MECHANICAL ENGINEERING

Director of undergraduate studies: Corey O'Hern, M203 ML, 432-4258, corey.ohern@yale.edu; seas.yale.edu/departments/mechanical-engineering-and-materials-science

Mechanical engineering is among the most diversified of the traditional engineering disciplines. The mechanical engineer builds machines to extend our physical and mental capabilities and to convert traditional and novel energy sources into useful forms.

The role of the mechanical engineer has changed dramatically over the past few decades with the extensive use of high-performance computers (in such areas as computational fluid dynamics, materials design, control, and manufacturing), the interfacing of microelectromechanical systems and actuators via microprocessors to build high-precision sensors and devices, and the advent of advanced materials (e.g., composites, shape-memory alloys, ceramics, and superconductors) for new applications (e.g., coatings, biomaterials, and computer storage). These areas offer mechanical engineering students special opportunities for creativity, demanding that they learn not only in depth but also in breadth. Demands for increased energy efficiency and reduced environmental impact—as might be realized, for example, in novel gas turbine or electric hybrid vehicles—require that students understand the fundamentals of mechanics, thermodynamics, fluid mechanics, combustion, and materials science. In all these tasks, the utmost consideration of the modern mechanical engineer is improving the quality of human life. The engineer must also be constantly aware both of the finiteness of Earth’s resources and its environment and of the burden that engineering places on them.

The educational mission of the Department of Mechanical Engineering and Materials Science is to provide an excellent education that will prepare students to become members of the next generation of mechanical engineers. To implement this mission, the department adheres to the following set of educational objectives: to provide a balanced technical and nontechnical education to enable graduates to enter highly selective graduate schools and/or to pursue technical careers in industry or government laboratories; to enable graduates to improve and adapt their skills to accommodate rapid technological changes; to prepare graduates to communicate effectively and to understand the ethical responsibilities and impact on society of their profession. To achieve these objectives, the following fundamental educational goals have been established for the Department of Mechanical Engineering and Materials Science: to provide a comprehensive introduction to basic science and mathematics, which form the foundation of mechanical engineering; to provide thorough training in analytical and experimental methods and in data analysis, including problem formulation; to provide instruction in the fundamentals of the design process, including project innovation, synthesis, and management, both individually and in a team setting; to provide both a technical and a nontechnical program of study in which oral and written communication skills are developed; and to instill in students an understanding of their professional and ethical responsibilities, which affect society and their profession.

COURSES FOR NONMAJORS

Mechanics and mechanical engineering content can be found in several courses intended for those not majoring in science. See under Engineering and Applied Science.

THE MECHANICAL ENGINEERING PROGRAM

At Yale, three mechanical engineering programs are offered: a B.S. degree program with a major in Mechanical Engineering, a B.S. degree program with a major in Engineering Sciences (Mechanical), and a B.A. degree program with a major in Engineering Sciences (Mechanical). Prospective majors in both B.S. programs are advised to complete introductory physics and mathematics through calculus (MATH 115) by the end of their first year.

A student’s undergraduate engineering program may include one or more special project courses (MENG 471, 472, 473, or 474), in which the student pursues a particular research interest through design-oriented projects and experimental investigations. Projects may be initiated by the student, may be performed in a team, or may be derived from the ideas of faculty members who place undergraduates in their ongoing research projects. All interested students should contact the director of undergraduate studies for more information on special project courses.

B.S. degree program in Mechanical Engineering This is the most technically intensive mechanical engineering degree program and is accredited by the Engineering Accreditation Commission of ABET, Inc. This program is appropriate for students who plan careers as practicing engineers in industry, consulting firms, or government as well as for students who are considering a career in research and plan to pursue an advanced degree in engineering.

B.S. degree program in Engineering Sciences (Mechanical) This non-ABET degree program is suitable for students who wish to gain significant expertise within mechanical engineering while combining their engineering studies with related disciplines. For example, a number of students have taken courses in architecture while pursuing a program in mechanical engineering that emphasizes structural mechanics; similarly, a student with an interest in computer graphics might combine engineering courses in computer-aided design with programming courses from the Department of Computer Science.

B.A. degree program in Engineering Sciences (Mechanical) In a society with increasing levels of technical sophistication, a well-rounded individual must have some background in science and technology. The non-ABET B.A. program is designed for students who may be planning careers in business, law, economics, medicine, journalism, or politics but need to understand the impact that science and technology can have on society at large. An understanding of engineering methods and practices, combined with a traditional liberal
arts education, provides a strong background for a variety of careers. The program is well suited for students who wish to fulfill the requirements of two majors.

