interactive art to unconventional set design, and from site-specific sculpture to immersive performance.nnThis is a two-quarter long commitment during which students will first learn the design, planning, story boarding, budgeting, engineering, proposal creation and concept pitching of projects for applying for grants and presenting to funders. The second quarter will concentrate on prototyping, maquette making, testing, team forming, project management, creative leadership, construction, site installation and documentation.nPart one of a two course series: ME 289A&B.
Same as: TAPS 289A

ME 289B. Interactive Art / Performance Creation. 3-4 Units.
This class is the continuation of ME289A where students experience the designing and creating of interactive art and performance pieces for public audiences, using design thinking as the method, and supported by guest speakers, artist studio visits and needfinding trips to music festivals, museums and performances.nnDrawing on the fields of design, art, performance, and engineering, each student will ideate, design, plan and lead a team to build an interactive art and/or performance piece to be showcased to audience of 5000 at the Frost Music and Art Festival held on the Stanford campus on May 17th 2014. Projects can range from interactive art to unconventional set design, and from site-specific sculpture to immersive performance.nnDuring this second quarter students will concentrate on prototyping, maquette making, testing, team forming, project management, creative leadership, construction, site installation and documentation.nPart two of a two course series : ME 289A&B.
Same as: TAPS 289B

ME 290. GIVE BIG OR GO HOME. 3-4 Units.
When individuals or organizations attempt to solve social problems by giving money, they often overlook the people at the center of the situation. The bigger the problem, the more removed the donors or funding institutions become from the human experience. You will learn how to use human centered design to shape your giving, while also considering the roles of larger systems. Students will learn design thinking methods, how to conceptualize a system in which you want to make a difference, and creative ways to think about financing change.

ME 292. Humanize My Ride: Investigations in User-Centric Vehicle Design. 3 Units.
Humanize My Ride is vehicle design for the extreme user. We will explore the relationship between specialized vehicles and their user¿s needs to inform a deep dive into designing and prototyping a unique purpose modified ride for a new type of user. Utilizing the designing thinking approach and emerging technology such as Google GLASS, student teams will interview drivers and users of specific purpose cars and trucks and then choose a new user to design and build for. Teams will work collectively on different elements of one vehicle to test with their user¿s needs. This project-based course is accessible to students of all backgrounds interested in exploring and transforming the intersection of user-centric design, automotive technology, creative customization and hands-on building.

ME 297. Forecasting for Innovators:Technology, Tools & Social Change. 3 Units.
Technologies from the steam engine to the microprocessor have been mixed gifts, at once benefitting humankind and creating many of the problems facing humanity today. This class will explore how innovators can use forecasting methods to identify new challenges, develop responsive innovations and anticipate unintended consequences. Students will produce a long-range forecast project, applying a variety of methodologies including research, expert interviews and graphical exploration.

ME 298. Silversmithing and Design. 3-4 Units.
Skills involved in working with precious metals at a small scale. The course gives equal attention to design and the techniques involved in investment casting.

ME 299A. Practical Training. 1 Unit.
For master's students. Educational opportunities in high technology research and development labs in industry. Students engage in internship work and integrate that work into their academic program. Following internship work, students complete a research report outlining work activity, problems investigated, key results, and follow-up projects they expect to perform. Meets the requirements for curricular practical training for students on F-1 visas. Student is responsible for arranging own internship/employment and faculty sponsorship. Register under faculty sponsor's section number. All paperwork must be completed by student and faculty sponsor, as the Student Services Office does not sponsor CPT. Students are allowed only two quarters of CPT per degree program. Course may be repeated twice.

ME 299B. Practical Training. 1 Unit.
For Ph.D. students. Educational opportunities in high technology research and development labs in industry. Students engage in internship work and integrate that work into their academic program. Following internship work, students complete a research report outlining work activity, problems investigated, key results, and follow-up projects they expect to perform. Meets the requirements for curricular practical training for students on F-1 visas. Student is responsible for arranging own internship/employment and faculty sponsorship. Register under faculty sponsor's section number. All paperwork must be completed by student and faculty sponsor, as the student services office does not sponsor CPT. Students are allowed only two quarters of CPT per degree program. Course may be repeated twice.

ME 300A. Linear Algebra with Application to Engineering Computations. 3 Units.
Computer based solution of systems of algebraic equations obtained from engineering problems and eigen-system analysis, Gaussian elimination, effect of round-off error, operation counts, banded matrices arising from discretization of differential equations, ill-conditioned matrices, matrix theory, least square solution of unsolvable systems, solution of non-linear algebraic equations, eigenvalues and eigenvectors, similar matrices, unitary and Hermitian matrices, positive definiteness, Cayley-Hamilton theory and function of a matrix and iterative methods. Prerequisite: familiarity with computer programming, and MATH51.
Same as: CME 200

ME 300B. Partial Differential Equations in Engineering. 3 Units.
Geometric interpretation of partial differential equation (PDE) characteristics; solution of first order PDEs and classification of second-order PDEs; self-similarity; separation of variables as applied to parabolic, hyperbolic, and elliptic PDEs; special functions; eigenfunction expansions; the method of characteristics. If time permits, Fourier integrals and transforms, Laplace transforms. Prerequisite: CME 200/ME 300A, equivalent, or consent of instructor.
Same as: CME 204

ME 300C. Introduction to Numerical Methods for Engineering. 3 Units.
Numerical methods from a user's point of view. Lagrange interpolation, splines. Integration: trapezoid, Romberg, Gauss, adaptive quadrature; numerical solution of ordinary differential equations: explicit and implicit methods, multistep methods, Runge-Kutta and predictor-corrector methods, boundary value problems, eigenvalue problems; systems of differential equations, stiffness. Emphasis is on analysis of numerical methods for accuracy, stability, and convergence. Introduction to numerical solutions of partial differential equations; Von Neumann stability analysis; alternating direction implicit methods and nonlinear equations. Prerequisites: CME 200/ME 300A, CME 204/ME 300B.
Same as: CME 206

ME 301. LaunchPad:Design and Launch your Product or Service. 4 Units.
This is an intense course in product design and development offered to graduate students only (no exceptions). In just ten weeks, we will apply principles of design thinking to the real-life challenge of imagining, prototyping, testing and iterating, building, pricing, marketing, distributing and selling your product or service. You will work hard on both sides of your brain. You will experience the joy of success and the (passing) pain of failure along the way. This course is an excellent chance to practice design thinking in a demanding, fast-paced, results-oriented group with support from faculty and industry leaders. This course may change your life. We will treat each team and idea as a real start-up, so the work will be intense. If you do not have a passionate and overwhelming urge to start a business or launch a product or service, this class will not be a fit. Teams must visit office hours in winter quarter (Tuesdays 2:30p-4:00p) in order to be considered for the course.

ME 302. The Future of the Automobile. 1 Unit.
This quarter, the seminar will take a specific focus on "Advanced Driver Assistance Systems", which help drivers to maneuver their vehicles through traffic. Those systems range from navigation systems, adaptive cruise control, night vision, lane departure warning over automated parking, traffic jam assistance, to self-driving cars. With this breadth of applications, advanced driver assistance systems play an important role in making traffic safer, more efficient, and more enjoyable. This course, lectured by an industry expert, will introduce students to technology behind the systems, the benefits, challenges, and future perspectives of this exciting field. At the end of the quarter, students will have developed a technical understanding as well as an understanding for the interactions of the technology, business, and society with a specific automotive focus.

ME 302A. Introduction to Automotive and Transportation Innovation at Stanford. 1 Unit.
The objective of this course is to survey the innovative automotive and transportation community within Stanford. Stanford University has become one of the best universities on earth to to change the future of transportation and this course is a 'who's who' of that world. This is the first part of a 3-quarter seminar series, which build on one another but can be taken independently. This quarter, the seminar will feature talks from Stanford experts in focus areas as varied as autonomous vehicles, entrepreneurship, design, ethics, aerodynamics, neuroscience, communications and security. At the end of the quarter, students will have developed an understanding of Stanford's portfolio of transportation work and know the specific individuals who are key to its future. To obtain credit, students must attend the first class (no exceptions) plus 7 additional classes for a total of 8 classes.

ME 302B. The Future of the Automobile- Driver Assistance and Automated Driving. 1 Unit.
The objective of this course is to develop an understanding for the requirements that go into the design of a highly complex yet easy-to-use product, i.e. the automobile. Students will learn about very different interdisciplinary aspects that characterize the automobile and personal mobility. This is the second part of a 3-quarter seminar series, which build on one another but can be taken independently. This quarter, the seminar will discuss how various vehicle systems help drivers to maneuver their vehicles through traffic. Advanced driver assistance systems range from navigation, adaptive cruise control, night vision, and lane departure warning to automated parking, traffic jam assistance, and eventually self-driving cars. These systems play an important role in making traffic safer, more efficient, and more enjoyable. This course, lectured by an industry expert, will introduce students to the technology behind the systems, the benefits, challenges, and future perspectives of this exciting field. Students will develop an understanding for the interactions of the technology, business, and society with a specific automotive focus.

ME 302C. The Future of the Automobile- Mobility Entrepreneurship. 1 Unit.
The objective of this course is to develop an understanding for the requirements that go into the design of a highly complex yet easy-to-use product, i.e. the automobile. Students will learn about very different interdisciplinary aspects that characterize the automobile and personal mobility. This is the third part of a 3-quarter seminar series, which build on one another but can be taken independently. This quarter, students will learn from 9 different founders / C-level executives about how they built their mobility startup to change the world of transportation. Founders from Varden Labs, Lyft, Pearl Auto, Turo and more will be featured. In hearing these founder stories, students will get an insight not only into the world of entrepreneurship but also the multidisciplinary nature of the transportation industry. The course consists of 50-minute discussions with founders, with students encouraged to participate and ask questions of the founders. To obtain credit, students must attend 7 out of 9 classes including the first class.

