MECHANICAL ENGINEERING

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Laboratory Directors: David W. Beach (Product Realization Laboratory), J. Edward Carryer (Smart Product Design Laboratory), Mark R. Cutkosky (Manufacturing Sciences Lab), Christopher Jacobs (Veterans Affairs Rehabilitation R&D Center), John K. Eaton (Heat Transfer and Turbulence Mechanics), Kosuke Ishii (Manufacturing Modeling Laboratory), Larry J. Leifer (Center for Design Research), Reginald E. Mitchell (High Temperature Gas Dynamics), Parviz Moin (Center for Turbulence Research), Friedrich B. Prinz (Rapid Prototyping Laboratory)

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

The programs in the Department of Mechanical Engineering (ME) are designed to provide background for a wide variety of careers. The discipline is very broad, but emphasizes an appropriate mix of applied mechanics, biomechanical engineering, computer simulations, design, and energy science and technology. Graduates at all degree levels have traditionally entered into energy industries, product manufacturing industries, transportation, government laboratories and agencies, and a variety of academic positions.

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 a good understanding of technology is often important. Both undergraduate and graduate programs provide excellent technical background for work in biomechanical engineering, environmental pollution control, ocean engineering, transportation, and on other multidisciplinary problems that concern society. Throughout the various programs, considerable emphasis is placed on developing systematic procedures for analysis, effective communication of one's work and ideas, practical and aesthetic aspects in design, and responsible use of technology. This can provide a student with an approach and a philosophy of great utility, irrespective of an ultimate career.

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 exist in collaboration with associated faculty in biology, engineering, and medicine. The Biomechanical Engineering Group has particularly strong research interactions with the Mechanics and Computation and the Design groups, and the departments of Functional Restoration, Neurology, Radiology, and Surgery in the School of Medicine.

The Design Group emphasizes cognitive skill development for creative design. It is concerned with automatic control, computer-aided design, creativity, design aesthetics, design for manufacturability, design research, experimental stress analysis, fatigue and fracture mechanics, finite element analysis, human factors, kinematics, manufacturing systems, microcomputers in design, micro-electromechanics systems (MEMS), robotics, and vehicle dynamics. The Design Group offers undergraduate and graduate programs in Product Design (jointly with the Department of Art and Art History) and is centrally involved in the founding of Stanford's new Institute of Design; for further information, see http://dschool.stanford.edu.

The Flow Physics and Computation Group (FPC) is developing new theories, models, and computational tools for accurate engineering design analysis and control of complex flows (including acoustics, chemical reactions, interactions with electromagnetic waves, plasmas, and other phenomena) of interest in aerodynamics, electronics cooling, environment engineering, materials processing, planetary entry, propulsion and power systems, and other areas. A significant emphasis of FPC research is on modeling and analysis of physical phenomena in engineering systems. FPC students and research staff are developing new methods and tools for generation, access, display, interpretation and post-processing of large databases resulting from numerical simulations of physical systems. Research in FPC ranges from advanced simulation of complex turbulent flows to active flow control. The FPC faculty teaches graduate and undergraduate courses in acoustics, aerodynamics, computational fluid mechanics, computational mathematics, fluid mechanics, combustion, and thermodynamics and propulsion.

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 working 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. There is a strong emphasis on fundamental experiments leading towards advances in modeling, optimization, and control of complex systems.

Mission Statement—The goal of Stanford's undergraduate program in Mechanical Engineering is to provide each student with a balance of intellectual and practical experiences, accumulation of knowledge, and self-discovery to prepare the graduate to address a variety of societal needs. The program prepares each student for entry-level work as a mechanical engineer, for graduate study in engineering, or for graduate study in another field where a broad and fundamental engineering background provides a desirable foundation. With solid grounding in the principles and practice of mechanical engineering, graduates are ready to engage in a lifetime of learning about and employing new concepts, technologies, and methodologies, whatever their ultimate career choice.

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 unique "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, a 48-node and 85-node Linux clusters 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. A wide spectrum of software is available on the laboratory machines, including major 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. The experimental capability of the 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 with 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 are outstanding. In addition to the general library, there are Engineering, Mathematics, Physics, and other department libraries of which engineering students make frequent use.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

Specializing in mechanical engineering (ME) during the undergraduate period may be done by following the curriculum outlined earlier under the "School of 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 (math; 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. Engineering (Product Design). An individually designed major in Biomechanical Engineering (B.S.E.: Biomechanical Engineering), offered by the Biomechanical Engineering Group, may be appropriate for some 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 engineering depth).

For information about an ME minor, see the "School of Engineering" section of this bulletin.

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 the 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 a transcript of courses taken at Stanford. In addition, the application is to 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 department honors, students admitted to the program must:

1. maintain the 3.5 GPA required for admission to the honors program.
2. under the direction of the thesis adviser, complete at least 9 units of ME 191H, Honors Thesis, during the senior year.
3. submit a completed thesis draft to the adviser by mid-May. Further revisions and final endorsement by the adviser are to be finished by the first week of June, when two bound copies are to be submitted to the Mechanical Engineering student services office.
4. present the thesis at the Mechanical Engineering Honors Symposium held in mid-May.

COTERMINAL B.S./M.S. PROGRAM

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 their application no later than the quarter prior to the expected completion of their undergraduate degree. This is normally the Winter Quarter (January 15 is the deadline) prior to the Spring Quarter graduation. The application must provide evidence of potential for strong academic performance as a graduate student. The department graduate admissions committee evaluates and acts on each application. Typically, a GPA of at least 3.5 in engineering, science, and math is expected. Applicants must have completed two of 80, 112, 113, 131A, and 131B, and must take the Graduate Record Examination (GRE) before action is taken on the application. Product designers must have completed ME 116 to be considered, and are required to work at least one year before rejoining the program. Coterminal information, applications deadlines, and forms can be obtained from the ME student services office.

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

GRADUATE PROGRAMS

ADMISSION AND FINANCIAL ASSISTANCE

To be eligible for admission to the department, a student must have a B.S. degree in engineering (the Ph.D. degree requires the completion of the M.S.), physics, or a comparable science program. Applications for all degree programs are accepted throughout the year, although applications for fellowship aid must be received by December 5. 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. Discipline 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.

Master's degree programs are offered in Mechanical Engineering (M.S.:ME), Engineering (Biomechanical Engineering, M.S.E.:BME), Engineering (Product Design, M.S.E.:PD), and Engineering (M.S.E.).

The following sections list specific requirements for the master's degrees listed above.

MASTER OF SCIENCE

The basic University requirements for the M.S. degree are discussed in the "Graduate Degrees" 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 year, particularly to explore their interests in working for the 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 in 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 not be used for other than the 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; furthermore, students who have already fulfilled certain categories of the M.S. degree requirements as a result of undergraduate work may find they have sufficient time (see item 3 below) to obtain the M.S. degree in the three quarters.

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 desire some research experience during the master's year may participate in research through ME 391 and 392.

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

1. *Mathematical Competence 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: CME 106, 200, 204, 206, 302; MATH 106, 109; CS 205; EE 263, 261; STATS 110 (requirement 6 units).

