MECHANICAL ENGINEERING

Emeriti: (Professors) James L. Adams, Holt Ashley,* Peter Bradshaw, Thomas J. Connolly, Daniel B. DeBra,* Robert H. Eustis, George Herrmann, Thomas J. R. Hughes, James P. Johnston, Thomas R. Kane, William M. Kays, Joseph B. Keller, Robert McKim, Robert J. Moffat, J. David Powell,* William C. Reynolds,* Rudolph Sher, Charles R. Steele, Milton D. Van Dyke, Douglass J. Wilde; *(Professors, Research)* Elliot Levinthal, Sidney Self, Felix Zajac

Chair: Friedrich B. Prinz

Vice Chair: John K. Eaton

Associate Chair for Student Services: Reginald E. Mitchell

Associate Chair for Graduate Admissions and Curriculum: Sheri D. Sheppard

Associate Chair for Faculty Affairs: Mark R. Cutkosky

Division Chairs: Thomas P. Andriacchi (Biomechanical Engineering), Reginald E. Mitchell (Thermosciences Division), Peter M. Pinsky (Mechanics and Computation); (the Design Division, and the Flow Physics and Computation Division operate without a chair)

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 Gasdynamics), Parviz Moin (Center for Turbulence Research), Friedrich B. Prinz (Rapid Prototyping Laboratory)

Professors: Thomas P. Andriacchi, David M. Barnett, Craig T. Bowman, Brian J. Cantwell, Dennis R. Carter, Mark R. Cutkosky, John K. Eaton, Joel H. Ferziger, Ronald K. Hanson, Kosuke Ishii, David M. Kelley, Charles H. Kruger, Larry J. Leifer, Parviz Moin, M. Godfrey Mungal, Drew V. Nelson, Peter M. Pinsky, Friedrich B. Prinz, Bernard Roth, Eric Shaqfeh

Associate Professors: Mark A. Cappelli, Scott Delp, Christopher Edwards, Kenneth E. Goodson, Thomas W. Kenny, Sanjiva Lele, Reginald E. Mitchell, Sheri D. Sheppard

Assistant Professors: Kyeongjae Cho, Eric Darve, J. Christian Gerdes, Andrian Lew, Gunter Niemeyer, Heinz Pitsch, Beth Pruitt, Juan G. Santiago, Charles Taylor

Acting Assistant Professor: George Kembel

Professors (Research): Richard M. Christensen, Paul Durbin, Kenneth Waldron

Associate Professor (Research): Christopher Jacobs

Professor (Teaching): David W. Beach

Courtesy Professors: Fu-Kuo Chang, George S. Springer, Robert T. Street, Paul Yock

Senior Lecturer: J. Craig Milroy

Lecturers: Nalu B. Kaahaaina, Matthew R. Ohline

Consulting Professors: Gary S. Beaupre, David M. Golden, Barry M. Katz, Victor D. Scheinman, Edith Wilson

Consulting Associate Professor: J. Edward Carryer

Consulting Assistant Professors: Michael Barry, Mark Bolas, Brendan J. Boyle, William Burnett, Vadim Khayms, Sara Little Turnbull

Visiting Professor: Huajian Gao

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* Recalled to active duty.

Student Services: Building 530, Room 125

Mail Code: 94305-3030

Student Services Phone: (650) 725-7695

Web Site: http://me.stanford.edu

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

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 is generally understood to emphasize 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 dealing with these problems, 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 our 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 divisions: Biomechanical Engineering, Design, Flow Physics and Computation, Mechanics and Computation, and Thermosciences. Each maintains its own labs, shops, and offices.

The Biomechanical Engineering (BME) Division 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 Division has particularly strong research interactions with the Mechanics and Computation Division, the Design Division, and the departments of Functional Restoration, Neurology, Radiology, and Surgery in the School of Medicine.

The Design Division 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), optimization, and robotics. The Design Division offers undergraduate and graduate programs in Product Design (jointly with the Department of Art and Art History).

The Flow Physics and Computation Division (FPC) is contributing 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 teach graduate and undergraduate courses in acoustics, aerodynamics, computational fluid mechanics, computational mathematics, fluid mechanics, combustion, and thermodynamics and propulsion.

The Mechanics and Computational Division 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 micromechanics, 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 Division 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 in order 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 divisions 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 include 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 available through the School of Medicine. Individual accommodation is provided for the work of each research student.

Major experimental and computational laboratories engaged in bioengineering work are located in the Biomechanical Engineering Division. Other Biomechanical Engineering Division 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, biologically and clinically oriented work is conducted in various facilities throughout the Stanford Medical Center and the Veterans Administration Palo Alto Health Care System.

The Design Division 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 Division students also have access to Center for Integrated Systems (CIS) and Ginzton Lab microfabrication facilities.

The division 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 and 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 Division 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 Division 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 Division is greatly enhanced by the interactions among CTR's and CITS's staff of postdoctoral researchers and distinguished visiting scientists.

The Mechanics and Computation Division 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 Division 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, pollutant formation, and reactive and nonreactive 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 Division and the Design Division 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 conversation 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 Divisions 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 is offered by the Design Division and 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 Division, 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 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 should apply for entrance after the beginning of the eighth quarter of undergraduate work and before the end of the 11th quarter. The application must provide evidence of potential for strong academic performance as a graduate student. The application is evaluated and acted on by the graduate admissions committee of the department. 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, 131B, and must take the Graduate Record Examination (GRE) before action is taken on the application. Product designers must have completed 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.