ME 303. Biomechanics of Flight. 3 Units.
Study of biological flight as an inspiration for designing robots. The goal is to give students a broad understanding of the biomechanics of natural flight, and an in-depth understanding of bird flight. This course elucidates how students can pick and choose exciting biological questions, use biological and engineering techniques to answer them, and use the results to identify bio-inspired design applications. Prerequisites: Fluid mechanics OR Aerodynamics AND Fluent Matlab skills. Course website URL: http://lentinklab.stanford.edu/impact/stanford_teaching.

ME 304. The Designer's Voice. 1 Unit.
This course for Masters students in the Stanford Design Program helps students develop a point of view about their design career that will enable them to articulate their design vision, inspire a design studio, or infect a business with a culture of design-thinking. This class focuses on the integration of work and worldview, professional values, design language, and the development of the designer's voice. Includes seminar-style discussions, role-playing, short writing assignments, guest speakers, and individual mentoring and coaching.

ME 306. Engineering Design Theory in Practice. 3 Units.
Introduction to theories and frameworks underlying engineering design practice. Why do we do the things we do in engineering design thinking? How can we improve performance using design frameworks? Four perspectives on design thinking ¿ design as social activity, cognitive activity, prototyping and learning. Practice of effective team behaviors for concept generation, decision-making, and conflict-handling. C-K Theory and its application to design practice. Media cascade and boundary object frameworks for prototyping. Application of Perception-Action framework and Social Learning Theory. Students engage in multiple projects to apply theories to practical situations.

ME 308. Spatial Motion. 3 Units.
The geometry of motion in Euclidean space. Fundamentals of theory of screws with applications to robotic mechanisms, constraint analysis, and vehicle dynamics. Methods for representing the positions of spatial systems of rigid bodies with their inter-relationships; the formulation of Newton-Euler kinetics applied to serial chain systems such as industrial robotics.

ME 309. Finite Element Analysis in Mechanical Design. 3 Units.
Basic concepts of finite elements, with applications to problems confronted by mechanical designers. Linear static, modal, and thermal formulations emphasized; nonlinear and dynamic formulations introduced. Application of a commercial finite element code in analyzing design problems. Issues: solution methods, modeling techniques, features of various commercial codes, basic problem definition. Individual projects focus on the interplay of analysis and testing in product design/development. Prerequisites: Math 51, or equivalent. Recommended: ME80 or CEE101A, or equivalent in structural and/or solid mechanics; some exposure to principles of heat transfer.

ME 310A. Product-Based Engineering Design, Innovation, and Development. 4 Units.
This is the 1st quarter of a 3-quarter sequence. It may be taken as a stand-alone course, and is a pre-requisite for ME310BC. It is designed for engineering graduate students seeking a start-up-like experience on projects related to sustainability, automotive interfaces, biomedical devices, robotics, and user interaction design. The ME310 Design Loft (bldg. 550 rm204) is your start-up flight-simulator. In October student teams are paired with teams from overseas partner universities. At that time, global corporations will present break-through product innovation challenges. The Stanford and partner teams engage in design exploration using ##design thinking methodology including team-dynamics, rapid prototyping and human-centric problem framing. A final report, based on functional prototype testing, defines design requirements and user experience opportunities for Winter and Spring.

ME 310B. Product-Based Engineering Design, Innovation, and Development. 4 Units.
This is the 2nd quarter of a 3-quarter sequence. ME310A may be taken as a stand-alone course, and is a pre-requisite for ME310BC. It is designed for engineering graduate students seeking a ##start-up-like## experience on projects related to sustainability, automotive interfaces, biomedical devices, robotics, and user interaction design. The ME310 Design Loft (bldg. 550 rm204) is your â##start-up flight-simulator. In October student teams are paired with teams from overseas partner universities. At that time, global corporations will present break-through product innovation challenges. The Stanford and partner teams engage in design exploration using design thinking## methodology including team-dynamics, rapid prototyping and human-centric problem framing. A final report, based on functional prototype testing, defines design requirements and user experience opportunities for Winter and Spring.

ME 310C. Project-Based Engineering Design, Innovation, and Development. 4 Units.
Winter and Spring quarters are taken as a unit, with a single grade for both quarters. Admission to ME310BC is by instructor consent, based on an application submitted in December. Industry-project specific teams work with paired design teams at overseas partner universities. Student/project alignment may change from ME310a, depending on enrollment details. International travel, typically during the spring break, is supported but not required. Teams manage a significant budget for prototyping, subcontracting and evaluating product performance. ME310BC embraces a human-centric design philosophy that includes detailed user-experience-testing for one or more identified user populations.

ME 310I. The Essential Elements of New Product Development: Business and Industry Perspectives. 1 Unit.
Restricted to graduate students. Topics include new product developmentnagenda, new product management skills, leadership and team management,ncultural awareness, organizational culture, industrial challenges andnopportunities. Seminar will include in-class discussions and guestnspeakers from industry.

ME 312. Advanced Product Design: Formgiving. 3 Units.
Lecture/lab. Small- and medium- scale design projects carried to a high degree of aesthetic refinement. Emphasis is on form development, design process, and model making.

ME 313. Human Values and Innovation in Design. 3 Units.
Introduction to the philosophy, spirit, and tradition of the product design program. Hands-on design projects used as vehicles for design thinking, visualization, and methodology. The relationships among technical, human, aesthetic, and business concerns. Drawing, prototyping, and design skills. Focus is on tenets of design philosophy: point of view, user-centered design, design methodology, and iterative design.

ME 315. The Designer in Society. 3 Units.
This class focuses on individuals and their psychological well being. The class delves into how students perceive themselves and their work, and how they might use design thinking to lead a more creative and committed life. As a participant you read parts of a different book each week and then engage in exercises designed to unlock learnings. In addition, there is a self-selected term project dealing with either eliminating a problem from your life or doing something you have never done before. Apply the first day during class. Attendance at first session is mandatory; otherwise, at most one absence is acceptable. Admission by application. See dschool.stanford.edu/classes for more information.

ME 316A. Product Design Master's Project. 2-6 Units.
For graduate Product Design or Design (Art) majors only. Student teams, under the supervision of the design faculty, spend the quarter researching master's project topics. Students are expected to demonstrate mastery of design thinking methods including; needfinding, brainstorming, field interviews and synthesis during this investigation. Masters projects are selected that involve the synthesis of aesthetics and technological concerns in the service of human need. Design Institute class; see http://dschool.stanford.edu. Prereq: ME277, ME312, ME313.

ME 316B. Product Design Master's Project. 2-6 Units.
Design Garage is a Winter/Spring class (a two quarter commitment is required). The class is a deep dive in design thinking that uses student-led projects to teach design process and methods. The projects come from investigations conducted during the Fall quarter where the preliminary need finding, customer research, and product or service ideas have been developed to provide the seed projects for the student design teams. Students will learn the methodologies of design thinking by bringing a product, service, or experience to market. Students apply to Design Garage in the Fall, and teams are formed after interviews and applications are reviewed. Prerequisite: graduate student standing.

ME 316C. Product Design Master's Project. 2-6 Units.
This is the second half of the two quarter Design Garage sequence. Students will complete projects begun in ME316B the prior quarter. Prerequisite: ME316B and graduate student standing. Design Institute class; see http://dschool.stanford.edu.

ME 317A. Design Methods: Product Definition. 4 Units.
Systematic methodologies to define, develop, and produce world-class products. Student team projects to identify opportunities for improvement and develop a comprehensive product definition. Topics include value engineering, quality function deployment, FMEA and risk analysis, robustness, design for variety, design for life-cycle quality, financial analysis and Monte Carlo simulation. Students must take 317B to complete the project and obtain a letter grade. On-campus enrollment limited to 25; SCPD class size is limited to 75.

ME 317B. Design Methods: Quality By Design. 4 Units.
Building on 317A, focus is on the implementation of competitive product design. Student groups apply structured methods to optimize the design of an improved product, and plan for its manufacture, testing, and service. The project deliverable is a comprehensive product and process specification. Topics: concept generation and selection (Pugh's Method), Poka Yoke, design for robustness, Monte Carlo and Design for Six Sigma, process capability analysis, financial analysis, and prototyping. On-campus class limited to 25. For SCPD students, limit is 75. Prerequisite: 317A.

ME 318. Computer-Aided Product Creation. 4 Units.
Design course focusing on an integrated suite of computer tools: rapid prototyping, solid modeling, computer-aided machining, and computer numerical control manufacturing. Students choose, design, and manufacture individual products, emphasizing individual design process and computer design tools. Field trips demonstrate Stanford Product Realization Lab's relationship to the outside world. Structured lab experiences build a basic CAD/CAM/CNC proficiency. Limited enrollment. Prerequisite: consent of instructor.

ME 319. Fundamentals of Design for Design Thinkers. 2-4 Units.
This course is an introduction to the fundamental principles of Design, geared toward graduate students involved and invested in innovation and design thinking. Core concepts include Contrast, Color, Materiality, Form, Proportion, Transitions, and more. Students will be introduced to the major philosophical concepts of design in readings and in class, and will practice techniques in class and via weekly hands-on projects out of class, culminating in a final personal project. Students will also be introduced to many hands-on prototyping and making skills via access to the Product Realization Lab and Room 36 (webshop.stanford.edu).

ME 320. Introduction to Robotics. 3 Units.
Robotics foundations in modeling, design, planning, and control. Class covers relevant results from geometry, kinematics, statics, dynamics, motion planning, and control, providing the basic methodologies and tools in robotics research and applications. Concepts and models are illustrated through physical robot platforms, interactive robot simulations, and video segments relevant to historical research developments or to emerging application areas in the field. Recommended: matrix algebra. Same as: CS 223A

ME 321. Optofluidics: Interplay of Light and Fluids at the Micro and Nanoscale. 3 Units.
Many optical systems in biology have sophisticated designs with functions that conventional optics cannot achieve: no synthetic materials, for example, can provide the camouflage capability exhibited by some animals. This course overviews recent efforts--some inspired by examples in biology--in using fluids, soft materials and nanostructures to create new functions in optics. Topics include electrowetting lenses, electronic inks, colloidal photonic crystals, bioinspired optical nanostructures, nanophotonic biosensors, lens-less optofluidic microscopes. The use of optics to control fluids is also discussed: optoelectronic tweezers, particle trapping and transport, microrheology, optofluidic sorters, fabrication and self-assembly of novel micro and nanostructures.

