# Department of Mechanical Engineering

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Mechanical Engineering applies the fields of physics, mathematics, and materials science to the design and realization of mechanical and thermal systems. For over a century mechanical engineers have played a central role in creating the infrastructure of modern society, while addressing the emerging interdisciplinary challenges of tomorrow. The undergraduate curriculum provides a rigorous theoretical foundation coupled with hands-on laboratories and projects. Mechanical engineering students have the opportunity to make real connections with faculty and work with them on cutting-edge research. Rooted in the Jesuit tradition, our curriculum challenges students to consider the moral, ethical, and social impacts of engineering, while supporting entrepreneurial thinking. Combined with the breadth of the core curriculum, the mechanical engineering program trains the whole person to create engineers of conscience, competence, and compassion.

The undergraduate Mechanical Engineering Program will educate students who:

* Become successful professionals, demonstrating their knowledge and depth of understanding of mechanical engineering in industry, or further academic studies.
* Develop ethical and innovative engineering solutions that meet our responsibilities to society and the environment, based on fundamental principles using modern analysis techniques, testing, and validation, and guided by the concepts of competence, conscience, and compassion.
* Work in a team environment, communicate effectively, share their knowledge and expertise, and exercise leadership as appropriate.
* Are dedicated to lifelong learning and personal growth for the betterment of society and to meet the challenges and obligations of tomorrow.

## 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
* MECH103/R
* AMTH 118 or MATH 166
* CHEM 11/11L
* PHYS 31, 32, 33
* MECH 15/15L

**Engineering**

* ENGR 1/1L
* CENG 41, 43/43L
* MECH 45/45L
* ELEN 50/50L or PHYS 70
* MECH 10L, 11, 12L, 101L, 114, 115, 121, 122/122L, 123/123L, 140, 141/141L, 142/142L, 160/160L, 194, 195, 196

**Technical Electives**

* 12 units of technical electives. This requirement may be satisfied by: (a) taking approved upper-division courses, (b) taking graduate courses with advisor approval, and/or (c) enrolling in MECH 199: Directed Research with a faculty advisor. Students may only satisfy up to 8 units of the technical elective requirement with MECH 199.

## 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**

* MECH 45/45L
* CENG 41
* ELEN 50/50L
* MECH 10L
* MECH 12L

**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.

The Energy System Design & Optimization Laboratory explores topics related to energy sustainability, including building energy system control via Internet-of-Things (IoT); renewable energy; energy storage materials and system optimization; energy harvesting and conversion; and transactive energy (smart grid). The overarching goal of the various projects in the lab is to reduce our reliance on fossil fuel for a sustainable future. The Lab is also interested in making an impact for people in emerging markets by providing sustainable and economically viable energy/water solutions: portable refrigerator for last mile delivery; clean cookstoves; and desalination.

The Theoretical and Computational Mechanics Laboratory explores emerging problems in fluid and solid mechanics, utilizing the tools of applied mathematics and numerical simulation. Research areas include low Reynolds number flow, microswimmers, biological flows and membranes, thin film mechanics, fracture simulation, auxetic metamaterials, and parallel computing.

**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 two, three-axis CNC vertical machining centers (VMC). 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 an Epilog Fusion Pro laser cutting/engraver system for nonmetallic materials.

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

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. Additionally, this lab 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 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 Laboratory is equipped with configurable torsional, rectilinear, and inverted pendulum test apparatuses (ECP Systems) allowing for exploration of both single and multiple degree-of-freedom forced and free vibration. In addition, the lab contains a portable laser doppler vibrometer (Polytec) to allow for non-contact measurement of vibration in continuous systems.

The Control Systems Laboratory is equipped with the Rotary Motion Platform, QUBE-Servo 2, Rotary Flexible Link, Ball and Beam, and Rotary Inverted Pendulum which are designed and manufactured by Quanser Company. All equipment works with the MATLAB/SIMULINK® environment and can be used to evaluate linear and nonlinear control algorithms.

