# Department of Mechanical Engineering

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Mechanical engineering includes all aspects of design, development, control, and manufacture of mechanical systems and energy conversion systems. Mechanical engineering is essential to the proper design and manufacture of nearly every physical product in our modern world. As such, mechanical engineers are a fundamental resource for most industries, and they work in interdisciplinary environments. Mechanical engineers must have the ability to see both broad perspectives across disciplines and industries, and solve very local and specialized problems. The undergraduate curriculum addresses the education and training of mechanical engineering students and concentrates on two technical areas: (1) design and analysis of thermofluid systems for effective use of energy; and (2) design, analysis, and control of mechanical systems including the use of materials. The Mechanical Engineering educational program develops future engineers with a solid understanding of fundamentals and competence in analyzing engineering systems.

The undergraduate Mechanical Engineering Program will educate students that can:

* Demonstrate their knowledge and depth of understanding of mechanical engineering in engineering practice and principles through professional success or attainment of advanced degrees.
* Design and development components, systems, tests, or services that meet specifications in the context of economic, environmental, and societal requirements.
* Develop engineering solutions based on fundamental principles using modern analysis techniques, testing, and validation.
* Work in a team environment, share their knowledge and expertise, and exercise leadership as appropriate.
* Communicate effectively with colleagues, customers, subordinates, and managers.
* Act ethically and professionally in their careers.
* Continue to learn and grow professionally.

## Requirements for the Major

In addition to fulfilling the undergraduate Core Curriculum requirements for the bachelor of science degree, students majoring in mechanical engineering must complete a minimum of 192 units and the following department requirements:

**English**

* ENGL 181

**Mathematics and Natural Science**

* MATH 11, 12, 13, 14
* AMTH 106 or MATH 22
* AMTH 118 or MATH 166
* CHEM 11/11L
* PHYS 31, 32, 33
* MECH 15/15L
* MECH 102 (required for students with an average GPA below 3.0 for MATH 13, MATH 14, AMTH 106) or an approved mathematics or natural science elective.

**Engineering**

* ENGR 1/1L
* CENG 41, 43/43L
* COEN 44/44L or MECH 45/45L
* ELEN 50/50L or PHYS 70
* MECH 10/10L, 11, 101L, 114, 115, 121, 122/122L, 123/123L, 125, 140, 141/141L, 142/142L, 160/160L, 194, 195, 196

**Technical Electives**

* 8 units of technical electives from approved upper-division or graduate engineering classes.

## Combined Bachelor of Science and Master of Science Program

The Department of Mechanical Engineering offers a combined degree program leading to the bachelor of science and a master of science open to mechanical engineering majors. Under the combined degree program, an undergraduate student begins taking courses required for a master’s degree before completing the requirements for the bachelor’s degree and can complete the requirements for a master of science in mechanical engineering at the end of the fifth year.

Undergraduate students admitted to the combined degree program may begin taking graduate classes during their senior year. They are required to enroll in the program between February of their junior year and December of their senior year. Students in this program will receive their bachelor’s degree after satisfying the standard undergraduate degree requirements. To earn the master of science degree, students must fulfill all the requirements for the degree, including the completion of 46 units of coursework beyond that applied to their bachelor’s degree and completion of thesis culminating experience. No course can be used to simultaneously satisfy requirements for both the bachelor’s degree and the master’s degree.

## Requirements for the Minor in Mechanical Engineering

Students must fulfill the following requirements for a minor in mechanical engineering:

**Lower-Division Requirements**

* COEN 44/44L or MECH 45/45L
* CENG 41
* ELEN 50/50L
* MECH 10/10L

**Lower-Division Electives**

Choose two courses from the following:

* MECH 11
* MECH 140
* CENG 43/43L
* MECH 15/15L

**Upper-Division Requirement**

* MECH 121

**Technical Sequence**

Choose one two-course sequence from the following:

* MECH 122/122L and MECH 123/123L
* MECH 122/122L and MECH 132
* MECH 114 and MECH 115
* MECH 141/141L and MECH 142/142L

Note: Please be aware of the prerequisites for the technical sequence courses; this may influence your choice of lower-division courses.