ME 322. Kinematic Synthesis of Mechanisms. 3 Units.
The rational design of linkages. Techniques to determine linkage proportions to fulfill design requirements using analytical, graphical, and computer based methods.

ME 323. Modeling and Identification of Mechanical Systems for Control. 3 Units.
Lecture/Lab. The art and science behind developing mathematical models for control system design. Theoretical and practical system modeling and parameter identification. Frequency domain identification, parametric modeling, and black-box identification. Analytical work and laboratory experience with identification, controller implementation, and the implications of unmodeled dynamics and non-linearities. Prerequisites: linear algebra and system simulation with MATLAB/SIMULINK; ENGR 105.

ME 324. Precision Engineering. 4 Units.
Advances in engineering are often enabled by more accurate control of manufacturing and measuring tolerances. Concepts and technology enable precision such that the ratio of overall dimensions to uncertainty of measurement is large relative to normal engineering practice. Typical application areas: non-spherical optics, computer information storage devices, and manufacturing metrology systems. Application experience through design and manufacture of a precision engineering project, emphasizing the principles of precision engineering. Structured labs; field trips. Prerequisite: consent of instructors.

ME 325. Making Multiples: Scaled Manufacturing Tooling. 3 Units.
Design course focusing on the process of injection molding as a prototyping and manufacturing tool. Coursework will include creating and evaluating initial design concepts, detailed part design, mold design, mold manufacturing, molding parts, and testing and evaluating the results. Students will work primarily on individually selected projects, using each project as a tool to continue developing and exercising individual design process. Lectures and field trips will provide students with context for their work in the Stanford Product Realization Lab. Prerequisite: ME318 or consent of instructors.

ME 326. Telerobotics and Human-Robot Interactions. 3 Units.
Focus is on dynamics and controls. Evaluation and implementation of required control systems. Topics include master-slave systems, kinematic and dynamic similarity; control architecture, force feedback, haptics, sensory substitutions; stability, passivity, sensor resolution, servo rates; time delays, prediction, wave variables. Hardware-based projects encouraged, which may complement ongoing research or inspire new developments. Limited enrollment. Prerequisites: ENGR 205, 320 or CS 223A, or consent of instructor. (Niemeyer).

ME 327. Design and Control of Haptic Systems. 4 Units.
Study of the design and control of haptic systems, which provide touch feedback to human users interacting with virtual environments and teleoperated robots. Focus is on device modeling (kinematics and dynamics), synthesis and analysis of control systems, design and implementation, and human interaction with haptic systems. Coursework includes homework/laboratory assignments and a research-oriented project. Directed toward graduate students and advanced undergraduates in engineering and computer science. Prerequisites: dynamic systems and MATLAB programming. Suggested experience with programming, feedback control design, and hardware prototyping.

ME 328. Medical Robotics. 3 Units.
Study of the design and control of robots for medical applications. Focus is on robotics in surgery and interventional radiology, with introduction to other healthcare robots. Delivery is through instructor lectures and weekly guest speakers. Coursework includes homework and laboratory assignments, an exam, and a research-oriented project. Directed toward graduate students and advanced undergraduates in engineering and computer science; no medical background required. Prerequisites: dynamic systems and MATLAB programming. Suggested experience with C/C++ programming, feedback control design, and linear systems. Cannot be taken concurrently with CS 571.

ME 329. Mechanical Analysis in Design. 3 Units.
This project based course will cover the application of engineering analysis methods learned in the Mechanics and Finite Element series to real world problems involving the mechanical analysis of a proposed device or process. Students work in teams, and each team has the goal of solving a problem defined jointly with a sponsoring company or research group. Each team will be mentored by a faculty mentor and a mentor from the sponsoring organization. The students will gain experience in the formation of project teams; interdisciplinary communication skills; intellectual property; and project management. Course has limited enrollment.

ME 330. Advanced Kinematics. 3 Units.
Kinematics from mathematical viewpoints. Introduction to algebraic geometry of point, line, and plane elements. Emphasis is on basic theories which have potential application to mechanical linkages, computational geometry, and robotics.

ME 331A. Advanced Dynamics & Computation. 3 Units.
Newton, Euler, momentum, and road-map methods and computational tools for 3-D force and motion analysis of multibody systems. Power, work, and energy. Numerical solutions (e.g., MATLAB, etc.) of nonlinear algebraic and differential equations governing the static and dynamic behavior of multiple degree of freedom systems.

ME 331B. Advanced Dynamics, Simulation & Control. 3 Units.
Advanced methods and computational tools for the efficient formulation of equations of motion for multibody systems. D'Alembert principle. Power, work, and energy. Kane's and Lagrange's method. Computed torque control. Systems with constraints. Quaternions. Numerical solutions (e.g., MATLAB, etc.) of nonlinear algebraic and differential equations governing the behavior of multiple degree of freedom systems. Team-based computational multi-body lab project (inclusion of feed-forward control optional).

ME 332. Introduction to Computational Mechanics. 3 Units.
Provides an introductory overview of modern computational methods for problems arising primarily in mechanics of solids and is intended for students from various engineering disciplines. The course reviews the basic theory of linear solid mechanics and introduces students to the important concept of variational forms, including the principle of minimum potential energy and the principles of virtual work. Specific model problems that will be considered include deformation of bars, beams and membranes, plates, and problems in plane elasticity (plane stress, plane strain, axisymmetric elasticity). The variational forms of these problems are used as the starting point for developing the finite element method (FEM) and boundary element method (BEM) approaches providing an important connection between mechanics and computational methods.
Same as: CME 232

ME 333. Mechanics. 3 Units.
Goal is a common basis for advanced mechanics courses. Introduction to variation calculus. Formulation of the governing equations from a Lagrangian perspective for finite and infinite dimensional mechanical systems. Examples include systems of particles and linear elastic solids. Introduction to tensors. Definition and interpretation of Cauchy stress tenor.

ME 333A. Mechanics - Fundamentals and Lagrangian Mechanics. 3 Units.
Goal is a common basis for advanced mechanics courses. Introduction to variational calculus. Formulation of the governing equations from a Lagrangian perspective for finite and infinite dimensional mechanical systems. Examples include systems of particles and linear elastic solids. Introduction to tensors. Definition and interpretation of Cauchy stress tensor.

ME 333B. Mechanics - Elasticity and Inelasticity. 3 Units.
Introduction to the theories of elasticity, plasticity and fracture and their applications. Elasticity: Definition of stress, strain, and elastic energy; equilibrium and compatibility conditions; and formulation of boundary value problems. Stress function approach to solve 2D elasticity problems and Greenâ##s function approach in 3D. Applications to contact and crack. Plasticity: Yield surface, associative flow rule, strain hardening models, crystal plasticity models. Applications to plastic bending, torsion and pressure vessels. Fracture: Linear elastic fracture mechanics, J-integral, Dugdale-Barrenblatt crack model. Applications to brittle fracture and fatigue crack growth. Computer programming in Matlab is used to aid analytic derivation and numerical solutions.

ME 333C. Mechanics - Continuum Mechanics. 3 Units.
Introduction to linear and nonlinear continuum mechanics of solids. Introduction to tensor algebra and tensor analysis. Kinematics of motion. Balance equations of mass, linear and angular momentum, energy, and entropy. Constitutive equations of isotropic and anisotropic hyperelastic solids. Introduction to numerical solution techniques.

ME 335A. Finite Element Analysis. 3 Units.
Fundamental concepts and techniques of primal finite element methods. Method of weighted residuals, Galerkin's method and variational equations. Linear eliptic boundary value problems in one, two and three space dimensions; applications in structural, solid and fluid mechanics and heat transfer. Properties of standard element families and numerically integrated elements. Implementation of the finite element method using Matlab, assembly of equations, and element routines. Lagrange multiplier and penalty methods for treatment of constraints. The mathematical theory of finite elements.

ME 335B. Finite Element Analysis. 3 Units.
Finite element methods for linear dynamic analysis. Eigenvalue, parabolic, and hyperbolic problems. Mathematical properties of semi-discrete (t-continuous) Galerkin approximations. Modal decomposition and direct spectral truncation techniques. Stability, consistency, convergence, and accuracy of ordinary differential equation solvers. Asymptotic stability, over-shoot, and conservation laws for discrete algorithms. Mass reduction. Applications in heat conduction, structural vibrations, and elastic wave propagation. Computer implementation of finite element methods in linear dynamics. Implicit, explicit, and implicit-explicit algorithms and code architectures.

ME 335C. Finite Element Analysis. 3 Units.
Newton's method for nonlinear problems; convergence, limit points and bifurcation; consistent linearization of nonlinear variational forms by directional derivative; tangent operator and residual vector; variational formulation and finite element discretization of nonlinear boundary value problems (e.g. nonlinear heat equation, nonlinear elasticity); enhancements of Newton's method: line-search techniques, quasi-Newton and arc-length methods.

ME 337. Mechanics of Growth. 3 Units.
Introduction to continuum theory and computational simulation of living matter. Kinematics of finite growth. Balance equations in open system thermodynamics. Constitutive equations for living systems. Custom-designed finite element solution strategies. Analytical solutions for simple model problems. Numerical solutions for clinically relevant problems such as: bone remodeling; wound healing; tumor growth; atherosclerosis; heart failure; tissue expansion; and high performance training.