The major for all three degree programs requires a group of prerequisites or equivalents; several courses beyond the prerequisites; and a senior requirement, as indicated below.

PREREQUISITES

B.S. degree program in Mechanical Engineering The prerequisites in mathematics are MATH 112, 115, and ENAS 151, or the equivalent. The basic science prerequisites are PHYS 180, 181, or 200, 201; one laboratory from PHYS 165L or 205L, and one from PHYS 166L or 206L, or equivalents.

B.S. degree program in Engineering Sciences (Mechanical) The prerequisites in mathematics are MATH 112, 115, and ENAS 151, or the equivalent. The basic science prerequisites are PHYS 180, 181, or 200, 201; one laboratory from PHYS 165L or 205L, and one from PHYS 166L, 206L, or MENG 286L.

B.A. degree program in Engineering Sciences (Mechanical) The prerequisites in mathematics are MATH 112 and 115. The basic science prerequisite is physics at least to the level of PHYS 170, 171.

REQUIREMENTS OF THE MAJOR

B.S. degree program in Mechanical Engineering

The major for the Class of 2019 and the Class of 2020 With DUS approval, the following changes to the requirements of the major may be fulfilled by students who declared their major under previous requirements.

The major for the Class of 2021 and subsequent classes requires 21 courses and 19.5 credits beyond the prerequisites as follows:

1. Advanced mathematics: ENAS 194 and MATH 222 or 225
2. Mechanical engineering and related: MENG 185, 211, 280, 285, 286L, MENG 325, 361, 363L, 383, 389, 390, MENG 487L and MENG 488L (the senior requirement), ENAS 130, EENG 200, and at least one lecture course in chemistry numbered CHEM 161 or higher
3. Technical electives: three approved technical electives chosen in consultation with the director of undergraduate studies; only one course from MENG 471, 472, 473, and 474 may be counted as one of the three technical electives

The curriculum in this program is arranged in prescribed patterns, but some departures from it are possible with approval of the DUS.

B.S. degree program in Engineering Sciences (Mechanical) The major requires twelve approved term courses in engineering, beyond the prerequisites and including the senior project, which can cover a broad array of topics within the subject provided that they contribute to a coherent program. Students should consult with the DUS at the beginning of their sophomore year.

B.A. degree program in Engineering Sciences (Mechanical) The program requires eight approved term courses beyond the prerequisites, including the senior project. Students should consult with the DUS at the beginning of their sophomore year.

Credit/D/Fail No courses taken Credit/D/Fail may be counted toward the Mechanical Engineering major, including prerequisites.

SENIOR REQUIREMENT

B.S. degree program in Mechanical Engineering

The major for the Class of 2019 and the Class of 2020 With DUS approval, the following change to the senior requirement may be fulfilled by students who declared their major under previous requirements.

The major for the Class of 2021 and subsequent classes MENG 487L (half-credit) and MENG 488L (half-credit) taken in the senior year fulfill the senior requirement.

B.S. degree program in Engineering Sciences (Mechanical) Students satisfy the senior project requirement by completing MENG 404; 471, 472, 473, or 474; 487L and 488L; 489; or another upper-level design course (taken during the senior year) chosen in consultation with the DUS.

B.A. degree program in Engineering Sciences (Mechanical) Students satisfy the senior project requirement by completing MENG 471, 472, 473, or 474; or another upper-level design course (taken during their senior year) chosen in consultation with the DUS.

REQUIREMENTS OF THE MAJOR

MECHANICAL ENGINEERING, B.S.

Prerequisites MATH 112, 115, and ENAS 151, or equivalent; PHYS 180, 181, or 200, 201, and 2 labs (1 from PHYS 165L or 205L, and 1 from PHYS 166L or 206L, or equivalents)

Number of courses 21 term courses beyond prerequisites (including senior req)

Specific courses required ENAS 130 and 194; EENG 200; MATH 222 or 225; MENG 185, 211, 280, 285, 286L, MENG 325, 361, 363L, 383, 389, 390
**Distribution of courses** 3 technical electives chosen in consultation with DUS (only one of MENG 471, 472, 473, or 474); 1 term course in chemistry numbered CHEM 161 or higher