## Requirements for the Minor in Aerospace Engineering

All undergraduates are eligible for the Aerospace Engineering minor. Students intending to earn this minor should seek advice from the Mechanical Engineering Department. Students must fulfill the following requirements for a minor in aerospace engineering:

* Two courses from the Fundamental Courses list
* MECH 145 and one course from the Aerospace Courses list
* At least 4 units from the Elective Courses list

**Fundamental Courses**

* MECH 140 Dynamics (4 units)
* CENG 43 Materials III: Strength of Materials (4 units)
* MECH 121 Thermodynamics (4 units)
* MECH 122 Fluid Mechanics (4 units)

**Aerospace Courses**

* MECH 132 Aerodynamics (4 units)
* MECH 153 Aerospace Structures (4 units)
* MECH 155 Astrodynamics (4 units)
* MECH 158 Aerospace Propulsion Systems (4 units)

**Elective Courses**

* MECH 205/206 Aircraft Flight Dynamics I, II (4 units)
* MECH 220/221 Orbital Mechanics I, II (4 units)
* MECH 313 Aerospace Structures (4 units)
* MECH 371/372 Space Systems Design and Engineering I, II (8 units)
* MECH 431/432 Spacecraft Dynamics I, II (4 units)
* Another course from the Aerospace Courses list (4 units)

## Mechanical Engineering Laboratories

**Research Laboratories**

The Materials Research Laboratory supports interdisciplinary research efforts related to process-structure-property relations in engineering materials. Its principal activities focus on the characterization, quantitative analysis, and modeling of nano- and micro-structural evolution in materials during thermal and mechanical processing.

The Micro Scale Heat Transfer Laboratory (MSHTL) develops state-of-the-art and thermal transport in thin films experimentation in processes such as micro-boiling, spray cooling, and advanced electronic materials. Today, trends indicate that these processes are finding interesting applications on drop-on-demand delivery systems, inkjet technology and fast transient systems.

The Robotic Systems Laboratory is an interdisciplinary laboratory specializing in the design, control, and teleoperation of highly capable robotic systems for scientific discovery, technology validation, and engineering education. Laboratory students develop and operate systems that include spacecraft, underwater robots, aircraft, and land rovers. These projects serve as ideal testbeds for learning and conducting research in mechatronic system design, guidance and navigation, command and control systems, and human-machine interfaces.

**Undergraduate Laboratories**

The Computer-Aided Manufacturing (CAM) and Prototyping Laboratory consists of two machine shops and a prototyping area. One machine shop is dedicated to student use for University-directed design and research projects. The second is a teaching lab used for undergraduate and graduate instruction. Both are equipped with modern machine tools such as lathes and milling machines. The milling machines all have two-axis computer numerically controlled (CNC) capability. The teaching lab also houses both a three-axis CNC vertical machining center (VMC) and a CNC lathe. Commercial CAM software is available to aid programming of the computer controlled equipment. The prototyping area is equipped with a rapid prototyping system that utilizes fused deposition modeling (FDM) to create plastic prototypes from CAD-generated models. Also featured in this area is a LaserCAMM CNC laser cutting system for nonmetallic materials.

The Fluid Dynamics/Thermal Science Laboratory contains equipment to illustrate the principles of fluid flow and to familiarize students with hydraulic machines, refrigeration cycles, and their instrumentation. The lab also contains a subsonic wind tunnel equipped with a variable frequency axial flow to study aerodynamics.

The Heat Transfer Laboratory contains equipment to describe three modes of heat transfer. The temperature measurement of the extended surface system allows students to learn steady state conduction, and the pyrometer enables measurement of emitted power by radiation. The training systems for heat exchanger and refrigeration system are also placed in the lab.

The Instrumentation Laboratory contains seven computer stations equipped with state-of-the-art, PC-based data acquisition hardware and software systems. A variety of transducers and test experiments for making mechanical, thermal, and fluid measurements are part of this lab.