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 in order 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: ME 300A,B,C; MATH 106, 109; CS 205; EE 263, 261; STATS 110, ENGR 155C; CS 237A,B (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. These sets have been approved by the faculty 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 have adviser approval. 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 graded (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 focus of the Joint Program in Design is the intersection of technology with human needs and aspirations. This program is a joint offering of the Department of Mechanical Engineering and the Department of Art and Art History. 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*
ARTHIST 60, 169/269, or 268	3
ARTHIST 160	3
ARTHIST 360A,B,C. Master's Project*	6
ME 216A,B, 312	11
ME 203. Manufacturing and Design	4
ME 316A,B,C. Master's Project*	12
ME 313. Human Values and Innovation in Design	3
Approved Electives†	10
Free Electives†	6
Total	59

Note: Stanford B.S. (Product Design) degree holders admitted to the program design a 45-unit program with their adviser.

* Taken jointly each quarter.

† These electives allow a student to pursue studies suited to personal needs. A list of pre-approved product design electives is outlined in the Mechanical Engineering Graduate Handbook.

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

A student studying for the Ph.D. degree ordinarily will 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 about the exam 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-division 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 296 or 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 residence requirements, but there is no minimum limit on registered dissertation units. Candidates should note that University residence requirements (see the "Graduate Degrees" section of this bulletin) are expressed in terms of equivalent full-time registration and not in terms of units per se; questions on this should be addressed to the 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 1—The following are especially suitable for freshmen.

ME11N. Aerodynamics of Sports Balls
ME12N. The Jet Engine
ME 13N. Designing the Human Experience: An Exploration into the Theory and Practice of Design Thinking
ME 14N. Stuff
ME 15N. Mechanical Design Issues for Sports Equipment
ME16N. Science of Flames
ME17N. Robotic Animals

Note 2—The following are especially suitable for sophomores.

ME18Q. Creative Teams and Individual Development
ME 20N. Mechanical Dissection
ME 101. Visual Thinking
ME 203. Manufacturing and Design

Note 3—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 11N. Aerodynamics of Sports Balls—(Formerly 70N.) Stanford Introductory Seminar. Preference to freshmen. The aerodynamics of the ball play a major role in sports including the curveball in baseball, the spiral of a football, top spin in tennis, and golf ball dimples. Simple, intuitive application of the basic principles precede lab and/or field experiments. Lab experiments involve flow visualization in a wind tunnel; field experiments may involve tests in throwing, hitting, or kicking various balls and interaction with local teams. Teams of two to three prepare a written report discussing the importance of aerodynamics in a particular sport. Prerequisites: high school physics.

3 units (Mungal) not given 2003-04

ME 12N. The Jet Engine—(Formerly 72N.) Stanford Introductory Seminar. Preference to freshmen. The basics of how a jet engine works and the technologies and analytical techniques required to understand them. Brief coverage of dynamics, thermodynamics, turbomachinery, combustion, advanced materials, cooling technologies, and control systems. Visits to research laboratories, examination of a partially disassembled engine, and probably operation of a small jet engine. Prerequisites: high school physics.

3 units, Aut (Eaton)

ME 13N. Designing the Human Experience—(Formerly 73N.) Stanford Introductory Seminar. Preference to freshmen. The theory and practice of design thinking. Readings, discussion, and projects explore the proposition that design education is for everyone.

3-5 units, Win (Leifer)

ME 14N. Stuff—(Formerly 74N.) Preference to freshmen. The advancement of human society largely depends on the stuff available for housing, transportation systems, industrial products, defense systems. Human-made stuff is exposed to unfriendly environments such as high temperatures, corrosive liquids, and gases. The most extreme conditions occur in aircraft engines. A trip to an airline maintenance facility provides insight into the environmental conditions which turbine blades suffer; how engineers prevent the premature death of turbine blades to avoid major catastrophes.

3 units (Prinz) not given 2003-04

ME 15N. Mechanical Design Issues for Sports Equipment—(Formerly 75N.) Stanford Introductory Seminar. Preference to freshmen. Any sporting goods department reveals examples of mechanical design, accompanied by literature which highlights novel design features. Design features such as perimeter weighting in golf clubs can be understood and are sensible; others such as bubble shafts in golf clubs or fat heads in baseball bats are less obvious and perhaps of no real utility. Analyses of designs, and conclusions about their relative merits.

3 units (Kenny) not given 2003-04

ME 16N. The Science of Flames—(Formerly 76N.) 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 and an interest in thermochemical phenomena.

3 units, Spr (Mitchell)

ME 17N. Robotic Animals—Stanford Introductory Seminar. Preference to freshmen. The dream of constructing robots that duplicate the functional abilities of humans and/or other animals has been promulgated primarily by science fiction writers. But biological systems provide models for the designers of the mechanical, electrical, and information systems of robots. Similarly, building electromechanical devices that perform locomotory and sensing functions similar to those of an animal is a way of learning about the ways biological systems function. Discussions of walking and running machines, and the problem of giving a robot the capability to respond to its environment.

3 units, Aut (Waldron)

ME 18Q. Creative Teams and Individual Development—Stanford Introductory Seminar. Preference to sophomores. Students learn what roles on a problem solving team 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.

3 units, Aut (Wilde)

ME 19N. Robots—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 most recently in hospitals doing surgery. Do fiction and reality have anything in common? What really is a robot, what can they do, and perhaps more importantly what can they not do? How do we build them and how are they changing our lives? Field trips and hands-on projects.

3 units (Niemeyer) not given 2003-04

ME 20N. Mechanical Dissection—Stanford Introductory Seminar. Preference to freshmen. Hands-on labs resolve common questions concerning everyday products. Students choose a current product, track its history, obtain current and antique samples, disassemble, and explore functions. Formal and informal presentations.