**Substitution permitted** With DUS approval

**Senior requirement** MENG 487L and MENG 488L taken in senior year

**ENGINEERING SCIENCES (MECHANICAL), B.S.**

**Prerequisites** MATH 112, 115, and ENAS 151, or equivalent; PHYS 180, 181, or 200, 201, and 2 labs (1 from PHYS 165L or 205L; 1 from PHYS 166L, 206L, or MENG 286L)

**Number of courses** 12 term courses beyond prerequisites (incl senior project)

**Substitution permitted** With DUS approval

**Senior requirement** MENG 404; 471, 472, 473, or 474; 487L and 488L; 489; or another upper-level design course chosen in consultation with the DUS

**ENGINEERING SCIENCES (MECHANICAL), B.A.**

**Prerequisites** MATH 112, 115; PHYS 170, 171

**Number of courses** 8 term courses beyond prerequisites (incl senior req)

**Substitution permitted** With DUS approval

**Senior requirement** MENG 471, 472, 473, or 474; or another upper-level design course chosen in consultation with the DUS

**FACULTY OF THE DEPARTMENT OF MECHANICAL ENGINEERING AND MATERIALS SCIENCE**

**Professors** Charles Ahn, Ira Bernstein (Emeritus), Juan Fernández de la Mora, Alessandro Gomez, †Sohrab Ismail-Beigi, †Shun-Ichiro Karato, Marshall Long, Corey O’Hern, Brian Scassellati, Jan Schroers, Udo Schwarz (Chair), Mitchell Smooke

**Associate Professors** Aaron Dollar

**Assistant Professors** Eric Brown, Judy Cha, Rebecca Kramer-Bottiglio, Madhusudhan Venkadesan

**Lecturers** Beth Anne Bennett, Joseph Zinter

†A joint appointment with primary affiliation in another department or school.

**Courses**

**MENG 185a or b, Mechanical Design**  Staff

A course designed for potential majors in mechanical engineering, with units on design methodology, statics, mechanics of materials, and machining. Includes a design project. Prerequisite: physics at the level of PHYS 180, or permission of instructor. **SC**

**MENG 211b, Thermodynamics for Mechanical Engineers**  Jeeyoung Cha

Study of energy and its transformation and utilization. First and Second Laws for closed and open systems, equations of state, multicomponent nonreacting systems, auxiliary functions (H, A, G), and the chemical potential and conditions of equilibrium. Engineering devices such as power and refrigeration systems and their efficiencies. Prerequisites: PHYS 180 or 200, and MATH 115. **QP, SC RP**

**MENG 280a, Mechanical Engineering I: Strength and Deformation of Mechanical Elements**  Eric Brown

Elements of statics; mechanical behavior of materials; equilibrium equations, strains and displacements, and stress-strain relations. Elementary applications to trusses, bending of beams, pressure vessels, and torsion of bars. Prerequisites: PHYS 180 or 200, and MATH 115. **QP, SC RP**

**MENG 285a, Introduction to Materials Science**  Jan Schroers

Study of the atomic and microscopic origin of the properties of engineering materials: metals, glasses, polymers, ceramics, and composites. Phase diagrams; diffusion; rates of reaction; mechanisms of deformation, fracture, and strengthening; thermal and electrical conduction. Prerequisites: elementary calculus and background in basic mechanics (deformation, Hooke's law) and structure of atoms (orbitals, periodic table). **QP, SC RP**

**MENG 286Lb, Solid Mechanics and Materials Science Laboratory**  Jan Schroers

Experiments that involve either structural mechanics or materials science. Comparisons between structural theories and experimental results. Relationships among processing, microstructure, and properties in materials science. Introduction to techniques for the examination of the structure of materials. **SC RP ½ Course cr**