The Materials Laboratory contains equipment for metallography and optical examination of the microstructure of materials as well as instruments for mechanical properties characterization including tension, compression, hardness, and fatigue testing. The Materials Laboratory also has a tube furnace for heat treating at controlled heating rates.

The Vibrations and Control Systems Laboratory is equipped with two flexible test systems. One is capable of single- or multi-DOF modes, free or forced motion, and adjustable damping. The other is an inverted pendulum. Both systems can be controlled by a wide variety of control algorithms and are fully computer connected for data acquisition and control.

## Lower-Division Courses

### 10. Graphical Communication in Design

Introduction to the design process and graphical communications tools used by engineers. Documentation of design through freehand sketching and engineering drawings. Basic descriptive geometry. Computer-aided design as a design tool. Conceptual design projects presented in poster format. Corequisite: MECH 10L. (4 units)

### 10L. Graphical Communication in Design Laboratory

Laboratory for MECH 10. Corequisite: MECH 10. (1 unit)

### 11. Materials and Manufacturing Processes

The principles of manufacturing processes as related to materials properties, design, and production. A review of structures, properties, and manufacturing processes for main groups of engineering materials including metals and metallic alloys, polymers, and ceramics. Prerequisite: MECH 15. (4 units)

### 15. Introduction to Materials Science

Physical basis of the electrical, mechanical, optical, and thermal behavior of solids. Relations between atomic structure and physical properties. Prerequisite: CHEM 11. Corequisite: MECH 15L. (4 units)

### 15L. Introduction to Materials Science Laboratory

Laboratory for MECH 15. Corequisite: MECH 15. (1 unit)

### 45. Applied Programming in MATLAB

Computer programming in MATLAB, including: use of the development environment, m-files, and debugging; data structures; flow control, including loops, vectorization, and conditional statements; functions and variable scope; file input and output; plotting and visualization; selected topics in object-oriented programming. Applications to engineering problems including linear algebra and differential equations. Prerequisite: MATH 13. Co-requisite: MECH 45L

### 45L. Applied Programming in MATLAB Lab

Laboratory for MECH 45. Co-requisite: MECH 45

### 80. Solar Home Analysis and Design

Students will research technologies and design approaches relevant to solar powered homes. Topics may include capture and use of solar thermal energy, conversion of solar energy to electricity, and passive solar home design. Available and emerging technologies will be investigated, and analysis tools will be used to compare options. Other aspects of house design, such as windows, lighting, and appliance choice will also be examined, as well as architecture and system-level design. Successive offerings will build on the developed knowledge and expertise. Careful documentation will be stressed as well as optimizing the design within constraints. Course may be taken several times. (4 units)

## Upper-Division Courses

### 101L. Machining Laboratory

Practical experience with machine tools such as mills, lathes, band saws, etc. Basic training in safe and proper use of the equipment associated with simple mechanical projects. Laboratory. P/NP grading. Prerequisites: MECH 10 and senior standing. Corequisite: MECH 194. (1 unit)

### 102. Introduction to Mathematical Methods in Mechanical Engineering

The application of mathematical methods to the solution of practical engineering problems. A review of fundamental mathematical methods and calculus of a single variable, multivariable calculus, ordinary differential equations, numerical methods, and basics of linear algebra. (4 units)

### 114. Machine Design I

Analysis and design of mechanical systems for safe operation. Stress and deflection analysis. Failure theories for static loading and fatigue failure criteria. Team design projects begun. Formal conceptual design reports required. Prerequisites: MECH 10 and 15 and CENG 43. (4 units)

### 115. Machine Design II

Continuation of MECH 114. Treatment of basic machine elements (e.g., bolts, springs, gears, bearings). Design and analysis of machine elements for static and fatigue loading. Team design projects completed. Design prototypes and formal final report required. Prerequisite: MECH 114. (4 units)

### 120. Engineering Mathematics

Review of ordinary differential equations (ODEs) and Laplace transform, vector, calculus, linear algebra, orthogonal functions and Fourier series, partial differential equations (PDEs), and introduction to numerical solution of ODEs. Also listed as AMTH 120. Prerequisite: AMTH 106. (4 units)