3 units, Win (Sheppard)

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.
4 units, Win (Cappelli), Spr (Mungal)

ME 80. Stress, Strain, and Strength—Review of the basic mechanics of materials and engineering properties of structural materials. Stress concentrations and their avoidance through design. Static failure theories for ductile and brittle materials. Introduction to fracture mechanics. Surface failure mechanisms including corrosion, fretting, and wear. Structural failure by global and local buckling of columns and plates. Introduction to failure by fatigue, fatigue failure criteria, and life prediction methods. Case studies in failure of structural components emphasizing applications to mechanical design. Prerequisite: ENGR 14.
3 units, Aut (Pruitt)

ME 99. Mechanical Dissection—Series of mechanical dissection labs resolve common questions of everyday products and provide confidence in hands-on skills. Students choose a current product, track its history, obtain samples (current and antique), disassemble, and explore functions. Formal and informal presentations. Lab. Enrollment limited to 20. Prerequisite: keen sense of curiosity.
3 units (Sheppard) not given 2003-04

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. Quickly executed diagrammatic, orthographic, perspective, and three-dimensional sketching with emphasis on fluent and flexible idea production. The relationship between visual thinking and the creative process. Enrollment limited to 60.
3 units, Aut, Win, Spr (Staff)

ME 102. Design Improv—Improvisational techniques and exercises explore topics relating to personal and group design processes and broader cultural issues in product design. The former include personal creative habits, team building, communication, cooperation and team work. Cultural issues include proxemics, status, product-user interaction, and the role of narrative in creating meaning. Prerequisite: enrollment in Product Design or consent of instructor.
3 units, Win (Ryan)

ME 103D. Engineering Drawing and Design—The fundamentals of engineering drawing including orthographic projection, dimensioning, sectioning, exploded and auxiliary views, and assembly drawings. Designed to accompany 103. Homework drawings are of parts fabricated by the student in the shop. Major assignments in 103 are supported by material in 103D and assignment dates are 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. Work is guided by instructors. Concurrent assignments in 115 and 216B,C provide subject matter, but the class is open to anyone wishing to improve freehand drawing skills. (AU)
1 unit, Win, Spr (Staff)

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

ME 112. Mechanical Systems Design—The function of basic machine elements such as gears and bearings, the trade-offs between classes of machine elements, performance characteristics of machine elements, and systems level design. Experience in working in teams; selecting machine classes in synthesis-type problems; iterative design including prototyping; communicating ideas in graphical, textual, and oral forms; and design critiquing. Lectures, labs. Prerequisites: 80, 101, Recommended: 203, ENGR 15.
4 units, Win (Gerdes)

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.
3 units, Spr (Nelson)

ME 115. Human Values in Design—Active encounters with human values in design. Lectures survey 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.
3 units, Win (Boyle)

ME 116. Advanced Product Design: Formgiving—Small- and medium-scale design projects are carried to a high degree of aesthetic refinement. Emphasis is on generating the appropriate forms to the task and setting. Prerequisites: 115, ARTHIST 160.
4units, 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.
3-4 units, Spr (Katz)

ME 121. Design and Construction in Wood—(Formerly 195.) The design and construction of objects using wood. Taught in the Product Realization Lab. Enrollment limited.
1-3 units, 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. Prerequistes: 70, ENGR 30. Recommended: intermediate calculus, ordinary differential equations.
3-4 units, Aut (Cappelli)

ME 131B. Fluid Mechanics: Compressible Flow and Turbomachinery—Introduction to engineering applications involving compressible flow: aircraft propulsion, 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. Introduction to 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.
3 units, Win (Mungal)

ME 140. Advanced Thermal Systems—Capstone course in thermal science, providing experience in thermal analysis and engineering, with emphasis on integrating heat transfer, fluid mechanics, and thermodynamics into a unified approach to treating complex systems. Lecture introduces mixtures, humidity, chemical and phase equilibrium, and availability. Labs apply principles through hands-on experience with a turbojet engine, a PEM fuel cell, and a hybrid solid/oxygen rocket motor. Analysis of systems is facilitated using MATLAB as a computational tool. Prerequisites: 70, 131A, 131B, and ENGR 30.
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: 140.
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 examples. Prerequisites: background in dynamics and calculus, e.g., ENGR 15 and MATH 43. Recommenced: ENGR 155A, and familiarity with differential equations, linear algebra, and basic electronics.
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—For ME seniors admitted to the honors program. Faculty supervision.
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. students and second-year fellowship students to show research opportunities across the department. Strategies for getting involved in a research project.
1 unit, Aut (Sheppard, Haccou)

ME 203. Manufacturing and Design—(Formerly 103/303.) Emphasis is on prototype development techniques as an intrinsic part of the design process. The fundamentals of machining, welding, and casting, introduced in lecture and supported by lab experience. Manufacturing processes through lecture, films, and field trips. Design aspects are developed in an individual term project chosen, designed, and fabricated by students. Limited enrollment with consent of instructor. Corequisite, unless student has prior drafting experience: 103D. Undergraduates majoring in Mechanical Engineering or Product Design must take course for 4 units. Corequisite for Mechanical Engineering and Product Design majors for WIM: Engineering 102M. Recommended: 101. (WIM)
3-4 units, Aut, Win (Beach)

ME 204. Bicycle Design and Frame-Building—(Formerly 396.) Emphasis is on both 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 (Milroy)

ME 205. Documenting Your Design Work—The importance of documenting one's three-dimensional design work in two-dimensional form, using both images and text. Students document and present their own work for peer feedback. Guest lecturers and critiques from professionals in the design field.
2 units, Spr (Staff)