   Students who 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 exempted from this requirement by their adviser *and* the Graduate Curriculum Committee, and place the units in the approved elective category.
2. *Specialty in Mechanical Engineering (Depth):* 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 Handbook* at http://me.stanford.edu.
3. *Breadth in Mechanical Engineering:* two additional graduate level courses (outside the depth) from the breadth chart listed in the *Mechanical Engineering Graduate Handbook* to bring the total number of ME units to at least 18.
4. *Approved Electives* (to bring the total number of units to 39): all these units must be approved by an adviser. Graduate engineering, math, and science courses are normally approved. Of the 39 units, no more than 6 may come from ME 391 and 392, and no more than 3 may come from seminars. Students planning a Ph.D. degree should discuss with their adviser the desirability of taking 391 or 392 during the master's year.
5. *Unrestricted Electives* (to bring the total number of units submitted for the M.S. degree to 45): students are encouraged to use these units outside of 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.
6. Within the courses satisfying the requirements above, there must be at least one graduate-level course dealing with lab studies. Courses which satisfy this requirement are 218A, 306A, 307B, 318, 310A,B,C, 317B, 324, 348, 354, 367, 382A,B.

Candidates for the M.S. in Mechanical Engineering are expected to have the approval of the faculty, and a minimum grade point average (GPA) of 2.75 in the 45 units presented in fulfillment of degree requirements. All courses used to fulfill depth, breadth, approved electives, and lab studies must be taken for a letter grade (excluding seminars and courses for which a Satisfactory/No Credit grade is given to all students).

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 60 units required for graduate registration.

PRODUCT DESIGN

The Joint Program in Design focuses on the synthesis of technology with human needs and values to create innovative product experiences. This program is a joint offering of the departments of Mechanical Engineering and Art and Art History. It provides a design education that integrates technical, human, aesthetic, and business concerns. The resulting two-year degree of M.S. in Engineering (Product Design) is considered a terminal degree for the practice of design.

Course No. and Subject	*Units*
ARTSTUDI 60. Design I: Fundamental Visual Language	3
ARTSTUDI 160. Design II: The Bridge	3
ME203. Manufacturing and Design	4
ME216A. Advanced Product Design: Needfinding	4
ME216B. Advanced Product Design: Implementation	4
ME312. Advanced Product Design: Formgiving	4
ME313. Human Value and Innovation in Design	3
ME316ABC.* Product Design Master's Project	12
ARTSTUDI 360A,B,C* Master's Project	6
Approved Electives†	17

* ME316A,B,C and ARTSTUDI 360A,B,C are taken concurrently for three quarters during the second year.

† Approved electives fulfill career objectives of the students. Students may focus their energy in engineering, business, psychology, or other areas relevant to design. Most students elect a broad approach that spans these domains and increases their cultural awareness. Approved electives must be discussed with the student's adviser.

Admission requirements are the same as for the M.S.:ME described above, with the additional requirements of a minimum of one year's experience after the bachelor's degree, and a portfolio showing strong evidence of design ability and aesthetic skills and sensitivity.

Students with non-engineering undergraduate degrees in design, art, architecture, and so on, may apply to the Department of Art and Art History for a similar graduate design program administered by that department and leading to an M.F.A. in Design. Students with non-engineering degrees who wish to earn the M.S. degree should consult with the program adviser.

BIOMECHANICAL ENGINEERING

Students interested in graduate studies in biomechanical engineering can choose one of the programs below.

1. *M.S. in Mechanical Engineering:* students who apply and are admitted to the M.S.:ME program can elect to take biomechanical engineering courses as part of their M.S.:ME requirements. These courses are usually applied towards the student's engineering breadth or technical electives.
2. *M.S. in Engineering: Biomechanical Engineering* (M.S.E.:BME): this degree program allows students more flexibility in taking courses in the life sciences and generally emphasizes a more interdisciplinary curriculum. Minimum grade point average (GPA) requirements are the same as for the M.S. in Mechanical Engineering.

A Ph.D. in Biomechanical Engineering is not given. Students from either master's degree path (Mechanical Engineering or Biomechanical Engineering) receive their Ph.D. degrees in Mechanical Engineering.

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 this program on 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 can 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.

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. It is most efficient to carry out this preliminary research effort during the M.S. degree year.

ENGINEER

The basic University requirements for the degree of Engineer are discussed in the "Graduate Degrees" section of this bulletin.

This degree represents 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 frequently involves a paid research assistantship awarded by individual faculty members (usually from the funds of sponsored research projects under their direction) and *not* by the department. Thus, personal arrangement is necessary. Students studying for the M.S. degree at Stanford and desiring to continue to the Engineer degree ordinarily make such arrangements during the M.S. degree year. 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 an acceptable thesis; up to 18 units of credit are allowed for thesis work. 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).

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) taken beyond those required for the master's degree.

DOCTOR OF PHILOSOPHY

The basic University requirements for the Ph.D. degree are discussed in the "Graduate Degrees" 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 math and the engineering sciences, together with intensive study and research experience in a specialized area, are the necessary requisites.

The department allows but does not require a minor field. However, if a minor is waived, the candidate must show breadth of training by taking courses in one or more related fields or departments as noted below.

A student studying for the Ph.D. degree ordinarily does not take an Engineer degree, although this is not precluded. However, the student must have a master's degree, and must fulfill in essence the requirements for the Stanford M.S. degree in Mechanical Engineering.

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 oral 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 oral 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 earns a master's degree. The student is expected to have a nominal graduate Stanford GPA of 3.5 to be eligible for the exam. Once the student's faculty sponsor has agreed that the exam is to take place, the student must submit an application folder containing several items including a curriculum vitae, research project abstract, and preliminary dissertation proposal. Information and examination dates may be obtained from the department's student services office.

Ph.D. candidates must complete a minimum of 27 units 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 reading committee 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 27-unit requirement, all Ph.D. candidates must participate each quarter in one of the following (or equivalent) seminars: ME 389, 390, 394, 395, 396 397; ENGR 311A,B, 298; AA 297.

The Ph.D. thesis normally represents at least one full year of research work and must be a substantial contribution to knowledge. 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. Candidates should note that only completed course units are counted toward the requirement. Questions should be directed to the department manager of student services.

The department has a breadth requirement for the Ph.D. degree. This may be satisfied either by a formal minor in another department or by course work that is approved by the dissertation reading committee.

The final University oral examination 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 and two faculty members chosen to read and sign the candidate's dissertation. 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

Students who wish a Ph.D. minor in ME should consult 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 selected from those satisfying requirement 2 for the M.S. in Mechanical Engineering.

COURSES

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

The department uses the following course numbering system:

10- 99	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

UNDERGRADUATE (FRESHMEN AND SOPHOMORES)

Note—Lab sections in experimental engineering are assigned in groups. If the lab schedule permits, students are allowed, with due regard to priority of application, to arrange their own sections and lab periods. Enrollment with the instructor concerned, on the day before instruction begins or the first day of University instruction, is essential in order that the lab schedule may be prepared. Enrollment later than the first week is not permitted.