### 121. Thermodynamics I

Definitions of work, heat, and energy. First and second laws of thermodynamics. Properties of pure substances. Application to fixed mass systems and control volumes. Irreversibility and availability. Prerequisite: PHYS 32. (4 units)

### 122. Fluid Mechanics

Fluid properties and definitions. Fluid statics, forces on submerged surfaces, manometry. Streamlines and conservation flow fields. Euler’s and Bernoulli’s equations. Mass, momentum, and energy analysis. Laminar and turbulent flows. Losses in pipes and ducts. Dimensional analysis and similitude. External flows. Prerequisite: MECH 121(may be taken concurrently). Corequisite: MECH 122L and MECH 140. (4 units)

### 122L. Fluid Mechanics Laboratory

Laboratory for MECH 122. Corequisite: MECH 122. (1 unit)

### 123. Heat Transfer

Introduction to the concepts of conduction, convection, and radiation heat transfer. Application of these concepts to engineering problems. Prerequisites: MECH 121, 122, and AMTH 118 or equivalent. Corequisite: MECH 123L. (4 units)

### 123L. Heat Transfer Laboratory

Laboratory work to understand the concept of heat transfer. Practical experience with temperature and heat flux measurement. Corequisite: MECH 123. (1 unit)

### 125. Thermal Systems Design

Analysis, design, and simulation of fluids and thermal engineering systems. Application of optimization techniques, life cycle, and sustainability concepts in these systems. Prerequisite: MECH 123. (4 units)

### 131. Thermodynamics II

Thermodynamic potential and availability, advanced power and refrigeration cycles, chemical equilibrium, advanced power and refrigeration cycles with non-reacting or reacting air/vapor mixture. Prerequisites: MECH 121. (4 units)

### 132. Aerodynamics

Fundamentals of aerodynamics. Governing equations (mass, momentum, energy). Inviscid, incompressible flow applied to subsonic air flow: Laplace’s equations and flow superposition, Kutta-Joukowski theorem and generation of lift. Incompressible flow over airfoils: Kutta condition, Kelvin circulation theorem. Lifting flow over arbitrary bodies. Incompressible flow over finite wings: downwash and induced drag. Introduction to fundamental principles of viscous flow and discussion of drag components. Prerequisites: MECH 121 and 122. (4 units)

### 140. Dynamics

Kinematics of particles in rectilinear and curvilinear motion. Kinetics of particles, Newton’s second law, energy and momentum methods. Systems of particles. Kinematics and kinetics of plane motion of rigid bodies, energy and momentum methods. Introduction to three-dimensional dynamics of rigid bodies. Prerequisite: CENG 41. Corequisite: AMTH 106. (4 units)

### 141. Mechanical Vibrations

Fundamentals of vibration, free and forced vibration of (undamped/damped) single degree and two-degree of freedom systems. Vibration under general forcing conditions. Determination of natural frequencies and mode shapes. Prerequisites: MECH 140 and AMTH 106. Corequisite: MECH 141L. (4 units)

### 141L. Mechanical Vibrations Laboratory

Laboratory for MECH 141. Corequisite: MECH 141. (1 unit)

### 142. Control Systems, Analysis, and Design

Introduction to system theory, transfer functions, and state space modeling of physical systems. Course topics include stability, analysis and design of PID, Lead/Lag, other forms of controllers in time and frequency domains, root locus, Bode diagrams, state space pole placement, and gain and phase margins. Prerequisite: MECH 141. Corequisite: MECH 142L. (4 units)

### 142L. Control Systems, Analysis, and Design Laboratory

Laboratory for MECH 142. Corequisite: MECH 142. (1 unit)

### 143. Mechatronics

Introduction to behavior, design, and integration of electromechanical components and systems. Review of appropriate electronic components/circuitry, mechanism configurations, and programming constructs. Use and integration of transducers, microcontrollers, and actuators. Also listed as ELEN 123 and COEN 123. Prerequisite: ELEN 50. Corequisite: MECH 143L. (4 units)

