Department of Mechanical Engineering

Allen Robinson, David and Susan Coulter Head of Mechanical Engineering and Raymond J. Lane Distinguished University Professor of Mechanical Engineering

Location: Wean Hall 4216
www.cmu.edu/me (http://www.cmu.edu/me/)

General Overview
Mechanical engineers use their knowledge of mechanical systems to describe phenomena, propose solutions to problems, and build those solutions. Concerned with the principles of force, energy and motion, they use their knowledge of physical systems, design, manufacture, and operational processes to advance the world around us. Mechanical engineers work in a variety of sectors: small start-up companies, multinational corporations, government agencies, national laboratories, consulting firms, and universities.

The Carnegie Mellon Mechanical Engineering curriculum emphasizes engineering theory, hands-on experience, and technical skills. Our students learn how to solve practical problems and analyze situations by converting ideas into reliable and cost-effective devices and processes.

A strong foundation in mechanical engineering fundamentals culminates in a design capstone class where student teams develop prototypes for new products. These projects expose students to the design process, from concept to product, and emphasize effective communication and presentations skills.

Our curriculum is intended to allow ample opportunity for students to pursue areas of personal interest. A student may choose to pursue a minor offered by departments in other colleges, or one of the designated minor programs offered in the College of Engineering, or to pursue an additional major. Students are encouraged to participate in research with department faculty members, explore their chosen field through internships, and take advantage of opportunities to study abroad and be exposed to other cultures. Students may also choose to pursue the Integrated Master’s Bachelor’s Program (IMB) which allows students to earn both a bachelor’s and a master’s degree with an additional semester or year of study.

Mechanical Engineering students access TechSpark for hands-on projects in multiple courses. TechSpark is the cornerstone of the College of Engineering’s maker ecosystem, having an integrated set of resources where faculty and students create and develop new ideas, concepts, and products for technology innovation. The space houses a simulation cluster, 3D printers, laser machines, electronics stations, PCB fabrication, manual & CNC mills, metal welding, wood working & CNC Router, polymer composite fabrication, paint booth, and more to allow students, faculty, and staff to design and prototype in a multi-disciplinary environment.

Accreditation
The Mechanical Engineering Undergraduate Program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org (http://www.abet.org/).

Educational Objectives
According to ABET (http://www.abet.org/), which evaluates applied science, computing, engineering and technology programs for accreditation, program educational objectives are broad statements that describe what graduates are expected to attain within a few years of graduation.

The core objective of our undergraduate program is to provide our students an education that enables them to be productive, impactful, and fulfilled professionals throughout their careers. In light of this vision, the objectives of the Bachelor of Science in Mechanical Engineering at Carnegie Mellon are to produce graduates who:

- distinguish themselves as effective problem solvers by applying fundamentals of Mechanical Engineering.
- are innovative and resourceful in their professional activities.
- excel in multidisciplinary team settings.
- become leaders in their organizations, their profession, and in society.
- conduct themselves in a professional and ethical manner in the workplace
- excel in diverse career paths within and beyond the engineering profession, including in industry and academia.

Educational Outcomes
The undergraduate curriculum in the Department of Mechanical Engineering offers students significant opportunities to pursue directions of personal interest, including minors, double majors, participation in research projects, and study abroad. Design and teamwork experiences occur at regular intervals in the curriculum, and graduates have significant hands-on experience through laboratories and projects.

The faculty of the Department has endorsed the following set of skills, or outcomes that graduates of the program are expected to have:

- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
- an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, economic, and environmental factors.
- an ability to communicate effectively with a range of audiences.
- an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
- an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Curriculum
Minimum units required for B.S. in Mechanical Engineering: 382

The following template outlines the four-year B.S. program through the standard and recommended course sequence. To ensure that prerequisites are completed and to prevent scheduling conflicts, students should discuss any changes to this sequence with their department academic advisor. Students need a minimum of 382 units to complete the B.S. degree.