ME 12N. The Jet Engine—Stanford Introductory Seminar. Preference to freshmen. How a jet engine works; the technologies and analytical techniques required to understand them. Dynamics, thermodynamics, turbomachinery, combustion, advanced materials, cooling technologies, and control systems. Visits to research laboratories, examination of a partially disassembled engine, and probable operation of a small jet engine. Prerequisites: high school physics. GER:DB-EngrAppSci

3 units, Win (Eaton)

ME 13N. Designing the Human Experience—Stanford Introductory Seminar. Preference to freshmen. Creative thinking skills such as observation of the human endeavor and how to transform concepts into products, services, and intellectual property. How products shape and sometimes undermine well-being. Hands-on projects. Web-based student idea logs. No prior design experience required. GER:DB-EngrAppSci

3-5 units, Spr (Leifer)

ME 15N. The Science and Engineering of Sports Equipment—(Same as AA 117N.) Stanford Introductory Seminar. Preference to freshmen. Scientific concepts of sports equipment. How design and manufacture improve performance and marketability. Why golf balls have dimples, tennis balls are fuzzy, golf shafts are made of steel or graphite, and sailboats win or break. How composite materials make structures light, strong, and tailored to the athlete's ability. Skis, snowboards, race cars, and bicycles demonstrated through photographs, models, and products. GER:DB-EngrAppSci

3 units, Aut (Kenny, Springer)

ME 16N. The Science of Flames—Stanford Introductory Seminar. Preference to freshmen. The roles that chemistry and fluid dynamics play in governing the behaviors of flames. Emphasis is on factors that affect flame microstructure, external appearance, and on the fundamental physical and chemical processes that cause flames and fires to propagate. Topics: history, thermodynamics, and pollutant formation in flames. Trips to labs where flames are studied. Prerequisites: high school physics. GER:DB-EngrAppSci

3 units, Win (Mitchell)

ME 18Q. Creative Teams and Individual Development—Stanford Introductory Seminar. 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. GER:DB-EngrAppSci

3 units, Aut (Wilde)

ME 19N. Robotics—Stanford Introductory Seminar. Preference to freshmen. Most people conjure up images of robots from science fiction movies or television shows. In real life, robots show up in factory automation, theme parks, at NASA, and in hospitals doing surgery. Do fiction and reality have anything in common? What really is a robot, what can they do, and what can they not do? How are they built and how are they changing lives? Field trips and hands-on projects. GER:DB-EngrAppSci

3 units, Win (Niemeyer)

ME 24N. Designing the Car of the Future—Stanford Introductory Seminar. 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. GER:DB-EngrAppSci

3 units, Aut (Gerdes)

ME 70. Introductory Fluids Engineering—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 demonstration experiments are related to course material. Limited enrollment Spring Quarter. When possible, register for Winter Quarter. Prerequisites: ENGR 14 and 30. GER:DB-EngrAppSci

4 units, Win (Cappelli), Spr (Santiago)

ME 80. Strength of Materials—Mechanics of materials and engineering properties of structural materials. Topics include static failure theories for ductile and brittle materials, stress concentrations, and buckling. Introduction to fracture, fatigue, corrosion, fretting, and wear. Prerequisite: ENGR 14. Corequisite: 81. GER:DB-EngrAppSci

3 units, Aut (Pruitt), Spr (Staff)

ME 81. Strength of Materials Laboratory—Failure and testing methods emphasizing applications to mechanical design. Experimental component addresses characterization of real materials and structures. Corequisite: 80. GER:DB-EngrAppSci

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

UNDERGRADUATE (JUNIORS AND SENIORS)

ME 101. Visual Thinking—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. Enrollment limited to 60. GER:DB-EngrAppSci

3 units, Aut, Win, Spr (Staff)

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

1 unit, Aut, Win (Milroy)

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

3 units, Win (Rock)

ME 110A. Design Sketching—Freehand sketching, rendering, and design development, guided by instructors. Concurrent assignments in 115 and 216B,C provide subject matter, but open to anyone wanting to improve freehand drawing skills.

1 unit, Win, Spr (Staff)

ME 110B. Advanced Design Sketching—Freehand sketching, rendering, design development, and some computer use, guided by instructors. Concurrent assignments in 116 provide subject matter. Prerequisite: 110A or consent of instructor based on drawing skill.
1 unit, Aut (Staff)

ME 112. Mechanical Engineering Design—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. GER:DB-EngrAppSci
4 units, Win (Staff)

ME 113. Mechanical Engineering Design—Goal is to create designs and models of new mechanical devices. Design is experienced by students as they work on a team design project obtained from industry or other organizations. Prerequisites: 80, 101, 112. GER:DB-EngrAppSci
4 units, Spr (Nelson)

ME 115. Human Values in Design—The central philosophy of the product design program, emphasizing the relation between technical and human values, the innovation process, and design methodology. Lab exercises include development of simple product concepts visualized in rapidly executed three-dimensional mockups. Prerequisite: 101. GER:DB-EngrAppSci
3 units, Win (Staff)

ME 116. Designing for People—Small- and medium-scale design projects are carried to a high degree of aesthetic refinement. Emphasis is on generating appropriate forms to the task and setting. Prerequisites: 115, ARTHIST 160. GER:DB-EngrAppSci
4 units, Aut (Moggridge)

ME 120. History and Philosophy of Design—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 40. GER:DB-EngrAppSci
3-4 units, Spr (Katz)

ME 121. Design and Construction in Wood—The design and construction of objects using wood. Taught in the Product Realization Lab. Enrollment limited.
1-3 units, Aut, Win, Spr (Milroy)

ME 131A. Heat Transfer—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. GER:DB-EngrAppSci
3-4 units, Aut (Goodson)

ME 131B. Fluid Mechanics: Compressible Flow and Turbomachinery—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. GER: DB-EngrAppSci
4 units, Win (Mungal)

ME 140. Advanced Thermal Systems—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. GER:DB-EngrAppSci
4 units, Spr (Edwards)

ME 150. Internal Combustion Engines—(Formerly 130.) 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: ME 140. GER:DB-EngrAppSci
3 units, Aut (Kaahaaina)

ME 161. Dynamic Systems—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: background in dynamics and calculus such as ENGR 15 and MATH 43. Recommenced: CME 102 (formerly ENGR 155A), and familiarity with differential equations, linear algebra, and basic electronics. Graduate students may enroll with adviser and instructor consent. GER:DB-EngrAppSci
4 units, Aut (Mitiguy)

ME 191. Engineering Problems and Experimental Investigation—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 the adviser.
1-5 units, Aut, Win, Spr, Sum (Staff)

ME 191H. Honors Research—Student must find faculty honors adviser and apply for admission to the honors program.
1-5 units, Aut, Win, Spr, Sum (Staff)

ADVANCED UNDERGRADUATE AND BEGINNING GRADUATE

ME 201. Dim Sum of Mechanical Engineering—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.
1 unit, Aut (Sheppard)

ME 203. Manufacturing and Design—Prototype development techniques as an intrinsic part of the design process. Machining, welding, and casting. Manufacturing processes. Design aspects developed in an individual term project chosen, designed, and fabricated by students. Labs, field trips. Undergraduates majoring in Mechanical Engineering or Product Design must take course for 4 units. Limited enrollment with consent of instructor. Corequisite: 103D or CAD experience. Corequisite for WIM for Mechanical Engineering and Product Design majors: ENGR 102M. Recommended: 101. WIM
3-4 units, Aut, Win (Beach)

ME 204. Bicycle Design and Frame-Building—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. Limited enrollment. Prerequisite: 203 or equivalent.
3 units, Spr (Connolly)

ME 206A,B. Entrepreneurial Design for Extreme Affordability—(Same as OIT 333,334.) 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 to 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 process; see http://www.stanford.edu/class/me206.