## Lower-Division Courses

### 10L. Engineering Graphics and Computer-Aided Design I

An introduction to engineering graphics and computer-aided design (CAD) using a 3D solid modeling software package. Topics include geometric construction, sketching, orthographic projection, isometric, and sectional views. Drawing and CAD laboratory classes will consist of lectures and exercises, demonstrations, and student work sessions. (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)

### 12L. Engineering Graphics and Computer Aided Design II

Continuation of MECH 10L. An introduction to engineering graphics and computer-aided design (CAD) using a 3D solid modeling software package. Topics include dimensioning and tolerancing, descriptive geometry and auxiliary views, and assemblies. Drawing and CAD laboratory classes will consist of lectures and exercises, demonstrations, and student work sessions. Light machining will be introduced, as well. Prerequisite: MECH 10L, MECH students only. (1 unit)

### 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. (4 units)

### 45L. Applied Programming in MATLAB Lab

Laboratory for MECH 45. Co-requisite: MECH 45. (1 unit)

## 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 12L 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)

### 103. Mathematical Methods in Mechanical Engineering

Review of ordinary differential equations and Laplace transform; Fourier series; partial differential equations with applications to problems in vibration and heat conduction; and selected topics from linear algebra. Prerequisite: AMTH 106. Corequisite: MECH 103R. (4 units)

### 103R. Mathematical Methods in Mechanical Engineering Recitation

Recitation for MECH 103. Corequisite: MECH 103. (1 unit)

### 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 12L, 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)

### 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. Feedback Control Systems

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. Feedback Control Systems 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: MECH 45 and 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. 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. 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. 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. Prerequisites: MECH 45 or equivalent and AMTH 106. (3 units)

### 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. Prerequisites: MECH 15, CENG 43, and 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 flight. 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

Optional laboratory for MECH 156. (1 unit)

### 157. Engineering Simulations and Modeling

Simulation and modeling of solids and fluids using modern computational methods. Application of finite element modeling techniques to analyze mechanical systems subjected to various types of loading. Heat conduction and fluid interaction effects with solids. Transient problems including vibrations. Practical experience gained in using commercial simulation packages and interacting with CAD systems. Review of basic finite element theory with particular attention to modeling loads, constraints and materials. Prerequisites: CENG 43, MECH 122, MECH 123 (can be taken concurrently) or equivalent knowledge. (4 units)

### 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)

### 171. Special Topics in Material, Mechanics, Manufacturing, and Design

Technical Elective in the area of material, mechanics, manufacturing, and design. A new topic in the area will be introduced. Topics vary every time it is offered. (4 units)

### 172. Special Topics in Thermofluids and Energy

Technical Elective in the area of thermofluids and energy. A new topic in the area will be introduced. Topics vary every time it is offered. (4 units)

### 173. Special Topics in Dynamics, Controls, and Robotics

Technical Elective in the area of dynamics, controls, and robotics. A new topic in the area will be introduced. Topics vary every time it is offered. (4 units)

### 177. Continuum Mechanics

General introduction to the mechanics of continuous media. Topics include the kinematics of deformation, the concept of stress, and the balance laws for mass, momentum, and energy. This is followed by an introduction to constitutive theory with applications to established models for viscous fluids and elastic solids. Concepts are illustrated through the solution of tractable initial-boundary-value problems. Prerequisites: MECH 122, CENG 43, AMTH 106. (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 the 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)

### 193. Peer Educator in Mechanical Engineering

Peer Educators in Mechanical Engineering work closely with a faculty member to help students understand course material; think more deeply about course material; benefit from collaborative learning; feel less anxious about testing situations; and/or to help students enjoy learning. Enrollment is by permission of the instructor. P/NP. (1-2 units)

### 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. (4 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. (2 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. (2 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. Weekly meetings with faculty advisor are required. (1-4 units per quarter, for a total of up to 8 units can be considered as technical electives)