* **MENG 325a, Machine Elements and Manufacturing Processes**  Joran Booth

This course provides students a working knowledge of two fundamental topics related to mechanical design: machine elements and manufacturing processes. Machine elements refer one or more of a range of common design elements that transmit power and enable smooth and efficient motion in mechanical systems with moving parts. This course introduces the most common of these elements and gives students the tools to systems design with them. Topics include common linkages, gearing, bearings, springs, clutches, brakes, and common actuators such as DC motors. Manufacturing processes are necessary for the mechanical design engineer to effectively perform her or his duties; they provide an understanding of how the parts and systems that they design are fabricated, allowing “Design for Manufacturing” principles to be taken into account in the product development process. Students learn the basics of common commercial manufacturing processes for mechanical systems, including low-volume processes such as machining to high-volume processes such as
course is of interest to students studying thin-film growth, surface coatings, mechanical and chemical properties of surfaces, so forces between atoms and molecules. Part two generalizes these concepts to surface forces. Part three then gives a variety of examples. The determination of mechanical and chemical properties of surfaces. In the first part, we discuss the fundamental principles and concepts of achieve new or greatly altered material properties. The course provides an in-depth discussion of intermolecular and surface forces, which determine the mechanical and chemical properties of surfaces. Modern materials science often exploits the fact that atoms located at surfaces or in thin layers behave differently from bulk atoms to achieve new or greatly altered material properties. The course provides an in-depth discussion of intermolecular and surface forces, which determine the mechanical and chemical properties of surfaces. In the first part, we discuss the fundamental principles and concepts of forces between atoms and molecules. Part two generalizes these concepts to surface forces. Part three then gives a variety of examples. The course is of interest to students studying thin-film growth, surface coatings, mechanical and chemical properties of surfaces, soft matter
including biomembranes, and colloidal suspensions. Some knowledge of basic physics, mathematics, chemistry, and thermodynamics is expected.  

* MENG 469a, Aerodynamics  Juan Fernández de la Mora  
Review of fluid dynamics. Inviscid flows over airfoils; finite wing theory; viscous effects and boundary layer theory. Compressible aerodynamics: normal and oblique shock waves and expansion waves. Linearized compressible flows. Prerequisite: MENG 361 or permission of instructor.  

* MENG 471a and MENG 472b, Special Projects I  Joran Booth  
Faculty-supervised one- or two-person projects with emphasis on research (experiment, simulation, or theory), engineering design, or tutorial study. Students are expected to consult the course instructor, director of undergraduate studies, and/or appropriate faculty members to discuss ideas and suggestions for topics. Focus on development of professional skills such as writing abstracts, prospectuses, and technical reports as well as good practices for preparing posters and delivering presentations. Permission of adviser and director of undergraduate studies is required.  

* MENG 473a and MENG 474b, Special Projects II  Joran Booth  
Faculty-supervised one- or two-person projects with emphasis on research (experiment, simulation, or theory), engineering design, or tutorial study. Students are expected to consult the course instructor, director of undergraduate studies, and/or appropriate faculty members to discuss ideas and suggestions for topics. These courses may be taken at any time during the student’s career and may be taken more than once. Prerequisites: MENG 471 or 472; permission of adviser and director of undergraduate studies.  

MENG 487La / MENG 488Lb, Mechanical Design: Process and Implementation I  Aaron Dollar and Joran Booth  
This course is the first half of the capstone design sequence (students take MENG 488 in the spring semester of the same academic year) and is a unique opportunity to apply and demonstrate broad and detailed knowledge of engineering in a team effort to design, construct, and test a functioning engineering system. The lecture portion of the class provides guidance in planning and managing your project, as well other topics associated with engineering design. This course sequence requires quality design; analyses and experiments to support the design effort; and the fabrication and testing of the engineered system; as well as proper documentation and presentation of results to a technical audience. Prerequisites: MENG 280 and MENG 361. MENG 185 and MENG 325 are strongly suggested.  

½ Course cr  

MENG 488Lb / MENG 487La, Mechanical Design: Process and Implementation II  Joran Booth  
This course is the second half of the capstone design sequence (students take MENG 487 in the fall semester of the same academic year) and is a unique opportunity to apply and demonstrate broad and detailed knowledge of engineering in a team effort to design, construct, and test a functioning engineering system. The lecture portion of the class provides guidance in planning and managing your project, as well other topics associated with engineering design. This course sequence requires quality design; analyses and experiments to support the design effort; and the fabrication and testing of the engineered system; as well as proper documentation and presentation of results to a technical audience. Prerequisites: MENG 487, MENG 280, and MENG 361. MENG 185 and MENG 325 are strongly suggested.  

½ Course cr  

MENG 489a, Mechanical Design: Process and Implementation  Staff  
Study of the design process, including concept generation, project management, teamwork, detail design, and communication skills. Student teams implement a real-world design project with hardware objectives that can be achieved in a term, and a problem definition that allows room for creative solutions. Prerequisite: MENG 280, 361, or permission of instructor.  

SC  

RP