ME 338. Continuum Mechanics. 3 Units.
Linear and nonlinear continuum mechanics for solids. Introduction to tensor algebra and tensor analysis. Kinematics of motion. Balance equations of mass, linear and angular momentum, energy, and entropy. Constitutive equations of isotropic and anisotropic hyperelasticity. Recommended as prerequisite for Finite Element Methods.

ME 338B. Continuum Mechanics. 3 Units.
Constitutive theory; equilibrium constitutive relations; material frame indifference and material symmetry; finite elasticity; formulation of the boundary value problem; linearization and well-posedness; symmetries and configurational forces; numerical considerations.

ME 339. Introduction to parallel computing using MPI, openMP, and CUDA. 3 Units.
This class will give hands on experience with programming multicore processors, graphics processing units (GPU), and parallel computers. Focus will be on the message passing interface (MPI, parallel clusters) and the compute unified device architecture (CUDA, GPU). Topics will include: network topologies, modeling communication times, collective communication operations, parallel efficiency, MPI, dense linear algebra using MPI. Symmetric multiprocessing (SMP), pthreads, openMP. CUDA, combining MPI and CUDA, dense linear algebra using CUDA, sort, reduce and scan using CUDA. Pre-requisites include: C programming language and numerical algorithms (solution of differential equations, linear algebra, Fourier transforms).
Same as: CME 213

ME 340. Theory and Applications of Elasticity. 3 Units.
This course provides an introduction to the elasticity theory and its application to material structures at microscale. The basic theory includes the definition of stress, strain and elastic energy; equilibrium and compatibility conditions; and the formulation of boundary value problems. We will mainly discuss the stress function method to solve 2D problems and will briefly discuss the Green's function approach for 3D problems. The theory and solution methods are then applied to contact problems as well as microscopic defects in solids, such as voids, inclusions, cracks, and dislocations. Computer programming in Matlab is used to aid analytic derivation and numerical solutions of elasticity problems.

ME 341. Design Experiments. 3 Units.
Design experiments to learn about the relationship between users and products, with an emphasis on quantitative output that is tested with statistics. Students will be exposed to all components of the experimental design process: research proposition, literature review, detailed hypotheses, method selection, experimental instruments, subject selection, pilot studies, analysis approaches, reporting results, and discussing conclusions. Students will receive human subjects training and complete the IRB certificate. Possible experiment design tools include in-person observation and interviews, web surveys, and eye-tracking.

ME 342. Theory and Application of Inelasticity. 3 Units.
Theories of plasticity and fracture phenomena from both phenomenological and micromechanical viewpoints. Yield surface, flow rules, strain hardening models, and applications to creep. Plastic zone near crack tip. Linear fracture mechanics and other criteria for crack initiation and growth. Application to fatigue. Classical analytic solutions will be discussed together with numerical solutions of plane elastoplatic problems by Matlab.

ME 342A. Mechanobiology and Biofabrication Methods. 3 Units.
Cell mechanobiology topics including cell structure, mechanical models, and chemo-mechanical signaling. Review and apply methods for controlling and analyzing the biomechanics of cells using traction force microscopy, AFM, micropatterning and cell stimulation. Practice and theory for the design and application of methods for quantitative cell mechanobiology.
Same as: BIOPHYS 342A

ME 342D. MEMS Fabrication/Projects. 1-3 Unit.
Emphasis is on process planning, in process testing, nanofabrication training, exposure to MEMS industry applications. Prerequisite: ENGR 341.

ME 344. Introduction to High Performance Computing. 3 Units.
ME344 is an introductory course on High Performance Computing (HPC) through parallel computer architectures and programming. This course will discuss fundamentals of a multi-processor architecture and how to take advantage of systems to solve large scale problems in wide ranging applications such as computational fluid dynamics, image processing, machine learning and analytics. The course will consist of lecture with interactive labs and homework conducted on an Intel® Xeon Phi¿ Processor based HPC cluster using various software tools that are part of the parallel studio toolkit. The course will address foundational performance tuning techniques on Intel-based machines and high-speed interconnects. This course is open to both computer scientists and computational scientists who are interested in learning about data parallelism, scaling to large number of nodes, and performance tuning methodologies and tools on standards driven languages and parallel models (C/C++/Fortrann/MPI/OpenMP/Threading Building Blocks/Python). As it¿s desirable to have such a mix of students, the course will not assume much background, though some programming skills will be needed to get the most of the course.

ME 345. Fatigue Design and Analysis. 3 Units.
The mechanism and occurrences of fatigue of materials. Methods for predicting fatigue life and for protecting against premature fatigue failure. Use of elastic stress and elastic-plastic strain analyses to predict crack initiation life. Use of linear elastic fracture mechanics to predict crack propagation life. Effects of stress concentrations, manufacturing processes, load sequence, irregular loading, multi-axial loading. Subject is treated from the viewpoints of the engineer seeking up-to-date methods of life prediction and the researcher interested in improving understanding of fatigue behavior. Prerequisite: undergraduate mechanics of materials.

ME 346A. Introduction to Statistical Mechanics. 3 Units.
The main purpose of this course is to provide students with enough statistical mechanics background to the Molecular Simulations classes (ME 346B,C), including the fundamental concepts such as ensemble, entropy, and free energy, etc. The main theme of this course is how the laws at the macroscale (thermodynamics) can be obtained by analyzing the spontaneous fluctuations at the microscale (dynamics of molecules). Topics include thermodynamics, probability theory, information entropy, statistical ensembles, phase transition and phase equilibrium. Recommended: PHYSICS 110 or equivalent.

ME 346B. Introduction to Molecular Simulations. 3 Units.
Algorithms of molecular simulations and underlying theories. Molecular dynamics, time integrators, modeling thermodynamic ensembles (NPT, NVT), free energy, constraints. Monte Carlo simulations, parallel tempering. Stochastic equations, Langevin and Brownian dynamics. Applications in solids, liquids, and biomolecules (proteins). Programming in Matlab.

ME 346C. Advanced Techniques for Molecular Simulations. 3 Units.
Advanced methods for computer simulations of solids and molecules. Methods for long-range force calculation, including Ewald methods and fast multipole method. Methods for free energy calculation, such as thermodynamic integration. Methods for predicting rates of rare events (e.g. nucleation), including nudged elastic band method and umbrella sampling method. Students will work on projects in teams.

ME 347. Mathematical Theory of Dislocations. 3 Units.
The mathematical theory of straight and curvilinear dislocations in linear elastic solids. Stress fields, energies, and Peach-Koehler forces associated with these line imperfections. Anisotropic effects, Green's function methods, and the geometrical techniques of Brown and Indenborn-Orlov for computing dislocation fields and for studying dislocation interactions. Continuously distributed dislocations and cracks and inclusions.

ME 348. Experimental Stress Analysis. 3 Units.
Theory and applications of photoelasticity, strain sensors, and holographic interferometry. Comparison of test results with theoretical predictions of stress and strain. Discussion of other methods (optical fiber strain sensors, digital image correlation, thermoelasticity, brittle coating, Moire interferometry, residual stress determination). Six labs plus mini-project. Limited enrollment. Lab fee.

ME 349. Variational Methods in Elasticity and Plate Theory. 3 Units.
An introduction to variational calculus methods and their applications to the theories of elasticity and plates.

ME 350A. Design @ the Intersection of Science, Technology, and Entrepreneurship. 1 Unit.
This 1 credit class is for graduate students who are passionate about turning their research into a product or service. This is a chance to explore the potential impact of your work beyond your lab or research group. We are looking for students from the sciences, engineering, or mathematics, or students who have business acumen or start-up experience focused on technology driven companies. If you want to get out of your lab, away from your machine, and start to design your future come join us. The class will begin your journey from research to product conceptualization and user centered design through exercises and group activities. We¿ll meet once a week over the quarter in 10 self-contained 2 hour workshops where students will focus on their own work as well as explore the practical applications of fellow students¿ ideas, experience team formation and collaboration, and begin to explore product and service design. Aside from class time you will need to commit up to one hour per week outside the class on customer and market exploration. Advisors from industry and academia will mentor student teams. The class will be structured for individuals with team formation optional.

ME 351A. Fluid Mechanics. 3 Units.
Exact and approximate analysis of fluid flow covering kinematics, global and differential equations of mass, momentum, and energy conservation. Forces and stresses in fluids. Euler¿s equations and the Bernoulli theorem applied to inviscid flows. Vorticity dynamics. Topics in irrotational flow: stream function and velocity potential for exact and approximate solutions; superposition of solutions; complex potential function; circulation and lift. Some boundary layer concepts.

ME 351B. Fluid Mechanics. 3 Units.
Laminar viscous fluid flow. Governing equations, boundary conditions, and constitutive laws. Exact solutions for parallel flows. Creeping flow limit, lubrication theory, and boundary layer theory including free-shear layers and approximate methods of solution; boundary layer separation. Introduction to stability theory and transition to turbulence, and turbulent boundary layers. Prerequisite: 351A.

ME 352A. Radiative Heat Transfer. 3 Units.
The fundamentals of thermal radiation heat transfer; blackbody radiation laws; radiative properties of non-black surfaces; analysis of radiative exchange between surfaces and in enclosures; combined radiation, conduction, and convection; radiative transfer in absorbing, emitting, and scattering media. Advanced material for students with interests in heat transfer, as applied in high-temperature energy conversion systems. Take 352B,C for depth in heat transfer. Prerequisites: graduate standing and undergraduate course in heat transfer. Recommended: computer skills.

ME 352B. Fundamentals of Heat Conduction. 3 Units.
Physical description of heat conduction in solids, liquids, and gases. The heat diffusion equation and its solution using analytical and numerical techniques. Data and microscopic models for the thermal conductivity of solids, liquids, and gases, and for the thermal resistance at solid-solid and solid-liquid boundaries. Introduction to the kinetic theory of heat transport, focusing on applications for composite materials, semiconductor devices, micromachined sensors and actuators, and rarefied gases. Prerequisite: consent of instructor.