ME 210. Introduction to Mechatronics—(Formerly 118.) The technologies involved in mechatronics (intelligent electro-mechanical systems), and the techniques to apply this technology to mecatronic system design. Topics include electronics (A/D, D/A converters, op-amps, filters, power devices); software program design, event-driven programming; hardware and DC stepper motors, solenoids, and robust sensing. Lab componen of structural assignments. Large and open-ended team project. Limited enrollment. Prerequisites: ENGR 40, CS 106, or equivalent.
4 units, Win (Kenny, Ohline)

ME 216A. Advanced Product Design: Needfinding—(Formerly 116B/316B.) 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 or consent of instructor.
4 units, Win (Patnaik, Barry)

ME 216B. Advanced Product Design: Implementation—(Formerly 116C/316C.) Summary project utilizing the knowledge, methodology, and skills obtained in 115 and 216A. Students implement design concept and present it to a professional jury. Prerequisite:216A.
4 units, Spr (Staff)

ME 218A. Smart Product Design Fundamentals—Introduction. Lecture, lab, and design project based series on programmable electromechanical systems design. Topics: transistors as switches, basic digital and analog circuits, boolean algebra, combinatorial and sequential logic, operational amplifiers, comparators, software design, programming in FORTH and C. Team project. Enrollment in 218B,C is contingent on completing 218A or passing a Smart Product Design Fundamentals proficiency examination given at the start of Autumn Quarter. Lab fee. Limited enrollment.
4-5 units, Aut (Carryer)

ME 218B. Smart Product Design Applications—Intermediate level in the series of programmable electromechanical systems design, introduced in the context of lab assignments and integrated into a team project. Topics: user I/O, timer systems, interrupts, signal conditioning, software design for embedded systems, sensors, actuators, noise, and power supplies. Team project. 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 the series on programmable electromechanical systems design. Topics: inter-processor communication, system design with multiple microprocessors, architecture and assembly language programming for the PIC microcontroller, design with programmable logic, understanding and controlling the embedded software tool chain, A/D and D/A techniques, electronic manufacturing technology. Lab fee. Limited enrollment. Team project. Prerequisite: completion of 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 that requires the application and extension of the knowledge gained in the prior three quarters, including prototyping of a final solution with hardware, software, and professional documentation and presentation. Lectures extend the students' knowledge of electronic and software design, and electronic manufacturing techniques. Topics: chip level design of microprocessor systems, real time operating systems, alternate microprocessor architectures, PCB layout and fabrication.
4 units, Aut (Carryer)

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 units, Spr (Staff)

ME 227. Vehicle Dynamics and Control—The application of the principles of dynamics, kinematics, and control theory to the design and analysis of ground vehicle behavior. Simplified models of ride, handling, and braking, their role in developing intuition, and their limitations in engineering design. Suspension design fundamentals. Multibody dynamics approaches to vehicle modeling. Performance and safety enhancement through automatic control systems such as anti-lock braking, active suspensions, and stability control. Limited enrollment. Prerequisite: 161 or ENGR 104; consent of instructor.

3 units, Spr (Gerdes)

ME 240. Introduction to Nanotechnology—Nanotechnology is multidisciplinary in nature with contributions from physical sciences, engineering, and business. Current topics in nanotechnology research and developments in nanomaterials, mechanics, electronics, and sensors and applications to provide background, current status, and perspective on future technological progress. Nano-scale materials building blocks, fabrication and assembly processes, characterization and properties, and novel system architectures. Implications for the future development.

3 units, Spr (Cho, Srivastara)

ME 256. Turbomachinery, Fluid Dynamics, and Design—Theory, performance, and design of turbomachines including turbines, pumps, compressors, and wind turbines. Turbomachines function as the result of the dynamic interaction of a moving fluid with a bladed rotor. Problems sets, and a final design problem such as the specification of blading for a compressor or a turbine stage to meet prescribed performance criteria. Prerequisites: 251A or equivalent, plus one-dimensional flow of a perfect gas as presented in 131B or equivalent.

3 units (Staff) not given 2003-04

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.

3 units, Spr (Carter)

ME 281. Biomechanics of Movement—Former 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, neurology, and rehabilitation.

3 units, Aut (Delp)

ME 283. Biomineralization—(Formerly 182.) The process of formation and adaptation of mineralized structures formed by organisms, principally animal skeletons. Engineering mineralized tissues. Emphasis is on the interacting influences of phylogenic history, material constraints, mechanical factors, and other ecological and physiological considerations. Skeletal formation processes and the skeletal microstructure and ultrastructure of every animal phylum. The evolutionary aspects of body plan design among the major animal phyla with skeletons.

2 units, Spr (Constantz)

ME 284. Cardiovascular Bioengineering—(Formerly 184A.) Bioengineering principles are developed and applied to the cardiovascular system. The relevance of engineering methods in the study of cardiovascular function is examined from a historical perspective. Overview of continuum mechanics. Behavior of blood and blood vessels. Cardiovascular anatomy, physiology, biology, and epidemiology. Diagnostic imaging, and treatments for congenital and adult cardiovascular disease. Overview of techniques used to model the cardiovascular system.

3 units, Win (Taylor)

ME 285. Mineralization of Bone—The mechanical properties of bone are dependent largely on mineralization. The relationship between mineralization and bone biomechanics; synthesis of bone's organic matrix and stimuli for its development and morphogenesis; the mechanisms of crystal nucleation and growth; pathological states of bone mineralization with respect to the normal state and processes of bone mineralization. Approaches to increase the mineral content of bone and therapeutic approaches that replace lost bone with synthetic bone materials.