A: *2-3 units, Win,* **B:** *3-4 units, Spr (Kelley, Patell)*

ME 207. Negotiation—(Same as CEE 151/251, MS&E 285.) Negotiation styles and processes to help students conduct and review negotiations. Workshop format integrating intellectual and experiential learning. Exercises, live and field examples, individual and small group reviews. Application required before first day of class; see http://www.stanford.edu/class/msande285/. Enrollment limited to 50.

3 units, Aut, Spr (Christensen)

ME 210. Introduction to Mechatronics—(Formerly 118.) Technologies involved in mechatronics (intelligent electro-mechanical systems), and techniques to apply this technology to mechatronic 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. Limited enrollment. Prerequisites: ENGR 40, CS 106, or equivalents.

4 units, Win (Kenny, Ohline)

ME 216A. Advanced Product Design: Needfinding—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. Prerequisite: 115, 203, 313, or consent of instructor.

3-4 units, Win (Staff)

ME 216B. Advanced Product Design: Implementation—Summary project using knowledge, methodology, and skills obtained in 115/313 and 216A. Students implement design concepts and present them to a professional jury. Prerequisite: 216A.

4 units, Spr (Staff)

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

4-5 units, Aut (Carryer)

ME 218B. Smart Product Design Applications—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, sensors, actuators, noise, and power supplies. Lab fee. Limited enrollment. Prerequisite: 218A or passing the smart product design fundamentals proficiency examination.

4-5 units, Win (Carryer)

ME 218C. Smart Product Design Practice—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. Lab fee. Limited enrollment. Team project. Prerequisite: 218B.

4-5 units, Spr (Carryer)

ME 218D. Smart Product Design: Projects—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 on 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.

4 units, Aut (Carryer)

ME 219. The Magic of Materials and Manufacturing—Methods for market-quantity manufacturing of parts and products from a product designer's point of view. Materials including metals, plastics, ceramics, fibers, and foams, and processes that manipulate, exploit, transform, and modify these materials. Manufacturing site visits and laboratory projects.

3 units, Spr (Beach)

ME 220. Introduction to Sensors—(Formerly 117/220.) 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.

3-4 units, Spr (Kenny)

ME 222. Beyond Green Theory: A Workshop in Ecological Design—Goal is to translate green theory into product form through short projects that address materials, product function and co-function, and situational patterns or habits. How to blend ecological design processes with standard design methodologies.

2-3 units, Spr (Staff)

ME 227. Vehicle Dynamics and Control—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.

3 units, Spr (Gerdes)

ME 229. Multiscale Methods in Engineering—(Enroll in CME 210.)

3 units (Darve) not given 2005-06

ME 240. Introduction to Nanotechnology—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. Nano-scale materials building blocks, fabrication and assembly processes, characterization and properties, and novel system architectures. Implications for future development.

3 units, Aut (Cho) alternate years, not given 2006-07

ME 260. Fuel Cell Science Technology—Emphasis is on proton exchange membrane (PEM) and solid oxide fuel cells (SOFC). Principles of electrochemical energy conversion. Topics in materials science, thermodynamics, and fluid mechanics. Limited enrollment.

3 units, Spr (Prinz)

ME 280. Skeletal Development and Evolution—(Formerly 180.) 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: 80, or Human Biology core, or Biological Sciences core. GER:DB-EngrAppSci

3 units, Spr (Carter)

ME 281. Biomechanics of Movement—(Same as BIOE 281; formerly 181.) Review of experimental techniques used to study human and animal movement including motion capture systems, EMG, force plates, medical imaging, and animation. The mechanical properties of muscle and tendon, and quantitative analysis of musculoskeletal geometry. Projects and demonstrations emphasize applications of mechanics in sports, orthopedics, and rehabilitation. GER:DB-EngrAppSci

3 units, Aut (Delp)

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

3-4 units, Aut (Taylor)

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

3-4 units, Win (Taylor)

ME 294. Medical Device Design—In collaboration with the School of Medicine. Introduction to medical device design for undergraduate and graduate engineering students. Design and prototyping. Labs; medical device environments including hands on device testing; and field trips to operating rooms and local device companies. Limited enrollment. Prerequisite: 203.

3 units, Aut (Milroy, Doshi)

ME 299. Practical Training—Educational opportunities in high technology research and development labs in industry. Qualified graduate students engage in internship work and integrate that work into their academic program. Following internship, work students complete a research report outlining their work activity, problems investigated, key results, and any follow-on projects they expect to perform. Meets the requirements for Curricular Practical Training for Students on F-1 visas. Student is responsible for arranging own employment and faculty sponsorship. Register under faculty sponsor's section number.

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

GRADUATE

ME 300A. Linear Algebra with Application to Engineering Computations—(Enroll in CME 200.)

3 units, Aut (Gerritsen)

ME 300B. Partial Differential Equations in Engineering—(Enroll in CME 204.)

3 units, Win (Shaqfeh)

ME 300C. Introduction to Numerical Methods for Engineering—(Enroll in CME 206.)

3 units, Spr (Farhat)

ME 305. Introduction to Control Design Techniques—(Enroll in ENGR 205.)

3 units, Aut (Rock)

ME 305. Engineering Risk Analysis—(Enroll in MS&E 250A.)

2-3 units, Win (Paté-Cornell)

ME 306A. Control System Design—(Enroll in ENGR 206.)

4 units, Spr (Niemeyer)

ME 306B. Analysis and Control of Nonlinear Systems—(Enroll in ENGR 209A.)

3 units (Tomlin) not given 2005-06

ME 307A. Modern Control Design I—(Enroll in ENGR 207A.)

3 units, Win (Lall)

ME 307B. Modern Control Design II—(Enroll in ENGR 207B.)

3 units, Spr (Lall)

ME 308. Spatial Motion—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.

3 units (Waldron) alternate years, given 2006-07

ME 309. Finite Element Analysis in Mechanical Design—Basic concepts of finite elements, with applications to problems confronted by mechanical designers. Linear static, modal, and thermal formulations; nonlinear and dynamic formulations. Students implement simple element formulations. 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. Prerequisite: MATH 103, or equivalent. Recommended: 80, or equivalent in structural and/or solid mechanics; some exposure to principles of heat transfer.