ME 352C. Convective Heat Transfer. 3 Units.
Prediction of heat and mass transfer rates based on analytical and numerical solutions of the governing partial differential equations. Heat transfer in fully developed pipe and channel flow, pipe entrance flow, laminar boundary layers, and turbulent boundary layers. Superposition methods for handling non-uniform wall boundary conditions. Approximate models for turbulent flows. Comparison of exact and approximate analyses to modern experimental results. General introduction to heat transfer in complex flows. Prerequisite: 351B or equivalent.

ME 353. Design for Additive Manufacturing. 4 Units.
Additive manufacturing and the associated emergence of algorithmic CAD software are changing the landscape for design engineers. The next generation of software is not solely based on geometry, but asks engineers to specify the desired performance parameters of their solution and leaves it up to the computer to create a geometry that optimizes that solution. Usually such geometries would be impossibly expensive or impossible to produce, but as additive manufacturing technologies and tools advance, we are approaching a world in which there will be virtually no geometric barriers associated with manufacturing cost.

ME 354. Experimental Methods in Fluid Mechanics. 4-5 Units.
Experimental methods associated with the interfacing of laboratory instruments, experimental control, sampling strategies, data analysis, and introductory image processing. Instrumentation including point-wise anemometers and particle image tracking systems. Lab. Prerequisites: previous experience with computer programming and consent of instructor. Limited enrollment.

ME 355. Compressible Flow. 3 Units.
Topics include quasi-one-dimensional isentropic flow in variable area ducts, normal shock waves, oblique shock and expansion waves, flow in ducts with friction and heat transfer, unsteady one-dimensional flow, and steady two-dimensional supersonic flow.

ME 357. Turbine and Internal Combustion Engines. 3 Units.
Principles of design analysis for aircraft gas turbines and automotive piston engines. Analysis for aircraft engines performed for Airbus A380 type aircraft. Design parameters determined considering aircraft aerodynamics, gas turbine thermodynamics, compressible flow physics, and material limitations. Additional topics include characteristics of main engine components, off-design analysis, and component matching. Performance of automotive piston engines including novel engine concepts in terms of engine thermodynamics, intake and exhaust flows, and in-cylinder flow.
Same as: ME 257

ME 358. Heat Transfer in Microdevices. 3 Units.
Application-driven introduction to the thermal design of electronic circuits, sensors, and actuators that have dimensions comparable to or smaller than one micrometer. The impact of thin-layer boundaries on thermal conduction and radiation. Convection in microchannels and microscopic heat pipes. Thermal property measurements for microdevices. Emphasis is on Si and GaAs semiconductor devices and layers of unusual, technically-promising materials such as chemical-vapor-deposited (CVD) diamond. Final project based on student research interests. Prerequisite: consent of instructor.

ME 359. Designing for Safety in Labor and Delivery. 3 Units.
Designing For Safety In Labor & Delivery will inform students about challenges in the L&D environment through direct observation in a simulated environment and the hospital. Simultaneously, we will be studying the users: their environment, standard protocols, communication and behavior. Our goal is to identify need spaces that will lead to product, system or service innovation and improve safety and quality of care. Student groups will have structured access to OB/GYN, pediatric and neonatology clinicians at Lucile Packard Children¿s Hospital, as well as parents for conducting ethnography. Field trips to Lucile Packard Children¿s Hospital and The Kaiser Garfield Healthcare Innovation Center are planned as well. Physical prototypes and/or scenarios can be tested and presented at CAPE¿s simulation lab in order to give students a realistic environment in which to evaluate and present their ideas. Prior design process experience is helpful but not a prerequisite. Collaboration with teammates is required and critical for student success. To be considered for admission, you must complete the application by 12/15/16 AND attend the first class. Admission by application. See dschool.stanford.edu/classes for more information.

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

ME 359B. Advanced Design and Engineering of Space Systems II. 4 Units.
Continuation of 359A. Topics include aerospace materials, mechanical environments, structural analysis and design, finite element analysis, mechanisms, thermal control, probability and statistics. Tours of Lockheed Martin facilities. Limited enrollment. Prerequisites: undergraduate degree in related field, or consent of instructor.

ME 361. Turbulence. 3 Units.
The nature of turbulent flows, statistical and spectral description of turbulence, coherent structures, spatial and temporal scales of turbulent flows. Averaging, two-point correlations and governing equations. Reynolds averaged equations and stresses. Free shear flows, turbulent jet, turbulent kinetic energy and kinetic energy dissipation, and kinetic energy budget. Kolmogorov's hypothesis and energy spectrum. Wall bounded flows, viscous scales, and law of the wall. Turbulence closure modeling for Reynolds averaged Navier Stokes equations. Direct and large eddy simulation of turbulent flows. Subgrid scale modeling.

ME 362A. Physical Gas Dynamics. 3 Units.
Concepts and techniques for description of high-temperature and chemically reacting gases from a molecular point of view. Introductory kinetic theory, chemical thermodynamics, and statistical mechanics as applied to properties of gases and gas mixtures. Transport and thermodynamic properties, law of mass action, and equilibrium chemical composition. Maxwellian and Boltzmann distributions of velocity and molecular energy. Examples and applications from areas of current interest such as combustion and materials processing.

ME 362B. Nonequilibrium Processes in High-Temperature Gases. 3 Units.
Chemical kinetics and energy transfer in high-temperature gases. Collision theory, transition state theory, and unimolecular reaction theory. Prerequisie: 362A or consent of instructor.

ME 363. Partially Ionized Plasmas and Gas Discharges. 3 Units.
Introduction to partially ionized gases and the nature of gas discharges. Topics: the fundamentals of plasma physics emphasizing collisional and radiative processes, electron and ion transport, ohmic dissipation, oscillations and waves, interaction of electromagnetic waves with plasmas. Applications: plasma diagnostics, plasma propulsion and materials processing. Prerequisite: 362A or consent of instructor.

ME 364. Optical Diagnostics and Spectroscopy. 3 Units.
The spectroscopy of gases and laser-based diagnostic techniques for measurements of species concentrations, temperature, density, and other flow field properties. Topics: electronic, vibrational, and rotational transitions; spectral lineshapes and broadening mechanisms; absorption, fluorescence, Rayleigh and Raman scattering methods; collisional quenching. Prerequisite: 362A or equivalent.

ME 367. Optical Diagnostics and Spectroscopy Laboratory. 4 Units.
Principles, procedures, and instrumentation associated with optical measurements in gases and plasmas. Absorption, fluorescence and emission, and light-scattering methods. Measurements of temperature, species concentration, and molecular properties. Lab. Enrollment limited to 16. Prerequisite: 362A or 364.

ME 368. d.Leadership: Design Leadership in Context. 1-3 Unit.
d.Leadership is a course that teaches the coaching and leadership skills needed to drive good design process in groups. d.leaders will work on real projects driving design projects within organizations and gain real world skills as they experiment with their leadership style. Take this course if you are inspired by past design classes and want skills to lead design projects beyond Stanford. Preference given to students who have taken other Design Group or d.school classes. Admission by application. See dschool.stanford.edu/classes for more information.
Same as: MS&E 489

ME 368A. Biodesign Innovation: Needs Finding and Concept Creation. 4 Units.
In this two-quarter course series (BIOE 374A/B, MED 272A/B, ME 368A/B, OIT 384/5), multidisciplinary student teams identify real-world unmet healthcare needs, invent new medtech products to address them, and plan for their development into patient care. During the first quarter (winter 2017), students select and characterize an important unmet healthcare problem, validate it through primary interviews and secondary research, and then brainstorm and screen initial technology-based solutions. In the second quarter (spring 2017), teams select a lead solution and move it toward the market through prototyping, technical re-risking, strategies to address healthcare-specific requirements (regulation, reimbursement), and business planning. Final presentations in winter and spring are made to a panel of prominent medtech experts and investors. Class sessions include faculty-led instruction and case demonstrations, coaching sessions by industry specialists, expert guest lecturers, and interactive team meetings. Enrollment is by application only, and students are expected to participate in both quarters of the course. Visit http://biodesign.stanford.edu/programs/stanford-courses/biodesign-innovation.html to access the application, examples of past projects, and student testimonials. More information about Stanford Biodesign, which has led to the creation of more than 40 venture-backed healthcare companies and has helped hundreds of student launch health technology careers, can be found at http://biodesign.stanford.edu/.
Same as: BIOE 374A, MED 272A

ME 368B. Biodesign Innovation: Concept Development and Implementation. 4 Units.
In this two-quarter course series (BIOE 374A/B, MED 272A/B, ME 368A/B, OIT 384/5), multidisciplinary student teams identify real-world unmet healthcare needs, invent new medtech products to address them, and plan for their development into patient care. During the first quarter (winter 2017), students select and characterize an important unmet healthcare problem, validate it through primary interviews and secondary research, and then brainstorm and screen initial technology-based solutions. In the second quarter (spring 2017), teams select a lead solution and move it toward the market through prototyping, technical re-risking, strategies to address healthcare-specific requirements (regulation, reimbursement), and business planning. Final presentations in winter and spring are made to a panel of prominent medtech experts and investors. Class sessions include faculty-led instruction and case demonstrations, coaching sessions by industry specialists, expert guest lecturers, and interactive team meetings. Enrollment is by application only, and students are expected to participate in both quarters of the course. Visit http://biodesign.stanford.edu/programs/stanford-courses/biodesign-innovation.html to access the application, examples of past projects, and student testimonials. More information about Stanford Biodesign, which has led to the creation of more than 40 venture-backed healthcare companies and has helped hundreds of student launch health technology careers, can be found at http://biodesign.stanford.edu/.
Same as: BIOE 374B, MED 272B

ME 369. Cracks, Dislocations, and Waves. 3 Units.
The 6-dimensional formalism of A. N. Stroh will be developed to treat two-dimensional problems in elastically anisotropic media. Stress fields of straight dislocations will be developed, from which the elastic fields of line cracks (treated as continuous distributions of straight dislocations) will be obtained along with stress intensity factors and energy release rates. Steady waves including plane waves, Rayleigh waves, and Stoneley waves will be treated along with problems of reflection and refraction of incident plane waves in joined anisotropic half-spaces. Anisotropic boundary element methods will be discussed. Assignments will include both analytical and semi-analytical work as well as simple numerical methods to implement Stroh's formalism. Class notes and readings will be provided.