2 units, Spr (Constantz)

ME 294. Medical Device Design—(Formerly 194/394.) In collaboration with the School of Medicine. Introduction to medical device design for undergraduate and graduate engineering students. Significant design and prototyping. Labs expose students to 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. Register under adviser's section number.

1 unit, Any quarter (Staff)

GRADUATE

ME 300A. Mathematical and Computational Methods in Engineering—Formerly 200A. The theory of linear algebra; basis, linear independence, column space, null space, rank. Emphasis is on computer solutions of the linear system of algebraic and differential equations. Roundoff errors, pivoting, and ill-conditioned matrices. Quadratic forms, norm and condition numbers, projection and least-squares, operation counts, eigenvalues, eigenvectors, and their computation. The canonical diagonal form, functions of a matrix. Unitary, Hermitian, and normal matrices. Principal stresses and axes. Recommended: familiarity with computer programming; MATH 103, 130, or equivalent.

3 units, Aut (Gerritsen)

ME 300B. Mathematical and Computational Methods in Engineering—Formerly 200B. Geometric interpretation of partial differential equations (PDEs), characteristics, solution of first-order equations, characteristics and classification of second-order PDEs, separation of variables, special functions, eigenfunction expansions, Fourier integrals and transforms, Laplace transforms, method of characteristics, analytic and numerical techniques, self-similarity. Prerequisite: 300A

3 units, Win (Lele)

ME 300C. Mathematical and Computational Methods in Engineering—(Formerly 200C.) Numerical methods from a user's point of view. Lagrange interpolation, splines. Integration: trapezoid, Romberg, Gauss, adaptive quadrature. Numerical solution of ordinary differential equations: explicit and implicit methods, multistep methods, Runge-Kutta and predictor-corrector methods, boundary value problems, eigenvalue problems. Systems of differential equations, stiffness.

Emphasis is on the analysis of numerical methods for accuracy, stability, and convergence. Introduction to numerical solutions of partial differential equations. Von Neumann stability analysis. Alternating direction implicit methods, non-linear equations. Prerequisites 300A.
3 units, Spr (Moin)

ME 305. Introduction to Control Design Techniques—(Enroll in ENGR 205.)
3 units, Aut (Tomlin)

ME 306A. Control System Design and Simulation—(Enroll in ENGR 206.)
4 units, Spr (Niemeyer)

ME 306B. Analysis and Control of Nonlinear Systems—(Enroll in ENGR 209A.)
3 units, Win (Tomlin)

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 interrelationships; the formulation of Newton-Euler kinetics applied to serial chain systems such as industrial robotics.
3 units (Waldron) alternate years, given 2004-05

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 (Sheppard) not given 2003-04

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.
3-5 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.
3-5 units, Win, Spr (Cutkosky, Leifer)

ME 313. Human Values and Innovation in Design—Visual and kinesthetic skills are developed and exercised in solving design problems. Quickly executed perspective, orthographic, diagrammatic, and three-dimensional sketches are emphasized in conjunction with fluent and flexible idea production. Exercises to appreciate and develop the entire body's role in creative thinking. Enrollment limited to 60.
3 units, Aut (Kelley)

ME 314. Good Products, Bad Products—(Formerly 214.) 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. Limited enrollment.
3-4 units, Win (Beach)

ME 315. The Designer in Society—(Formerly 215.) Open to all graduate students. Participants' career objectives and psychological orientation are 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. Attendance mandatory. Enrollment limited to 24.
3 units, Win (Roth)

ME 316A,B,C. Product Design Master's Thesis—(Formerly 211A,B,C.) For 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 317B 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 units, Aut (Erhun)

ME 318. Computer-Aided Product Creation—(Formerly 213.) Design course concentrating on an integrated suite of modern 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's Product Realization Lab's relationship to the outside world. Structured lab experiences build a basic CAD/CAM/CNC proficiency. Limited enrollment.
4 units, Spr (Beach), Win (Milroy)

ME 319. Robotics and Vision Lab—For graduate students with some familiarity in robotics who want project experience with robotic and vision systems. Current topics in robotics and machine vision with applications to flexible, automated manufacturing; emphasis is on integrated problems and techniques for fine motion control, calibration, acquisition of sensory data, and programming. Cell level topics: architectures and strategies for cell control. Research issues: dexterous manipulation and languages for high-level task specification. Typical projects: robotic deburring, assembly using force feedback and/or vision, part inspection, and cell control. Assignments provide practice with equipment. Enrollment limited to 30. Prerequisites: 320 or equivalent, some familiarity with programming.
3 units (Cutkosky) not given 2003-04

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

ME 321. Materials Selection In Design—(Enroll in MATSCI 170, MATSCI 270.)
3-4 units (Prinz) not given 2003-04

ME 322. Kinematic Synthesis of Mechanisms—(Formerly 222.) The rational design of linkages. Techniques are presented to determine linkage proportions to fulfill various design requirements using analytical, graphical, and computer based methods.
3 units, Win (Roth)

ME 323. Modeling and Identification of Mechanical Systems for Control—One important step in any feedback control problem is obtaining a mathematical description or model of the system to be controlled. System modeling and parameter identification from a theoretical and a practical standpoint. Energy-based methods for systematic modeling, frequency domain modeling and identification, parameter identification, and state space techniques. Modeling techniques, controller implementation, and the implications of unmodeled dynamics and nonlinearities. Prerequisites: familiarity with linear algebra and system simulation with MATLAB/SIMULINK, ENGR 105.
3 units, Aut (Gerdes)