3 units, Spr (Sheppard)

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

3-4 units, Aut (Cutkosky, Leifer)

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

B: *3-5 units, Win,* **C:** *3-4 units, Spr (Cutkosky, Leifer)*

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

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

ME 312. Advanced Product Design: Formgiving—Small- and medium-scale design projects carried to a high degree of aesthetic refinement. Emphasis is on generating appropriate forms to the task and setting. Prerequisites: 203, 313, ARTHIST 160.

3-4 units, Aut (Moggridge)

ME 313. Human Values and Innovation in Design—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. Enrollment limited to 60.
3 units, Aut (Kelley)

ME 314. Good Products, Bad Products—The characteristics of industrial products that cause them to be successes or failures: the straightforward (performance, economy, reliability), the complicated (human and cultural fit, compatibility with the environment, craftsmanship, positive emotional response of the user), the esoteric (elegance, sophistication, symbolism). Engineers and business people must better understand these factors to produce more successful products. Projects, papers, guest speakers, field trips. GER:DB-EngrAppSci
3-4 units, Win (Beach)

ME 315. The Designer in Society—(Formerly 215.) For graduate students. Career objectives and psychological orientation compared with existing social values and conditions. Emphasis is on assisting individuals in assessing their roles in society. Readings on political, social, and humanistic thought are related to technology and design. Experiential, in-class exercises, and term project. Enrollment limited to 24.
3 units, Spr (Roth)

ME 316A,B,C. Product Design Master's Project—For graduate Product Design or Design (Art) majors only. Students create and present two master's theses under the supervision of engineering and art faculty. Theses involve the synthesis of aesthetics and technological concerns in the service of human need and possibility. Product Design students take for 4 units; Art students for 2 units. Corequisite: ARTHIST 360.
2-4 units, Aut, Win, Spr (Kelley)

ME 317A. Design for Manufacturability: Product Definition for Market Success—(Formerly 217A.) Systematic methodologies to define, develop, and produce world-class products. Student teams work on projects to identify opportunities for improvement and develop a comprehensive product definition. Topics: value engineering, quality function deployment, design for assembly and producibility, design for variety and supply chain, design for life-cycle quality, and concurrent engineering. Students must take ME217B to complete the project and obtain a letter grade. On-campus class limited to 28. SCPD class does not have a limit, but each site must have at least 3 students to form a project team and define a project.
4 units, Win (Ishii)

ME 317B. Design for Manufacturability: Quality by Design for Customer Value—(Formerly 217B.) 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), FMEA applied to the manufacturing process, design for robustness, Taguchi Method, SPC and six sigma process, tolerance analysis, flexible manufacturing, product testing, rapid prototyping. Enrollment limited to 40, not including SITN students. Minimum enrollment of two per SITN viewing site; single student site by prior consent of instructor. On-campus class limited to 25. For SITN students, no enrollment limit, but each site must have a minimum of three students to form a project team and define a project on their own. Prerequisite: 317A.
4 units, Spr (Ishii)

ME 317C. Manufacturing Systems Design—(Enroll in MS&E 264.)
3-4 units, Aut (Erhun)

ME 318. Computer-Aided Product Creation—Design course focusing on an integrated suite of computer tools: rapid prototyping, solid modeling, computer-aided machining, computer numerical control manufacturing. Students choose, design, and manufacture individual products, emphasizing product definition, user benefits, and computer design tools. Manufacturing focuses on CNC machining. Stanford Product Realization Lab's relationship to the outside world. Structured lab experiences build a basic CAD/CAM/CNC proficiency. Limited enrollment.
4 units, Aut (Beach, Milroy), Win (Milroy), Spr (Milroy)

ME 320. Introduction to Robotics—(Enroll in CS 223A.)
3 units, Win (Roth)

ME 321. Materials Selection In Design—(Enroll in MATSCI 170/270.)
3-4 units (Prinz) not given 2005-06

ME 322. Kinematic Synthesis of Mechanisms—The rational design of linkages. Techniques to determine linkage proportions to fulfill design requirements using analytical, graphical, and computer based methods.
3 units, Win (Roth)

ME 323. Modeling and Identification of Mechanical Systems for Control—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.
2-4 units (Gerdes) alternate years, given 2006-07

ME 324. Precision Engineering—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.
4 units, Spr (Beach, DeBra)

ME 325. Interdisciplinary Interaction Design—(Same as CS 447; formerly ME 293.) Small teams develop technology prototypes combining product and interaction design. Focus is on software and hardware interfaces, interaction, design aesthetics, and underpinnings of successful design including a reflective, interactive design process, group dynamics of interdisciplinary teamwork, and working with users. Prerequisite: CS 247A.
3-4 units (Winograd) not given 2005-06

ME 326. Telerobotics and Human-Robot Interactions—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.
3 units (Niemeyer) alternate years, given 2006-07

ME 327A. Advanced Robotics—(Enroll in CS 327A.)
3 units, Spr (Khatib)

ME 329. Physical Solid Mechanics—(Formerly 229.) Quantum mechanics, statistical mechanics, and solid state physics for engineering students. The theory describes physical processes at nanoscale in solid materials. Atomic structures of solids and their electronic structures. Statistical mechanics provides a theoretical framework for thermodynamics to connect the nanoscale processes to macroscopic properties of solids.
3 units (Cho) alternate years, given 2006-07

ME 330. Advanced Kinematics—(Formerly 230.) 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.
3 units, Aut (Roth)

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

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

ME 333. Mechanics—Goal is a common basis for advanced mechanics courses. Formulation of the governing equations from a Lagrangian perspective. Examples include systems of particles and linear elastic solids. Waves in discrete and continuous media. Linear elasticity formulation in the static and dynamic cases, and elementary measures of stress and strain. Tensor and variational calculus.
3 units, Aut (Lew)

ME 334. Introduction to Statistical Mechanics—Concepts and tools of classical statistical mechanics and applications to molecular systems. Thermodynamics and probability theory. Statistical ensembles. Information and entropy. Free energy and transition between metastable states. Brownian motion, Langevin dynamics, and Fokker-Planck equation. Non-equilibrium systems: correlation and response functions, fluctuation-dissipation theorem. Applications to self-assembly, thin film growth, and structural transformation of proteins.
3 units, Win (Cai)

ME 335A. Finite Element Analysis—(Formerly 235A.) Emphasis is on fundamental concepts and techniques of primal finite element methods. Method of weighted residuals, Galerkin's method, and variational equations. Linear elliptic 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. Active column equation solver, assembly of equations, and element routines. The mathematical theory of finite elements.
3 units, Aut (Pinsky)

ME 335B. Finite Element Analysis—(Formerly 235B.) 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.
3 units, Win (Pinsky)

ME 335C. Finite Element Analysis—(Formerly 235C.) Nonlinear continuum mechanics. Galerkin formulation of nonlinear elliptic, parabolic, and hyperbolic problems. Explicit, implicit, and implicit-explicit algorithm in nonlinear transient analysis. Stability of ordinary differential equation solvers for nonlinear problem classes; energy-conserving algorithms. Automatic time-step selection strategies. Methods of solving nonlinear algebraic systems. Newton-type methods and quasi-Newton updates. Iterative procedures. Arc-length methods. Architecture of computer codes for nonlinear finite element analysis. Applications from structural and solid mechanics such as nonlinear elasticity.
3 units (Pinsky) not given 2005-06