ME 370A. Energy Systems I: Thermodynamics. 3 Units.
Thermodynamic analysis of energy systems emphasizing systematic methodology for and application of basic principles to generate quantitative understanding. Exergy, mixtures, reacting systems, phase equilibrium, chemical exergy, and modern computational methods for analysis. Prerequisites: undergraduate engineering thermodynamics and computer skills such as Matlab.

ME 370B. Energy Systems II: Modeling and Advanced Concepts. 4 Units.
Development of quantitative device models for complex energy systems, including fuel cells, reformers, combustion engines, and electrolyzers, using thermodynamic and transport analysis. Student groups work on energy systems to develop conceptual understanding, and high-level, quantitative and refined models. Advanced topics in thermodynamics and special topics associated with devices under study. Prerequisite: 370A.

ME 370C. Energy Systems III: Projects. 3-5 Units.
Refinement and calibration of energy system models generated in ME 370B carrying the models to maturity and completion. Integration of device models into a larger model of energy systems. Prerequisites: 370A,B, consent of instructor.

ME 371. Combustion Fundamentals. 3 Units.
Heat of reaction, adiabatic flame temperature, and chemical composition of products of combustion; kinetics of combustion and pollutant formation reactions; conservation equations for multi-component reacting flows; propagation of laminar premixed flames and detonations. Prerequisite: 362A or 370A, or consent of instructor.

ME 372. Combustion Applications. 3 Units.
The role of chemical and physical processes in combustion; ignition, flammability, and quenching of combustible gas mixtures; premixed turbulent flames; laminar and turbulent diffusion flames; combustion of fuel droplets and sprays. Prerequisite: 371.

ME 373. Nanomaterials Synthesis and Applications for Mechanical Engineers. 3 Units.
This course provides an introduction to both combustion synthesis of functional nanomaterials and nanotechnology. The first part of the course will introduce basic principles, synthesis/fabrication techniques and application of nanoscience and nanotechnology. The second part of the course will discuss combustion synthesis of nanostructures in zero-, one- two- and three- dimensions, their characterization methods, physical and chemical properties, and applications in energy conversion systems.

ME 374. Dynamics and Kinetics of Nanoparticles. 3 Units.
Part 1: Thermodynamics, transport theories and properties, aerosol dynamics and reaction kinetics of nanoparticles in fluids. Nucleation, gas kinetic theory of nanoparticles, the Smoluchowski equation, gas-surface reactions, diffusion, thermophoresis, conservation equations and useful solutions. Part 2: Introduction to soot formation, nanoparticles in reacting flows, particle transport and kinetics in flames, atmospheric heterogenous reactions, and nanocatalysis.

ME 375A. StoryViz: COMMUNICATION REDESIGNED. 2-3 Units.
StoryViz is about creating authentic & compelling communication in many media: this year's topics include sketching, video, visual design & performance. Fantastic guests and a bevy of assignments will prepare students to communicate their work and ideas genuinely, concisely, and with a keen sense of wit. Limited enrollment; application required; see http://dschool.stanford.edu/classes. Please see notes.

ME 375B. Institute of Design Project 2. 1-6 Unit.
Hands-on, project-based series for d.school students emphasizing innovation and design thinking. Resolving constraints among technical, business, and human concerns to create solutions that benefit society. Real-world design projects in areas suck as K-12 education, social entrepreneurship, business prototyping, sustainability, and health and wellness. Design reviews and final course presentations. Industry and adviser interaction. Limited enrollment; application required; see http://dschool.stanford.edu/classes.

ME 375C. Institute of Design Project 3. 1-6 Unit.
Hands-on, project-based series for d.school students emphasizing innovation and design thinking. Resolving constraints among technical, business, and human concerns to create solutions that benefit society. Real-world design projects in areas suck as K-12 education, social entrepreneurship, business prototyping, sustainability, and health and wellness. Design reviews and final course presentations. Industry and adviser interaction. Limited enrollment; application required; see http://dschool.stanford.edu/classes.

ME 376A. Imagining the Future of Learning: SparkTruck - Designing Mobile Interventions for Education. 4 Units.
Created at the d.school last year, SparkTruck has traveled over 15,000 miles across the USA, teaching thousands of kids how to build stuff and unleash their creativity. In this class, students will explore the potential of a mobile platform for affecting change in the educational ecosystem. Topics will include introductions to the design process, modern prototyping tools, and the complex education ecosystem. Students will work in teams in this project-based class, and an emphasis will be placed on real-world prototyping through hands-on field work in local schools. Interested and qualified students will have the opportunity to embark on a cross-country road trip in the SparkTruck this summer. Open to all graduate students and well-qualified undergrads of any major. Enrollment is limited. Apply at www.sparktruck.org/apply.
Same as: EDUC 333B

ME 376C. Institute of Design Project 2. 1-6 Unit.
Hands-on, project-based series for d.school students. Design thinking, design processes, innovation methodologies, need finding, human factors, rapid prototyping, team dynamics, negotiation, and project management. Focus is on resolving constraints among technical, business, and human concerns to create solutions that benefit society. Real-world design projects. Weekly design reviews, final course presentations. Industry and adviser interaction. Limited enrollment; application required; see http://dschool.stanford.edu/classes.

ME 377. Design Thinking Studio: Experiences in Innovation and Design. 4 Units.
Design Thinking Studio is an immersive introduction to design thinking. You will engage in the real world, with your eyes, with your mind, with your hands, and with classmates to learn, practice, and use the tools and attitudes of design. The fundamental goal of the class is to cultivate the creative, synthetic, and divergent thinking of students. This is a project-based class, asking students to take on new behaviors of work: collaboration, experimentation, empathizing, visualization, craft and inference. Field work and collaboration with teammates are required and critical for student success. Winter 2016: This quarter, we will work on exercising your design muscles, the things designers do everyday (outside of projects or process) that shape their practice. In addition to teamwork, we will practice different core design capacities to stimulate creativity, and make you a better communicator and collaborator. Admission by application. See dschool.stanford.edu/classesnfor more information.

ME 378. Tell, Make, Engage: Action Stories for Entrepreneuring. 1-3 Unit.
Individual storytelling action and reflective observations gives the course an evolving framework of evaluative methods, from engineering design; socio cognitive psychology; and art, that are formed and reformed by collaborative development within the class. Stories attached to an idea, a discovery or starting up something new, are considered through iterative narrative work, and small group challenges. This course will use qualitative and quantitative methods for story engagement, assessment, and class determined research projects with practice exercises, artifacts, short papers and presentations. Graduate and Co-Term students from all programs welcome.

ME 379. Fail Faster. 1 Unit.
Fail Faster will dive deeply into one of design thinking's key tenets: Fail early, fail often. Students will explore ways to: [1] become comfortable with uncertainty, [2] develop tools to navigate situations of failure, and [3] learn to turn failures into opportunities. This exercised-based workshop will examine the physiological impact of failure and practice the psychological traits and the power of resilience through hands-on activities. Participants will acquire techniques to help them navigate, bounce back, grow and even flourish in the face of their failures.

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

ME 385. Tissue Engineering Lab. 1-2 Unit.
Hands-on experience in the fabrication of living engineered tissues. Techniques include sterile technique, culture of mammalian cells, creation of cell-seeded scaffolds, and the effects of mechanical loading on the metabolism of living engineered tissues. Theory, background, and practical demonstration for each technique. Lab.

ME 386. Neuromuscular Biomechanics. 3 Units.
The interplay between mechanics and neural control of movement. State of the art assessment through a review of classic and recent journal articles. Emphasis is on the application of dynamics and control to the design of assistive technology for persons with movement disorders.
Same as: BIOE 386

ME 387. Soft Tissue Mechanics. 3 Units.
Structure/function relationships and mechanical properties of soft tissues, including nonlinear elasticity, viscoelasticity, and poroelasticity.

ME 388. Transport Modeling for Biological Systems. 3 Units.
Introduction to electric fields, fluid flows, transport phenomena and their application to biological systems. Maxwell's equations, electrostatics, electro-chemical-mechanical driving forces in physiological systems. Ionic diffusion in electrolytes and membrane transport. Fluid and solid continua theory for porous, hydrated biological tissues. Applications include ionic and molecular transport in tissues and cells, electrophoresis, electromechanical and physicochemical interactions in cells and the extracellular matrix of connective tissue.

ME 389. Biomechanical Research Symposium. 1 Unit.
Guest speakers present contemporary research on experimental and theoretical aspects of biomechanical engineering and bioengineering. May be repeated for credit.

ME 390. Thermosciences Research Project Seminar. 1 Unit.
Review of work in a particular research program and presentations of other related work.

ME 390A. High Temperature Gasdynamics Laboratory Research Project Seminar. 1 Unit.
Review of work in a particular research program and presentations of other related work.

ME 391. Engineering Problems. 1-10 Unit.
Directed study for graduate engineering students on subjects of mutual interest to student and staff member. May be used to prepare for experimental research during a later quarter under 392. Faculty sponsor required.

ME 392. Experimental Investigation of Engineering Problems. 1-10 Unit.
Graduate engineering students undertake experimental investigation under guidance of staff member. Previous work under 391 may be required to provide background for experimental program. Faculty sponsor required.