ME 324. Precision Engineering—(Formerly 224.) 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 is gained through the design and manufacture of a precision engineering project, emphasizing the principles of precision engineering. Lectures, structured labs, and field trips. Prerequisite: consent of instructors.
4 units, Spr (Beach, DeBra)

ME 325. Interdisciplinary Interaction Design—(Same as CS 447; formerly 293.) Small teams develop innovative technology prototypes that combine product and interaction design. Focus is on software and hardware interfaces, interaction, design aesthetics, and some underpinnings of successful design: a reflective, interactive design process, group dynamics of effective interdisciplinary teamwork, and working with users. Prerequisite: 247A.
3-4 units, Spr (Kelley, Winograd)

ME 326. Telerobotics and Human-Robot Interactions—Analysis of telerobotics and human-robot interactions with focus 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. Prerequisites: ENGR 105, 320 or CS 223A, or consent of instructor. Limited enrollment.
3 units, Win (Niemeyer) alternate years, given 2004-05

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

ME 329. Physical Solid Mechanics—(Formerly 229.) Statistical mechanics of solids. Microscopic foundation of solid mechanics including metals, ceramics, amorphous and alloy materials. Thermodynamics and statistical mechanics of materials. Atomic structure of solids. Dynamics of crystals. Point defects, dislocations, grain boundaries in solids. Micromechanics of interfaces and thin films. Mechanics of nanostructures.
3 units (Cho) not given 2003-04

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 princple, 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. Prerequiste: ENGR 15 or equivalent.
3 units, Aut (Rock)

ME 331B. Classical 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 dfferential equations govering the behavior of multiple degree of freedom systems. Computer simulation of multi-body dynamic systems. Computer simulation of multi-body dynamic systems. Linearization and computed torque control.
3 units, Win (Mitiguy)

ME 332A. Introduction to Computational Mechanics—(Formerly 232A.) Modern computational methods for solving problems arising in the mechanics of solids and structures. Basic concepts of the finite element method (FEM) and boundary element method (BEM). Equations of linear solid mechanics including variational formulations. Elastic bars (elasticity in one dimension), steady heat conduction (diffusion), and plane elasticity (plane stress and strain, axisymmetric elasticity). Students develop a finite element code in Matlab using the PDE Toolbox pre- and post-processor, solve problems, and visualize results. Introduction to simulation-based design methodologies.
3 units (Pinsky) not given 2003-04

ME 332B. Introduction to Computational Mechanics II—(Formerly 232B.) Introduction to convergence analysis of the finite and boundary element method. Advanced element formulations: mixed finite element models for incompressible and constrained media. Variational treatment of constraints based on Lagrange multiplier and penalty methods.. Extension of the finite element and boundary element methods to time-depen-

dent problems, including transient heat conduction and dynamic analysis. Extension of Matlab finite element code for the time-dependent problems.
3 units (Pinsky) not given 2003-04

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, e.g., nonlinear elasticity.
3 units (Pinsky) not given 2003-04

ME 337. Free and Forced Motion of Structures—(Enroll in AA 244A.)
3 units (Ashley) not given 2003-04

ME 338A. Continuum Mechanics—(Formerly 238A.) Review of tensor algebra and calculus. Kinematics of continuum deformation; finite deformations and compatibility; measures of strain and stress; linearized kinematics; conservation laws for mass, momenta, and energy; Lagrangian formulation of continuum mechanics; symmetries and Noether's theorem; continuum thermodynamics.
3 units, Aut (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.
3 units, Win (Lew)

ME 340A. Theory and Applications of Elasticity—(Formerly 240A.) Concepts of deformation, strain, stress, and strain energy. Kinematic relations, generalized Hooke's law, and symmetry properties of elastic constants. Compatibility and uniqueness of solutions. Formulation of plane boundary value problems and solution methods using stress functions. Elastic waves in deformable solids. Stress concentration at holes, inclusions, dislocations, and cracks. Prerequisite: 338A or equivalent, or consent of instructor.
3 units, Win (Barnett)

ME 340B. Micromechanics of Solids—(Formerly 240B.) Use of theory of elasticity to discuss fields of dislocations, transformed inclusions and in homogeneities (Eshelby's problem), and their interactions in deformable solids. Applications to the microscopic foundations of plasticity, the energetics associated with phase transformations and fracture, and the determination of effective properties of composite solids. Prerequisite: basic familiarity with the theory of elasticity or consent of instructor.
3 units, Spr (Barnett)

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, Win (Puria)

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.
4 units, Spr (Pruitt)

ME 342B. MEMS Laboratory II—Emphasis is on team-based innovative design, prototyping, and characterization of new devices driven by customer requirements and the study of the device and market. Limited enrollment. Prerequisite: 342A.
4 units, Sum (Pruitt)

ME 344A. Computational Nanotechnology—(Formerly 244A.) Computational tools to design nanoscale materials and devices. Material properties of main classes of nano building blocks: carbon nanomatrials (fullerenes and nanotubes); nanoparticles and quantum dots; semiconductor and metal nanowires; and molecular wires. Atomistic modeling programs with graphical user interace to gain hands-on experience of nanomatrials design.
3 units, Aut (Cho)

ME 344B. Nanomaterials Modeling—(Formerly 244B.) Atomistic and quantum mechanical simulation methods. Concepts and practical techniques of atmostic 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 of computational design of nanomaterials, and fundamentals of simulation.
3 units, Win (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 348. Experimental Stress Analysis—(Formerly 248.) 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). Limited enrollment.
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 (Lele)

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 2003-04

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.) Recommended for students with little experience in compressible flow. 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 (Mungal) not given 2003-04

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. Emphasis is on 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 specific mission to be completed in groups. Tours of Lockheed Martin facilities. Limited enrollment. Prerequistes: 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.