ME 337. Free and Forced Motion of Structures—(Enroll in AA 244A.)
3 units (Staff) not given 2005-06

ME 338. Continuum Mechanics—Nonlinear continuum mechanics for solids and fluids. Kinematics of finite deformations. Measures of strain and stress. Finite rotations. Linearized kinematics and infinitesimal measures of deformations. Rates. Conservation laws for mass, momenta, and energy. Boundary value problem in continuum mechanics. Prerequisites: 333 and 300, or equivalent background with consent of instructor.
3 units, Win (Lew)

ME 338B. Continuum Mechanics—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. GER:DB-EngrAppSci
3 units (Lew) not given 2005-06

ME 339. Mechanics of the Cell—Kinematical description of basic structural elements used to model parts of the cell: rods, ropes, membranes, and shells. Formulation of constitutive equations: nonlinear elasticity and entropic contributions. Elasticity of polymeric networks. Applications to model basic filaments of the cytoskeleton: actin, microtubules, intermediate filaments, and complete networks. Applications to biological membranes.
3 units, Spr (Jacobs)

ME 340. Elasticity in Microscopic Structures—Introduction to elasticity theory and application to material structures at microscale. Theories: stress, strain, and energy; equilibrium and compatibility conditions; boundary value problem. Solution methods: stress function, Green's function, Fourier transformation. Numerical exercises using Matlab. Applications to defects in solids, thin films, and biomembranes.
3 units, Spr (Cai)

ME 340B. Elasticity in Microscopic Structures—Elasticity theory and applications to structures in micro devices, material defects, and biological systems. Theoretical basis: stress, strain, and energy; equilibrium and compatibility conditions; boundary value problem formulation. Solution methods: stress function, Green's function, and Fourier transformation; moderate numerical exercises using Matlab. Methods and solutions applied to the elastic behaviors of thin films and MEMS structures, cracks and dislocations, and cell filaments and membranes.
3 units (Cai) not given 2005-06

ME 341. Building Mathematical Models in Biomechanics—Theory and practice of mathematical models. Based on the research literature, examples from hearing and speech sciences, orthopedic bioengineering, and neuromuscular biomechanics. General, meta-theoretical issues that go beyond the particular subject matter. Examples include: What is a model? What constitutes a good model? What is the process of building a model? What are the different approaches to modeling? Dualisms in modeling include: the interplay between theory and experiment, analytic and computational models, and forward and inverse approaches.
3 units, Spr (Puria) alternate years, not given 2006-07

ME 342A. MEMS Laboratory—Practice and theory of MEMS device design and fabrication, orientation to fabrication facilities, and introduction to techniques for design and evaluation of MEMS devices in the context of designed projects. Emphasis on MEMS design (need finding, brainstorming, evaluation, and design methodology), characterization, and fabrication, including photolithography, etching, oxidation, diffusion, and ion implanation. Limited enrollment. Prerequisite: engineering or science background and consent of instructor.
3-4 units, Spr (Pruitt)

ME 342B. MEMS Laboratory II—Emphasis is on tools and methodologies for designing and fabricating MEMS-based solutions. Student interdisciplinary teams collaborate with students and faculty from other to invent, develop, and integrate MEMS/biomedical. Design alternatives fabricated and tested. Manufacturability, assembly, test, and design for redesign. At least one design alternative developed into a functional prototype. Limited enrollment. Prerequisite: 342A or equivalent.
3-4 units, Sum (Pruitt)

ME 342D. MEMS Laboratory Assignments—Prerequisite: consent of instructor.
1-2 units (Pruitt) not given 2005-06

ME 343. An Introduction to Waves in Elastic Solids—One-dimensional motion of an elastic continuum, the linearized theory of elasticity and elastodynamic theory, elastic waves in an unbounded medium, plane harmonic waves in elastic half-spaces including reflection and refraction, slowness, energy velocity and anisotropic effects. Text is first five chapters of Achenbach's *Wave Propagation in Elastic Solids*.
3 units (Barnett) not given 2005-06

ME 344A. Computational Nanotechnology—(Formerly 244A.) Atomistic simulations as computational tools to design nanoscale materials and devices. Nanoparticles and nanowires introduced as main classes of nano building blocks. Computational modeling of carbon nanomaterials (fullerenes and nanotubes); nanoparticles and quantum dots; semiconductor and metal nanowires; and molecular wires. Atomistic modeling programs with graphical user interface used to gain hands-on experience of nanomaterials design. GER:DB-EngrAppSci
3 units, Win (Cho)

ME 344B. Nanomaterials Modeling—(Formerly 244B.) Atomistic and quantum mechanical simulation methods. Focus is quantum simulation of nanomaterials. Review of concepts and practical techniques of atomistic simulations; finite difference algorithms and practical computational issues for molecular dynamics and Monte Carlo simulations. Graphical user interface, designing nanomaterials through analysis and feedback processes, configuration optimization, dynamic mode analysis, and electronic structure analysis. Hands-on experience in computational design of nanomaterials, and fundamentals of simulations.
3 units, Spr (Cho)

ME 345. Fatigue Design and Analysis—(Formerly 245.) The mechanism and occurrences of fatigue in service. Methods for predicting fatigue life and for protecting against premature fatigue failure. Use of elastic stress and inelastic 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.
3 units, Win (Nelson)

ME 346. Introduction to Molecular Simulations—Algorithms of molecular simulations and underlying theories. Molecular dynamics, Monte Carlo, energy minimization, and transition path search algorithms. Classical dynamics in Hamiltonian and Lagrangian form. Elementary statistical mechanics: ensembles, Boltzmann's distribution, and free energy. Measure and control of temperature and stress in molecular systems. Length and time scale limits of simulation methods. Applications in solids, liquids, and biomolecules. Programming in Matlab.
3 units, Aut (Cai)

ME 347. Mathematical Theory of Dislocations—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.
3 units, Spr (Barnett)

ME 348. Experimental Stress Analysis—Theory and applications of photoelasticity, strain gages, and holographic interferometry. Comparison of test results with theoretical predictions of stress and strain. Other methods of stress and strain determination (optical fiber strain sensors, thermoelasticity, Moire, residual stress determination).
3 units, Spr (Nelson)

ME 351A. Fluid Mechanics—(Formerly 251A.) 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.
3 units, Aut (Staff)

ME 351B. Fluid Mechanics—(Formerly 251B.) 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.
3 units, Win (Staff)

ME 352A. Radiative Heat Transfer—(Formerly 252A.) 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.
3 units (Mitchell) not given 2005-06

ME 352B. Fundamentals of Heat Conduction—(Formerly 252B.) 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.
3 units, Win (Goodson)

ME 352C. Convective Heat Transfer—(Formerly 252C.) 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.
3 units, Spr (Eaton)

ME 354. Experimental Methods in Fluid Mechanics—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.
4 units, Win (Santiago)