ME 393. Topics in Biologically Inspired or Human Interactive Robotics. 1 Unit.
Application of observations from human and animal physiology to robotic systems. Force control of motion including manipulation, haptics, and locomotion. Weekly literature review forum led by student. May be repeated for credit. (Cutkosky, Waldron, Niemeyer).

ME 395. Seminar in Solid Mechanics. 1 Unit.
Required of Ph.D. candidates in solid mechanics. Guest speakers present research topics related to mechanics theory, computational methods, and applications in science and engineering. May be repeated for credit.

ME 397. Design Theory and Methodology Seminar. 1-3 Unit.
What do designers do when they do design? How can their performance be improved? Topics change each quarter. May be repeated for credit.

ME 399. Fuel Cell Seminar. 1 Unit.
Interdisciplinary research in engineering, chemistry, and physics. Talks on fundamentals of fuel cells by speakers from Stanford, other academic and research institutions, and industry. The potential to provide high efficiency and zero emissions energy conversion for transportation and electrical power generation.

ME 400. Thesis. 2-15 Units.
Investigation of some engineering problems. Required of Engineer degree candidates.
Same as: Engineer Degree

ME 405. Physics-Based Computational Modeling. 3 Units.
This course is not a standard teaching of asymptotic methods as thought in the applied math programs. Nor does it involve such elaborate algebra and analytical derivations. Instead, the class relies on students¿ numerical programing skills and introduces improvements on numerical methods using standard asymptotic and scaling ideas. The main objective of the course is to bring physical insight into numerical programming. Majority of the problems to be explored involve one-¬ and two-dimensional transient partial differential equations. Topics include: 1¿Review of numerical discretization and numerical stability, 2-Implicit versus explicit methods, 3-Introduction to regular and singular perturbation problems, 4¬¿Method of matched asymptotic expansions, 5¬¿Stationary thin interfaces: boundary layers, Debye layers,¿ 6¿Moving thin interfaces: shocks, phase-¬¿interfaces, 7-Reaction-¬diffusion problems, 8-Directional equilibrium and lubrication theory.

ME 406. Turbulence Physics and Modeling Using Numerical Simulation Data. 2 Units.
Prerequisite: consent of instructor.

ME 408. Spectral Methods in Computational Physics. 3 Units.
Data analysis, spectra and correlations, sampling theorem, nonperiodic data, and windowing; spectral methods for numerical solution of partial differential equations; accuracy and computational cost; fast Fourier transform, Galerkin, collocation, and Tau methods; spectral and pseudospectral methods based on Fourier series and eigenfunctions of singular Sturm-Liouville problems; Chebyshev, Legendre, and Laguerre representations; convergence of eigenfunction expansions; discontinuities and Gibbs phenomenon; aliasing errors and control; efficient implementation of spectral methods; spectral methods for complicated domains; time differencing and numerical stability.
Same as: CME 322

ME 410A. Introductory Foresight and Technological Innovation. 3 Units.
Learn to develop long-range, technology-based innovations (5+ years based on industry). This course offers an intensive, hands-on approach using multiple engineering foresight strategies and tools. Model disruptive opportunities and create far-to-near development plans. Three quarter sequence.

ME 410B. Advanced Foresight and Technological Innovation. 1 Unit.
Continuation of ME410A. Students will continue developing their invention, integrate additional engineering foresight, and develop an intrinsic innovation mindset. Ongoing discussion of industry examples and contemporary events demonstrate foresight principals and engineering leadership in action.

ME 410C. Advanced Foresight and Technological Innovation. 1 Unit.
Continuation of ME410B. Students will continue developing their invention, integrate additional engineering foresight, and develop an intrinsic innovation mindset. Ongoing discussion of industry examples and contemporary events demonstrate foresight principals and engineering leadership in action.

ME 411. Advanced Topics in Computational Solid Mechanics. 3 Units.
Discussion of the use of computational simulation methods for analyzing and optimizing production processes and for developing new products, based on real industrial applications in the metal forming industry. Brief review of linear and nonlinear continuum mechanics and the use of finite element methods to model solid mechanics problems, constitutive relations for metals, coupled thermo-elasto-plastic (viscoplastic) problems, modeling metal productions processes: bulk metal forming processes using rigid/viscoplastic material models, application examples: hot rolling of plates and the Mannesmann piercing processes and modeling the service behavior of steel pipes. Prerequisites: ME 338A, ME 335A,B,C, or consent of instructor.

ME 412. Engineering Functional Analysis and Finite Elements. 3 Units.
Concepts in functional analysis to understand models and methods used in simulation and design. Topology, measure, and integration theory to introduce Sobolev spaces. Convergence analysis of finite elements for the generalized Poisson problem. Extensions to convection-diffusion-reaction equations and elasticity. Upwinding. Mixed methods and LBB conditions. Analysis of nonlinear and evolution problems. Prerequisites: 335A,B, CME 200, CME 204, or consent of instructor. Recommended: 333, MATH 171.
Same as: CME 356

ME 413. Quantum Confinement Structures: Physics and Fabrication. 3 Units.
Quantum mechanics principles and the thermodynamics of confinement structures. Focus is on potential applications such as solar cells and catalysis. Student presentations. Lab demonstrations. Prerequisite: background in quantum mechanics and statistical thermodynamics.

ME 414. Solid State Physics for Mechanical Engineering Experiments. 3 Units.
Introductory overview of principles of statistical mechanics, quantum mechanics and solid-state physics. Provides graduate Mechanical Engineering students with the understanding needed to work on devices or technologies which rely on solid-state physics. (Alternate years, not offered summer 2012).

ME 417. Total Product Integration Engineering. 4 Units.
For students aspiring to be product development executives and leaders in research and education. Advanced methods and tools beyond the material covered in ME 317: quality design across global supply chain, design for robustness, product development risk management, Monte Carlo simulation and product financial analysis, and decision analysis. Small teams or individuals conduct a practical project that produces a case study or enhancement to existing development methods and tools. Enrollment limited to 12. Prerequisites: 317A, B.

ME 420. Applied Electrochemistry at Micro- and Nanoscale. 3 Units.
Applied electrochemistry with a focus on energy conversion and storage. Basic concepts of thermodynamics, electrochemistry, and first principal calculations are presented, of which today's fundamentals of electrochemical energy conversion/storage are built. Conventional as well as advanced Li battery concepts/systems and their applications will be a main subject area. intercalation and conversion cathode and anode material families will be introduced and electrochemical function/challenges for energy storage of these materials will be highlighted. Conventional electrolyte materials such as carbonate based liquid electrolyte system and advanced solid-state material will be a topic in class.

ME 421. European Entrepreneurship and Innovation Thought Leaders Seminar. 1 Unit.
Lessons from real-world experiences and challenges in European startups, corporations, universities, non-profit research institutes and venture finance organizations. Speakers include entrepreneurs, leaders from global technology companies, university researchers, venture capitalists, legal experts, senior policy makers and other guests from selected European countries and regions. Geographic scope encompasses Ireland to Russia, and Scandinavia to the Mediterranean region. Enrollment open to undergraduates and graduates in any school or department at Stanford.

ME 429. COMMERCIAL MEMS DEVICE DESIGN. 3 Units.
This course will provide insight into designing MEMS based devices for use in commercial/consumer and automotive sensor applications. Topics to be covered in this MEMS sensor design course will include electromechanical modeling/simulation, compensation for cross-wafer and wafer-to-wafer fabrication variations in a high volume semiconductor manufacturing facility, design for extreme environments (drop shock, temperature, etc.), and some discussion of the unique challenges with respect to consumer and automotive sensor markets. Student teams will develop a MEMS sensor/transducer design (capacitive 3-axis accelerometer), electro-mechanical system model (Matlab based), fabrication process flow with manufacturing analysis (Excel based) in response to a provided design specification sheet.

ME 440. Electronic States and Transitions In Quantum Confined Structures. 3 Units.
Summary of selected quantum mechanical concepts with focus on phenomena related to charge separation and transfer. The physics and thermodynamics of excitons described and related to experimental observations. The energy state of electrons as function of confinement size and strength. Presentations include on electron tunneling, measuring the density of electronic states, dielectric behavior of materials, Bose Einstein condensation of quasi particles, and excitons in quantum wells and dots.

ME 450. Advances in Biotechnology. 3 Units.
Guest academic and industrial speakers. Latest developments in fields such as bioenergy, green process technology, production of industrial chemicals from renewable resources, protein pharmaceutical production, industrial enzyme production, stem cell applications, medical diagnostics, and medical imaging. Biotechnology ethics, business and patenting issues, and entrepreneurship in biotechnology.

ME 451A. Advanced Fluid Mechanics Multiphase Flows. 3 Units.
Single particle and multi-particle fluid flow phenomena, mass, momentum and heat transfer, characteristic time and length scales, non-dimensional groups; collection of dispersed-phase elements: instantaneous and averaged descriptions for multiphase flow, Eulerian-Eulerian and Lagrangian-Eulerian statistical representations, mixture theories; models for drag, heat and mass transfer; dilute to dense two-phase flow, granular flows; computer simulation approaches for multiphase flows, emerging research topics. Prerequisites: graduate level fluid mechanics and engineering mathematics, and undergraduate engineering mechanics and thermodynamics.

ME 451B. Advanced Fluid Mechanics Flow Instability. 3 Units.
Waves in fluids: surface waves, internal waves, inertial and acoustic waves, dispersion and group velocity, wave trains, transport due to waves, propagation in slowly varying medium, wave steepening, solitons and solitary waves, shock waves. Instability of fluid motion: dynamical systems, bifurcations, Kelvin-Helmholtz instability, Rayleigh-Benard convection, energy method, global stability, linear stability of parallel flows, necessary and sufficient conditions for stability, viscosity as a destabilizing factor, convective and absolute instability. Focus is on flow instabilities. Prerequisites: graduate courses in compressible and viscous flow.