3 units (Golden) not given 2003-04

ME 363. Partially Ionized Plasmas and Gas Discharges—(Formerly 263.) Introduction to partially ionized gases and the nature of gas discharges. Topics: the fundamentals of plasma physics emphasizing collisional and radiative processes, electron and ion transport, ohmic dissipation, oscillations and waves, interaction of electromagnetic waves with plasmas. Applications: plasma diagnostics, plasma propulsion and materials processing. Prerequisite: 362A or consent of instructor.

3 units, Spr (Staff)

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 mecha-

nisms; 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.) Introduction to the 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. Prerequisite: undergraduate background in 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 370B carrying the models to maturity and completion. Integration of device models into a larger model of energy systems. Prerequisites: 370A, 370B, consent of instructor.
3-5 units, Spr (Staff)

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 370; or consent of instructor.
3 units, Win (Mitchell)

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 (Bowman)

ME 374A. Biodesign Innovation—Two quarter sequence. Skills essential for the development of new biomedical technologies and first steps in invention, patenting, early prototyping, and development of new concepts. Working in small entrepreneurial teams, students gain exposure to techniques of intellectual property analysis, clinical and scientific literature review, prototyping, and feasibility and market assessment. Guest speakers. Limited enrollment. Prerequisite: consent of instructor.
3-4 units, Win (Yock, Makower)

ME 374B. Biodesign Innovation—Continuation of 374A. Prerequisite: 374A.
3-4 units, Spr (Yock, Makower)

ME 381. Orthopaedic Bioengineering—Engineering approaches are 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 are considered and the role of mechanics in normal development and pathogenesis is addressed. 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, Delp)

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 strtegies for funding new medical ventures.
4 units, Spr (Andriacchi)

ME 385A. Tissue Engineering—(Formerly 285.) Tissue engineering is an expanding discipline that applies biological and engineering principles to create substitutes or replacements for defective tissues or organs. The principles of cell biology as a foundation for using engineering approaches to generate tissue structure and function. Emphasis is on how scaffolds, smart polymers, and mechanical forces can be used to reproduce the physical environment that acts, at the whole organ system level, to maintain specialized cellular function through molecular and genetic mechanisms.
2 units, Win (Smith, Carter)

ME 385B. Tissue Engineering Lab—(Formerly 285B.) Hands-on experience in the fabrication of living engineered tissues. Techniques to be covered 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. The underlying theory and background for each technique are described followed by a practical demonstration. Students are then given access to the lab and provided with supplies and expected to develop hands-on proficiency.
1 unit, Win (Jacobs)

ME 386. Neuromuscular Biomechanics—(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 2003-04

ME 389. Bioengineering and Biodesign Forum—(Formerly 288.) Invited speakers present research topics at the interfaces of biology, medicine, physics, and engineering. (AU)
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. (AU)
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. Biomimetic Locomotion Seminar—(Formerly 294X.) Results from the study of animal locomotion and physiology and their implications for the design and control of small robots. Arthropods provide insights for building small robots that are robust and comparatively easy to control. Weekly forum. One or two papers are reviewed each week. Each student leads the discussion of one of the papers, with the guidance of the instructor.

1 unit, Aut, Win, Spr (Cutkosky, Waldron)

ME 394. Design Forum—(Formerly 294.) Invited speakers address issues of interest to designers. Brief presentation followed by open discussion. Spring Quarter emphasis on manufacturing and design. (AU)

1 unit, Aut (Neimeyer), Spr (Reis)

ME 395. Seminar in Solid Mechanics—Problems in all branches of solid mechanics. All Ph.D. candidates in solid mechanics are normally expected to attend. (AU)

1 unit, Aut, Win, Spr (Staff)

ME 396. Design and Manufacturing Forum—(Formerly 296.) Invited speakers address issues of interest to design and manufacturing engineers. Presentations followed by discussion. Sponsored by Stanford Engineering Club for Automation and Manufacturing (SECAM). (AU)

1 unit, Win, Spr (Staff)

ME 397. Design Theory and Methodology Forum—(Formerly 297.) Research reports, literature reviews, and designer interviews promote rigorous examinations of the cognitive basis for designer behavior and design tool development. (AU)

1 unit, Aut, Win, Spr (Leifer, Mabogunje)

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. Prerequistes: 300B, graduate level fluid mechanics.

3 units, Aut (Staff)

ME 406. Turbulence Physics and Modeling Using Numerical Simulation Data

2 units, Sum (Staff)

ME 408. Spectral Methods in Computational Physics—(Formerly 308.) Data analysis, spectra and correlations, sampling theorem, nonperiodic data and windowing. Spectral methods for numerical solution of ordinary and partial differential equations. Accuracy and computational cost. Fast Fourier transform. Galerkin, collocation, and Tau methods. Spectral and pseudospectral methods based on Fourier series and eigenfunctions of singular Sturm-Liouville problems. Chebyshev, Legendre, and Laguerre representations. Convergence of eigen function expansions. Discontinuities and Gibbs phenomenon. Aliasing errors and control. Efficient implementation of spectral methods. Spectral methods for complicated domains. Time differencing and numerical stability. Data management methods for the Navier-Stokes equations.