### 143L. Mechatronics Laboratory

Laboratory for MECH 143. Also listed as COEN 123L and ELEN 123L. Corequisite: MECH 143. (1 unit)

### 144. Smart Product Design

Design of innovative smart electromechanical devices and products. Topics include a review of the basics of mechanical, electrical, and software design and prototyping, and will emphasize the synthesis of functional systems that solve a customer need, that are developed in a team-based environment, and which are informed by the use of methodologies from the fields of systems engineering, concurrent design, and project/business management. Designs will be developed in the context of a cost-constrained business environment, and principles of accounting, marketing, and supply chain are addressed. Societal impacts of technical products and services are reviewed. Enrollment is controlled in order to have a class with students from diverse majors. Offered every other year. Prerequisites: Core Foundation-level natural science and mathematics, or equivalent; instructor permission required. Corequisite: MECH 144L. (4 units)

### 144L. Smart Product Design Laboratory

Laboratory for MECH 144. Corequisite: MECH 144. (1 unit)

### 145. Introduction to Aerospace Engineering

Basic design and analysis of atmospheric flight vehicles. Principles of aerodynamics, propulsion, structures and materials, flight dynamics, stability and control, mission analysis, and performance estimation. Introduction to orbital dynamics. Offered every other year. Prerequisites: MECH 122 and 140. Corequisite: MECH 121. (4 units)

### 146. Mechanism Design

Kinematic analysis and synthesis of planar mechanisms. Graphical synthesis of linkages and cams. Graphical and analytical techniques for the displacement, velocity, and acceleration analysis of mechanisms. Computer-aided design of mechanisms. Three or four individual mechanism design projects. Offered every other year. Prerequisite: MECH 114. (4 units)

### 151. Finite Element Theory and Applications

Basic introduction to finite elements; direct and variational basis for the governing equations; elements and interpolating functions. Applications to general field problems: elasticity, fluid mechanics, and heat transfer. Extensive use of software packages. Offered every other year. Prerequisites: COEN 44 or equivalent and AMTH 106. (3 units)

### 151L. Finite Element Theory and Applications Laboratory

Laboratory for MECH 151. Corequisite: MECH 151. (1 unit)

### 152. Composite Materials

Analysis of composite materials and structures. Calculation of properties and failure of composite laminates. Manufacturing considerations and design of simple composite structures. Knowledge of MATLAB or equivalent programming environment is required. Offered every other year. Prerequisites: MECH 15, CENG 43, and COEN 44 or MECH 45. (4 units)

### 153. Aerospace Structures

This introductory course presents the application of fundamental theories of elasticity and stress analysis to aerospace structures. Course topics include fundamentals of elasticity, virtual work and matrix methods, bending and buckling of thin plates, component load analysis, and airframe loads, torsion shear, and bending of thin-walled sections. Prerequisites: CENG 43 and 43L. (4 units)

### 155. Astrodynamics

This course provides the foundations of basic gravitation and orbital theory. Topics include Review of particle dynamics, classical orbital elements, basic transformation matrices, ground tracks, Hohmann transfer, coplanar rendezvous, combined change maneuver, and interplanetary fight. Prerequisite: MECH 140. (4 units)

### 156. Introduction to Nanotechnology

Introduction to the field of nanoscience and nanotechnology. Properties of nanomaterials and devices. Nanoelectronics: from silicon and beyond. Measurements of nanosystems. Applications and implications. Laboratory experience is an integral part of the course. Also listed as ELEN 156. Prerequisites: PHYS 33 and either PHYS 34 or MECH 15. Corequisite: MECH 156L. (4 units)

### 156L. Introduction to Nanotechnology Laboratory

Laboratory for MECH 156. Corequisite: MECH 156. (1 unit)