ME 451C. Advanced Fluid Mechanics - Compressible Turbulence. 3 Units.
Conservation equations. Thermodynamics of ideal gases. Isentropic flows. Crocco-Vazsonyi¿s equation, creation and destruction of vorticity by compressibility effects. Acoustics and generation of sound by turbulence. Shock waves. Kovasznay's modal decomposition of compressible flow, linear and nonlinear modal interactions, interaction of turbulence with shock waves. Turbulent Mach number. Shocklets. Energetics of compressible turbulence, effects of compressibility on homogeneous turbulence, free-shear flows and turbulent boundary layers. Van Driest transformation, recovery temperature, and shock/boundary layer interaction. Strong Reynolds analogy. Subgrid-scale modeling for compressible turbulence. Hypervelocity flows. Prerequisites: Familiarity with compressible laminar flows (ME 355) and incompressible turbulence (ME 361), or consent of the instructor.

ME 451D. Microhydrodynamics. 3 Units.
Transport phenomena on small-length scales appropriate to applications in microfluidics, complex fluids, and biology. The basic equations of mass, momentum, and energy, derived for incompressible fluids and simplified to the slow-flow limit. Topics: solution techniques utilizing expansions of harmonic and Green's functions; singularity solutions; flows involving rigid particles and fluid droplets; applications to suspensions; lubrication theory for flows in confined geometries; slender body theory; and capillarity and wetting. Prerequisites: 120A,B, 300, or equivalents.
Same as: CHEMENG 310

ME 453A. Finite Element-Based Modeling and Simulation of Linear Fluid/Structure Interaction Problems. 3 Units.
Basic physics behind many fluid/structure interaction phenomena. Finite element-based computational approaches for linear modeling and simulation in the frequency domain. Vibrations of elastic structures. Linearized equations of small movements of inviscid fluids. Sloshing modes. Hydroelastic vibrations. Acoustic cavity modes. Structural-acoustic vibrations. Applications to liquid containers and underwater signatures. Prerequisite: graduate course in the finite element method or consent of instructor.

ME 453B. Computational Fluid Dynamics Based Modeling of Nonlinear Fluid/Structure Interaction Problems. 3 Units.
Basic physics behind many high-speed flow/structure interaction phenomena. Modern computational approaches for nonlinear modeling and simulation in the time domain. Dynamic equilibrium of restrained and unrestrained elastic structures. Corotational formulation for large structural displacements and rotations. Arbitrary Lagrangian-Eulerian description of inviscid and viscous flows. Time-accurate CFD on moving and deforming grids. Discrete geometric conservation laws. Discretization of transmission conditions on non-matching discrete fluid/structure interfaces. Coupled fluid/mesh-motion/structure time integration schemes. Application to divergence, flutter, and buffeting. Prerequisites: graduate course in the finite element method, and in computational fluid dynamics.

ME 455. Complex Fluids and Non-Newtonian Flows. 3 Units.
Definition of a complex liquid and microrheology. Division of complex fluids into suspensions, solutions, and melts. Suspensions as colloidal and non-colloidal. Extra stress and relation to the stresslet. Suspension rheology including Brownian and non-Brownian fibers. Microhydrodynamics and the Fokker-Planck equation. Linear viscoelasticity and the weak flow limit. Polymer solutions including single mode (dumbbell) and multimode models. Nonlinear viscoelasticity. Intermolecular effects in nondilute solutions and melts and the concept of reptation. Prerequisites: low Reynolds number hydrodynamics or consent of instructor.
Same as: CHEMENG 462

ME 457. Fluid Flow in Microdevices. 3 Units.
Physico-chemical hydrodynamics. Creeping flow, electric double layers, and electrochemical transport such as Nernst-Planck equation; hydrodynamics of solutions of charged and uncharged particles. Device applications include microsystems that perform capillary electrophoresis, drug dispension, and hybridization assays. Emphasis is on bioanalytical applications where electrophoresis, electro-osmosis, and diffusion are important. Prerequisite: consent of instructor.

ME 458. Advanced Topics in Electrokinetics. 3-5 Units.
Electrokinetic theory and electrokinetic separation assays. Electroneutrality approximation and weak electrolyte electrophoresis theory. Capillary zone electrophoresis, field amplified sample stacking, isoelectric focusing, and isotachophoresis. Introduction to general electrohydrodynamics (EHD) theory including the leaky dielectric concept, the Ohmic model formulation, and electrokinetic flow instabilities. Prerequisite: ME 457.

ME 461. Advanced Topics in Turbulence. 3 Units.
Turbulence phenomenology; statistical description and the equations governing the mean flow; fluctuations and their energetics; turbulence closure problem, two-equation turbulence models, and second moment closures; non-local effect of pressure; rapid distortion analysis and effect of shear and compression on turbulence; effect of body forces on turbulent flows; buoyancy-generated turbulence; suppression of turbulence by stratification; turbulent flows of variable density; effect of rotation on homogeneous turbulence; turbulent flows with strong vortices. Prerequisites: 351B and 361A, or consent of instructor.

ME 463. Advanced Topics in Plasma Science and Engineering. 3 Units.
Research areas such as plasma diagnostics, plasma transport, waves and instabilities, and engineering applications.

ME 469. Computational Methods in Fluid Mechanics. 3 Units.
The last two decades have seen the widespread use of Computational Fluid Dynamics (CFD) for analysis and design of thermal-fluids systems in a wide variety of engineering fields. Numerical methods used in CFD have reached a high degree of sophistication and accuracy. The objective of this course is to introduce ¿classical¿ approaches and algorithms used for the numerical simulations of incompressible flows. In addition, some of the more recent developments are described, in particular as they pertain to unstructured meshes and parallel computers. An in-depth analysis of the procedures required to certify numerical codes and results will conclude the course.

ME 469B. Computational Methods in Fluid Mechanics. 3 Units.
Advanced CFD codes. Geometry modeling, CAD-CFD conversion. Structured and unstructured mesh generation. Solution methods for steady and unsteady incompressible Navier-Stokes equations. Turbulence modeling. Conjugate (solid/fluid) heat transfer problems. Development of customized physical models. Batch execution for parametric studies. Final project involving solution of a problem of student¿s choosing. Prerequisite: ME 300C/CME 206.

ME 470. Uncertainty Quantification. 3 Units.
Uncertainty analysis in computational science. Probabilistic data representation, propagation techniques and validation under uncertainty. Mathematical and statistical foundations of random variables and processes for uncertainty modeling. Focus is on state-of-the-art propagation schemes, sampling techniques, and stochastic Galerkin methods. The concept of model validation under uncertainty and the determination of confidence bounds estimates. Prerequisite: basic probability and statistics at the level of CME 106 or equivalent.

ME 471. Turbulent Combustion. 3 Units.
Basis of turbulent combustion models. Assumption of scale separation between turbulence and combustion, resulting in Reynolds number independence of combustion models. Level-set approach for premixed combustion. Different regimes of premixed turbulent combustion with either kinematic or diffusive flow/chemistry interaction leading to different scaling laws and unified expression for turbulent velocity in both regimes. Models for non-premixed turbulent combustion based on mixture fraction concept. Analytical predictions for flame length of turbulent jets and NOx formation. Partially premixed combustion. Analytical scaling for lift-off heights of lifted diffusion.

ME 472. Computational Modeling of Radiative Transfer. 3 Units.
Overview of physical modeling and computational methods for radiation heat transfer in participating media. Review of surface transfer. Radiation hydrodynamics and the radiative transfer equation. Constitutive relations for transport coefficients of participating media. Formal solution and one-dimensional transfer. Moment methods: diffusion and spherical harmonics. The discrete ordinates method: spatial and angular discretization, false scattering and ray effects, the finite volume method, parallelization. Monte Carlo ray tracing: ray tracing, Monte Carlo simulations, surface transfer, transfer in participating media, variance reduction techniques, parallelization. Additional topics covered time permitting: spectral modeling, collimated sources, transient radiative transfer, reverse ray-tracing. Pre-requisites: ME 300C or equivalent; STATS 116 or equivalent; undergraduate heat transfer; ME 352A strongly recommended but not required.

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

ME 485. Modeling and Simulation of Human Movement. 3 Units.
Direct experience with the computational tools used to create simulations of human movement. Lecture/labs on animation of movement; kinematic models of joints; forward dynamic simulation; computational models of muscles, tendons, and ligaments; creation of models from medical images; control of dynamic simulations; collision detection and contact models. Prerequisite: 281, 331A,B, or equivalent.
Same as: BIOE 485

ME 491. Ph.D. Teaching Experience. 3 Units.
Required of Ph.D. students. May be repeated for credit.

ME 492. Mechanical Engineering Teaching Assistance Training. 1 Unit.
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ME 495A. ME Seminar Series: Product Design. 1 Unit.
Seminars will feature accomplished product designers and product design researchers. Guest speakers will come from the U.S. and internationally, and will present on topics of current interest to the Product Design Community.

ME 495B. ME Seminar Series: At the Interface between Mechanical Engineering and Biology. 1 Unit.
Seminars will feature early career mechanical engineers working on leading edge problems in biomechanical engineering. Topics include mechanobiology, cell mechanics, transport phenomena in biological systems, bio-inspired design, design and analysis of biodevices or bioinstrumentation, biomaterials, and modeling of physiological systems. Guest speakers will come from top universities within the U.S. and internationally, and will discuss both their past research and plans for building a research program in the future.

ME 500. Thesis. 1-15 Unit.
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Same as: Ph.D.

ME 571. Surgical Robotics Seminar. 1 Unit.
Surgical robots developed and implemented clinically on varying scales. Seminar goal is to expose students from engineering, medicine, and business to guest lecturers from academia and industry. Engineering and clinical aspects connected to design and use of surgical robots, varying in degree of complexity and procedural role. May be repeated for credit.
Same as: CS 571

ME 801. TGR Project. 0 Units.
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ME 802. TGR Dissertation. 0 Units.
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