3 units, Aut (Moin)

ME 410. Multigrid Methods and Parallel Computation—Multigrid methods to solve partial differential equations for engineering problems. Iterative methods: Jacobi, Guass-Seidel. Multigrid cycles, full multigrid. Multigrid theory, local Fourier analysis. Advanced multigrid, anistropic equations, nonlinear problems. Parallel multigrid, grid partitioning, parallel line smoothers. Algebraic multigrid. Application examples from aerodynamics, atmospheric and oceanic research, structural mechanics, and quantum mechanics. Prerequisites: advanced engineering mathematics, matrix theory (300A), partial differential equations (300B), and computer programming (C, C++, computational package such as MATLAB).

3 units, Aut (Darve)

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) alternate years, not given 2004-05

ME 436. Computational Molecular Mechanics—Molecular mechanics is the study of molecules and their dynamics at the atomic level. The advent of massively parallel computers and high end workstations has enabled the simulation of complex molecular systems with realistic size and time scales. How to set up and run a simulation, understand its components, select the appropriate numerical methods, and analyze and validate simulation results. Emphasis is on molecular dynamics and Monte Carlo methods. Some advanced simulation techniques such as biased Monte Carlo, multiscale techniques, and free energy computation methods. Prerequisites: elementary mechanics and dynamics, numerical solution of ordinary differential equations, and computer programming.

3 units (Darve) not given 2003-04

ME 444A. Quantum Simulations of Molecules and Materials—(Enroll in CHEMENG 444A.)

3 units (Staff) not given 2003-04

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, Spr (Cho)

ME 448. Experiments in Motion Capture—The process of recording human movement in physical space, and transforming that information in a computer-usable form. Example applications include biomedical analysis, re-use in computer animation, or visual input for new Human-Computer-Interfaces. The history of motion capture; all stages of recent marker-based and marker-less, vision based motion capture technology. How to implement the key algorithms and experimental setups. Group project of student's choice. Prerequisites: ability to code in Matlab or C++, basic knowledge in linear algebra, statistics, graphics, and computer vision.

3 units (Alexander, Bregler) not given 2003-04

ME 451A. Advanced Fluid Mechanics—(Formerly 351A.) For advanced students specializing in fluid mechanics. 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 level courses in compressible and viscous flow.

3 units (Lele) not given 2003-04

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. Stability 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. Focus is on flow instabilities. Prerequisites: graduate-level courses in compressible and viscous flow.

3 units, Spr (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 equivalent.

3 units, Win (Pitsch)

ME 453. Introduction to Dilute Multiphase Flow—(Formerly 353.) Introduction to muliphase flow in diluate particle, droplet, and spray systems. Forces on particles, particle motion and dispersion, the Stokes number, and preferential transport. Atomization of liquids and spray formation. Spray description and measurements. Droplet hydrodynamics; deformation, breakup, and coalescence. Droplet and spray evaporation. The spray equation. Modeling approaches to dilute particle/spray flows.

3 units (Edwards) not given 2003-04

ME 457. Fluid Flow in Microdevices—(Formerly 257.) Introduction to the effects of physico-chemical forces on fluid flow of micron-scales. Creeping flow, charge double-layers, and electrochemical transport (e.g., Nernst-Planck equations); the hydrodynamics of solutions of charged and uncharged particles. Device applications of interest include microsystems that perform capillary electrophoresis, drug dispension, and hybridization assays. Emphasis is on bioanalytical applications where electrophoresis, electro-osmosis, and Brownian motion effects are important. Prerequisite: consent of instructor.

3 units, Spr (Santiago)

ME 459. Frontiers in Interdisciplinary Biosciences—(Crosslisted in multiple departments in the schools of Humanities and Sciences, Engineering, and Medicine. Students should enroll through their affiliated department; otherwise enroll in CHEMENG 459.) See CHEMENG 459 or http://biox.stanford.edu/chemeng_index.html for description.

1 unit, Aut, Win, Spr (Robertson)

ME 461. Advanced Topics in Turbulence—(Formerly 261B.) Topics vary each year and may include: spectral representation, rapid distortion theory, Cayley-Hamilton theorem and constitutive modeling of turbulence, turbulent dispersion, stochastic differential equations, Reynolds average and modeling for reacting flows, vortical structures (topology), intermittancy, proper orthogonal characteristic eddy decomposition, chaos, Lyapunoff exponents, fractals, large eddy simulations, subgrid closure, and geophysical turbulence.

3 units (Ferziger, Durbin) not given 2003-04

ME 469A. Computational Methods in Fluid Mechanics—(Formerly 269A.) Advanced methods for solving systems of linear equations: multigrid and conjugate gradient methods; methods for potential flow; integral methods for boundary layers and their coupling to potential flow solutions; methods for the boundary layer equations; methods for solving the incompressible flow equations on structured grids: projection, fractional step and artificial compressibility methods. Students use and modify provided codes. Prerequisites: 300C, 351B, or equivalents.

3 units, Win (Durbin)

ME 469B. Computational Methods in Fluid Mechanics—(Formerly 269B.) Introduction to 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: 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, Spr (Pitsch)

ME 484. Computational Methods in Cardiovascular Bioengineering—(Formerly 184B.) Lumped parameter, one-dimensional nonlinear and linear wave propagation, and three-dimensional modeling techniques applied to simulate blood flow in the cardiovascular system. Construction of anatomic models from medical imaging data. Problems in blood flow within the context of disease research, device design, and surgical planning.

3 units, Spr (Taylor)

ME 485. Modeling and Simulation of Human Movement—(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, 331, or equivalent.

3 units (Delp) not given 2003-04

Ph.D THESIS

ME 500. Thesis (Ph.D.)—(Formerly 301.)

2-15 units, any quarter (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 99B. Mechanical Dissection

3 units, Spr (Sheppard)

ME 113B. Engineering Design

3 units, Spr (Sheppard)

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