### 158. Aerospace Propulsion Systems

Fundamentals of air breathing and rocket jet propulsion. Gas dynamics fundamentals, review of thermodynamic relation. Basic theory of aircraft gas turbine engines, propulsive efficiency, and application of Brayton cycle to gas turbine engine analysis. Rocket engine nozzle configuration and design. Thrust Equation. Chemical rocket engine fundamentals. Solid versus liquid propellant rockets. Prerequisites: MECH 121 and 122. (4 units)

### 160. Modern Instrumentation for Engineers

Introduction to engineering instrumentation, sensors, electric circuits, computer data acquisition, hardware and software, sampling theory, statistics, and error analysis. Theory of pressure, temperature, acceleration, and strain measurement. Prerequisites: MECH 123 and 141. Corequisite: MECH 160L. (4 units)

### 160L. Modern Instrumentation for Engineers Laboratory

Laboratory work spans the disciplines of mechanical engineering: dynamics, controls, fluids, heat transfer, and thermodynamics, with emphasis on report writing. Students will design their own experiment and learn how to set up instrumentation using computer data acquisition hardware and software. Corequisite: MECH 160. (1 unit)

### 163. Materials Selection and Design

Design considerations in the use of materials; materials selection for optimizing multiple properties; materials failure modes and failure mechanism; materials selection to prevent failure; case studies and discussions on process economics, life-cycle thinking, and eco-design. CES EduPack will be introduced as a materials and processes database and a tool for students to compare, analyze, and select materials and processes. Prerequisites: MECH 11 and CENG 43. (4 units)

### 179. Satellite Operations Laboratory

This laboratory course reviews the physical principles and control techniques appropriate to communicating with, commanding, and monitoring spacecraft. Students learn to operate real satellite tracking, commanding, and telemetry systems, and to perform spacecraft-specific operations using approved procedures. Given the operational status of the system, students may conduct these operations on orbiting NASA spacecraft and interact with NASA scientists and engineers as part of operations processes. Instructor permission required. (1 unit)

### 188. Co-op Education

Practical experience in a planned program designed to give students practical work experience related to their academic field of study and career objectives. Satisfactory completion of the assignment includes preparation of a summary report on co-op activities. P/NP grading. May be taken for graduate credit. (2 units)

### 189. Co-op Technical Report

Credit given for a technical report on a specific activity such as a design or research project after completing the co-op assignment. Approval of department co-op advisor is required. Letter grades are based on content and presentation quality of report. Prerequisite: MECH 188. (2 units)

### 191. Mechanical Engineering Project Manufacturing

Laboratory course that provides supervised evening access to the machine shop and/or light fabrication area for qualified mechanical engineering students to work on their University-directed projects. Students wishing to utilize the machine shop or light fabrication during the evening lab/shop hours are required to enroll. Enrollment in any section allows students to attend any/all evening shop hours on a drop-in basis. Staff or faculty will be present during each scheduled meeting to supervise as well as be available for consultation and manufacturing advising. Prerequisites: Students must be qualified for machine shop use through successful completion of MECH 101L and passing grade on the Mechanical Engineering Lab Safety Test. Qualifications for light fabrication area use: successful completion of the Light Fabrication Training Seminar and a passing grade on the Mechanical Engineering Lab Safety Test. P/NP. (1 unit)

### 194. Advanced Design I: Tools

Design tools basic to all aspects of mechanical engineering, including design methodology, computer-design tools, simulation, engineering economics, and decision making. Senior design projects begun. Prerequisite: MECH 115. Corequisite: MECH 101L. (3 units)

### 195. Advanced Design II: Implementation

Implementation of design strategy. Detail design and fabrication of senior design projects. Quality control, testing and evaluation, standards and specifications, and human factors. Prerequisite: MECH 194. (4 units)

### 196. Advanced Design III: Completion and Evaluation

Design projects completed, assembled, tested, evaluated, and judged with opportunities for detailed re-evaluation by the designers. Formal public presentation of results. Final written report required. Prerequisite: MECH 195. (3 units)

### 198. Independent Study

By arrangement with faculty. (1–5 units)

### 199. Directed Research/Reading

Investigation of an engineering problem and writing an acceptable report. Meetings with faculty advisor required. Prerequisite: senior standing. (2–4 units)