ME 355. Compressible Flow—(Formerly 255.) Introduction to compressible flow. Sound waves and normal shock waves. Quasi-one-dimensional steady flows in variable area ducts with friction, heating, and

cooling; unsteady one-dimensional flow, two-dimensional supersonic flow; oblique shock waves, Prandtl-Meyer expansions, detonation waves, method of characteristics.
3 units, Spr (Mungal)

ME 358. Heat Transfer in Microdevices—(Formerly 258.) 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.
3 units, Spr (Goodson)

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

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

ME 361. Turbulence—Governing equations. Averaging and correlations. Reynolds equations and Reynolds stresses. Free shear flows, turbulent jet, turbulent length and time scales, turbulent kinetic energy and kinetic energy dissipation, and kinetic energy budget. Kolmogorov's hypothesis and energy spectrum. Wall bounded flows, channel flow and boundary layer, viscous scales, and law of the wall. Turbulence modeling, gradient transport and eddy viscosity, mixing length model, two-equation models, Reynolds-stress model, and large-eddy simulation.
3 units, Spr (Pitsch)

ME 362A. Physical Gas Dynamics—(Formerly 262A.) 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.
3 units, Aut (Bowman)

ME 362B. Nonequilibrium Processes in High-Temperature Gases—(Formerly 262B.) Introduction to chemical kinetics and energy transfer in high-temperature gases. Collision theory, transition state theory, and unimolecular reaction theory. Prerequisite: 362A or consent of instructor.
3 units (Hanson) not given 2005-06

ME 364. Optical Diagnostics and Spectroscopy—(Formerly 264.) Introduction to 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.
3 units, Win (Hanson)

ME 367. Optical Diagnostics and Spectroscopy Laboratory—(Formerly 267.) 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. Prerequisites: 362A and/or 364.
4 units, Spr (Hanson)

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

ME 370B. Energy Systems II: Modeling and Advanced Concepts—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.
4 units, Win (Edwards)

ME 370C. Energy Systems III: Projects—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.
3-5 units, Spr (Simon)

ME 371. Combustion Fundamentals—(Formerly 271.) 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.
3 units, Win (Bowman)

ME 372. Combustion Applications—(Formerly 272.) 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.
3 units, Spr (Mitchell)

ME 374A,B. Biodesign Innovation—(Same as BIOE 374A,B, OIT 384,385.)
3-4 units, **A:** *Win,* **B:** *Spr (Makower, Yock, Zenios, Milroy)*

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

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

ME 375. Institute of Design Projects—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 375A. Institute of Design Project 1
2-6 units, Aut (Kelley, Kembel)
ME 375B. Institute of Design Project 2
2-6 units, Win (Kelley, Kembel)
ME 375C. Institute of Design Project 3
2-6 units, Spr (Kelley, Kembel)
ME 376A. Institute of Design Project 4
2-6 units, Aut (Kelley, Kembel)
ME 376B. Institute of Design Project 5
2-6 units, Win (Kelley, Kembel)
ME 376C. Institute of Design Project 6
2-6 units, Spr (Kelley, Kembel)
ME 377A. Institute of Design Project 7
2-6 units, Aut (Kelley, Kembel)
ME 377B. Institute of Design Project 8
2-6 units, Win (Kelley, Kembel)
ME 377C. Institute of Design Project 9
2-6 units, Spr (Kelley, Kembel)

ME 381. Orthopaedic Bioengineering—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.
3 units, Aut (Carter)

ME 382A. Biomedical Device Design and Evaluation I—(Formerly 282A.) Real world problems and challenges of biomedical device design and evaluation. Students engage in industry sponsored projects resulting in new designs, physical prototypes, design analyses, computational models, and experimental tests, gaining experience in: the formation of design teams; interdisciplinary communication skills; regulatory issues; biological, anatomical, and physiological considerations; testing standards for medical devices; and intellectual property.
4 units, Win (Andriacchi)

ME 382B. Biomedical Device Design and Evaluation II—(Formerly 282B.) Continuation of industry sponsored projects from 382A. With the assistance of faculty and expert consultants, students finalize product designs or complete detailed design evaluations of new medical products. Bioethics issues and strategies for funding new medical ventures.
4 units, Spr (Andriacchi)

ME 385. Tissue Engineering Lab—(Formerly 285B.) 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.
1-2 units, Win (Jacobs)

ME 386. Neuromuscular Biomechanics—(Same as BIOE 386; formerly 286.) The interplay between mechanics and neural control of movement. State of the art assessment through a review of classic and recent journal articles. Emphasis is on the application of dynamics and control to the design of assistive technology for persons with movement disorders.
3 units (Delp) not given 2005-06

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

ME 390. Thermosciences Research Project Seminar—(Formerly 290.) Review of work in a particular research program and presentations of other related work.
1 unit, Aut, Win, Spr (Staff)

ME 391. Engineering Problems—(Formerly 291.) 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. Students must find a faculty sponsor.
1-5 units, Aut, Win, Spr, Sum (Staff)

ME 392. Experimental Investigation of Engineering Problems—(Formerly 292.) 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.
1-5 units, Aut, Win, Spr, Sum (Staff)

ME 393. Topics in Biologically Inspired or Human Interactive Robotics—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.
1 unit, Aut, Win, Spr (Cutkosky, Waldron, Niemeyer)

ME 394. Design Forum—Introduction to the design faculty and research labs. Faculty describe their work and research interests followed by open discussion.
1 unit, Aut (Niemeyer)

ME 395. Seminar in Solid Mechanics—Required of Ph.D. candidates in solid mechanics. Problems in all branches of solid mechanics. May be repeated for credit.
1 unit, Aut, Win, Spr (Lew)

ME 396. Design and Manufacturing Forum—(Formerly 296.) Guest speakers address issues of interest to design and manufacturing engineers. Sponsored by Stanford Engineering Club for Automation and Manufacturing (SECAM). May be repeated for credit.
1 unit, Win, Spr (Reis)

ME 397. Design Theory and Methodology Forum—(Formerly 297.) Research reports, literature reviews, and designer interviews. The cognitive basis for designer behavior and design tool development. May be repeated for credit.
1-3 units (Leifer, Mabogunje, Eris) not given 2005-06

ME 399. Fuel Cell Seminar—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.
1 unit (Staff) not given 2005-06

ADVANCED GRADUATE

ME 400. Thesis (Engineer Degree)—(Formerly 300.) Investigation of some engineering problems. Required of Engineer degree candidates.
2-15 units, Aut, Win, Spr, Sum (Staff)

ME 405. Asymptotic Methods and Applications—(Formerly 305.) Asymptotic versus convergent expansions, approximation of integrals, method of matched asymptotics, WKB method and turning points, method of multiple scales. Applications: viscous and potential flow, wave propagation, combustion, and electrostatics. Prerequisites: CME 204 (formerly ME 300B), graduate level fluid mechanics.
3 units (Staff) not given 2005-06

ME 408. Spectral Methods in Computational Physics—(Enroll in CME 322.)
3 units, Aut (Moin)

ME 412. Engineering Functional Analysis and Finite Elements—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.
3 units, Spr (Lew)

ME 414. Solid State Physics Issues for Mechanical Engineering Experiments—(Formerly 314.) Introductory overview of the principles of statistical mechanics, quantum mechanics, and solid-state physics. Provides graduate mechanical engineering students with understanding needed to work on devices or technologies which rely on solid-state physics.
3 units, Sum (Kenny)

ME 417. Total Product Integration Engineering—(Formerly 317.) For students aspiring to be product development executives and leaders in dfM research and education. Advanced methods and tools beyond the material covered in 217: quality design across global supply chain, robust product architecture for market variety and technology advances, product development risk management. Small teams or individuals conduct a practical project that produces either an in-depth case study or a significant enhancement to the dfM methods and tools. Enrollment limited to 16. Prerequisites: 317AB.
4 units, Aut (Ishii)

ME 420. Applied Electrochemistry: Micro- and Nanoscale—Concepts of physical chemistry such as thermodynamic equilibrium, reaction kinetics, and mass transport mechanisms from which the fundamentals of electrochemistry are derived. Theory of electrochemical methods for material analyses and modifications with emphasis on scaling behaviors. Electrochemical devices such as sensors, actuators, and probes for scanning microscopes, and their miniaturization concepts. Examples of these devices built, characterized, and applied in labs using technologies such as scanning probe techniques. Projects focus on current problems in biology, material science, microfabrication, and energy conversion.
3 units, Aut (Fasching)

ME 436. Computational Molecular Modeling and Parallel Computing—Advanced methods for computer simulation of proteins. Long-range force calculation, particle mesh Ewald, fast multipole method, multigrid. Free energy methods, umbrella sampling, acceptance ratio, thermodynamic integration, non equilibrium methods, adaptive biasing force, parallel computing. Parallel algorithms, MPI, implementation issues. Prerequisites: 346, statistical mechanics, advanced programming in C.
3 units, Spr (Darve)

ME 444A. Quantum Simulations of Molecules and Materials—(Enroll in CHEMENG 444A.)
3 units, Win (Musgrave)

ME 444B. Quantum Simulations: Materials Micro Mechanics—(Formerly 249B.) Quantum atomistic simulations of materials to predict structure, strength, defect energetics and motion, and surfaces and interfaces. Tight-binding and density functional methods for covalent, ionic, and metallic solids. Pseudopotential and plane wave basis for ab initio solid electronic structure calculations. Applications to real materials systems including micromechanics of electronic devices, MEMS, nanotechnology, and biomaterials.
3 units (Staff) not given 2005-06

ME 451A. Advanced Fluid Mechanics—(Formerly 351A.) Topics: kinematics (analysis of deformation, critical points and flow topology, Helmholtz decomposition); constitutive relations (viscous and visco-elastic flows, non-inertial frames); vortex dynamics; circulation theorems, vortex line stretching and rotation, vorticity generation mechanisms, vortex filaments and Biot-Savart formula, local induction approximation, impulse and kinetic energy of vortex systems, vorticity in rotating frame. Prerequisite: graduate courses in compressible and viscous flow.
3 units (Staff) not given 2005-06

ME 451B. Advanced Fluid Mechanics—(Formerly 351B.) 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.
3 units, Win (Lele)

ME 451C. Advanced Fluid Mechanics—(Formerly 351C). Compressible flow: governing equations, Crocco-Vazsonyi's equations, creation and destruction of vorticity by compressibility effects, shock waves. Modal decomposition of compressible flow, linear and nonlinear modal interactions, interaction of turbulence with shock waves. Energetics of compressible turbulence, effects of compressibility on free-shear flows, turbulent boundary layers, Van Direst transformation, recovery temperature, and shock/boundary layer interaction. Strong Reynolds analogy, modeling compressible turbulent flows. Prerequisites: 355, 361A, or equivalents.
3 units (Staff) not given 2005-06

ME 453. Introduction to Modeling and Simulation of Fluid/Flow/Structure Interaction Problems—Vibrations of elastic structures. Linearized equations of small movements of inviscid fluids. Sloshing modes. Hydroelastic vibrations. Acoustic cavity modes. Structural acoustic vibrations. Arbitrary Lagrangian-Eulerian description of flow problems. Geometric and discrete geometric conservation laws. CFD on moving grids. Coupled flow/structure time-integrators. Applications to nonlinear computational aeroelasticity: divergence and flutter. Prerequisites: graduate course in the finite element method and in computational fluid dynamics.
4 units, Win (Farhat)

ME 455. Complex Fluids and Non-Newtonian Flows—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.
3 units, Spr (Shaqfeh)

ME 457. Fluid Flow in Microdevices—(Formerly 257.) Introduction to 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.
3 units, Aut (Santiago)

ME 461. Advanced Topics in Turbulence—(Formerly 261B.) Large eddy simulation, constitutive equations and filtering, dynamic subgrid scale models, scale similarity, and reconstruction models; wall models; compressibility effects on turbulence, shock/turbulence interactions, compressible turbulent boundary layers, and multi-phase flow modeling; reduced order modeling, proper orthogonal decomposition; space-time characteristics of organized structures; complexity; computational issues, and higher order conservations.
3 units, Spr (Moin) alternate years, not given 2006-07

ME 463. Advanced Topics in Plasma Science and Engineering—Research areas such as plasma diagnostics, plasma transport, waves and instabilities, and engineering applications.
3 units, Aut (Cappelli)

ME 469A. Computational Methods in Fluid Mechanics—Finite volume methods on structured and unstructured grids. Advanced methods for the solution of systems of equations. ADI schemes, preconditioned conjugate gradient and generalized minimum residual algorithms, multigrid methods, and deferred-correction approaches. Projection, fractional step, and artificial compressibility methods. Turbulent flows: direct numerical simulatio, large eddy simulation, and Reynolds-averaged Navier-Stokes methods. Prerequisite: CME 206 (formerly ME 300C) or equivalent.
3 units (Farhat) not given 2005-06

ME 469B. Computational Methods in Fluid Mechanics—(Formerly 269B.) 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: CME 206 (formerly ME 300C).
3 units, Spr (Iaccarino)

ME 471. Turbulent Combustion—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.
3 units, Aut (Pitsch)

ME 484. Computational Methods in Cardiovascular Bioengineering—(Formerly 184B; same as BIOE 484.) 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.
3 units (Taylor) alternate years, given 2006-07

ME 485. Modeling and Simulation of Human Movement—(Same as BIOE 485; formerly 382.) 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.
3 units (Delp) not given 2005-06

ME 500. Thesis (Ph.D.)—(Formerly 301.)
2-15 units, Aut, Win, Spr, Sum (Staff)

OVERSEAS STUDIES

Courses approved for the Mechanical Engineering major and taught overseas can be found in the "Overseas Studies" section of this bulletin, or in the Overseas Studies office, 126 Sweet Hall.

BERLIN

ME 112X. Mechanical Engineering Design
4 units, Win (Gerdes)

ME 114X. Why Do We Drive What We Drive?
3 units, Win (Gerdes)