First Year
Fall
21-120 Differential and Integral Calculus 10
24-101 Fundamentals of Mechanical Engineering 12
33-141 Physics I for Engineering Students 12
99-101 Computing @ Carnegie Mellon 3
76-101 Interpretation and Argument 9

Units 46

Spring
21-122 Integration and Approximation 10
xx-xxx Second Introductory Engineering Course 12
xx-xxx Physics II/Chemistry/Computer Science * 10-12
xx-xxx General Education Course 9

Units 41-43

First Year Curriculum Notes:
1. During the first year, students complete 24-101 Fundamentals of Mechanical Engineering and one other introductory engineering course. 24-101 Fundamentals of Mechanical Engineering is a prerequisite for 24-251, 24-261, and 24-351. Students who are not able to take 24-101 in their first year, will push the 24-261 Mechanics I and 24-262 Mechanics II into their junior year. If 24-101 is taken in fall of sophomore year, students can take 24-251 Electronics for Sensing and Actuation and 24-351 Dynamics in sophomore spring.
2. All Mathematics courses (21-xxx or 24-282) required for the engineering degree must have a minimum grade of C in order to fulfill the graduation requirement for the BS engineering degree and to count as a prerequisite for engineering core classes.
3. Students must pass the following three courses before they begin the core Mechanical Engineering courses in the fall of their sophomore year:
   21-120 Differential and Integral Calculus
### Sophomore Year

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<td>21-254 / 24-282</td>
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<td>24-xxx</td>
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<td>24-370</td>
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**Physics II/Chemistry/Computer Science:**

- First year students are encouraged to prioritize completing Physics II and Chemistry requirement over programming in the first year.
- Students should complete Mechanics 2: 3D Design (new course - see description below).
- The Chemistry requirement can be met with one of the following options: 24-302 Mechanical Engineering Seminar I, 76-270 Writing for the Professions, 70-340 Business Communications, or 39-402 Leadership Development Seminar.

### Machine Shop/Engineering/Computer Science:

- The course number 24-360 or 24-351 is offered in the fall and spring.
New Course Descriptions

24-251 Electronics for Sensing and Actuation
Mechanical engineers design, build, and troubleshoot basic circuits that perform signal conditioning on sensor measurements and provide power amplification for actuation. This course covers the basics of passive circuit design, applications of operational amplifiers, and the use of transistors to amplify low-power signals coming from microcontrollers. Lecture materials are coupled with hands-on in-class exercises and homework assignments using the Arduino to interface with sensors and actuators.

24-261 Mechanics I: 2D Design
This is the first course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. In the first semester, students review and extend methods of 2D statics to study single and multiple bodies, such as structures and machines. Internal loads in 2D are defined and quantified, followed by a study of stresses and strains under axial loading, bending and shear. Students will also learn engineering design process methods and skills, including concept design, detailed design, analysis, fabrication, and testing. As topics are introduced and applied by students in hands-on assignments, they will compare theoretical computations and experimental testing of their design ideas, so as to reinforce fundamentals and practice the engineering design process.

24-262 Mechanics II: 3D Design
This is the second course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. In the second semester, students extend their foundation in 2D statics to the analysis of 3D engineering systems, including determination of reactions at connections and internal loads. Friction, shear stress, and shear strain are introduced, followed by a study of stresses and deformation in torsion. Multiaxial stresses, such as those occurring in combinations of torsion and bending or in pressure vessels, are studied. Stress transformations are introduced, as well as the formulation of simple failure criteria. Students will expand their engineering design skills through team-based hands-on and computational projects that utilize stress and failure analysis of 3D engineered systems. In addition, students will learn elementary aspects of machine design and catalog selection to support projects. Altogether, students will learn to express ideas in sketches, interpret and create engineering drawings, model detailed shapes with CAD tools, analyze product performance with CAE tools, choose materials and manufacturing schemes, and create and test prototypes.

24-370 Mechanical Design: Methods and Applications
This is the third course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. Building on the principles and design methodology introduced in the first two courses, this course consists of a detailed study of typical loading conditions and resulting stresses and deflections in commonly used machine elements, such as shafts, gears, power screws, fasteners, brakes/couplings, flywheels, and bearings, and best practices in their design and application. Machine design against static and dynamic failure will be considered with focus on the effect of material properties, manufacturability, and cost considerations. Students will also learn the connections between theory and analytical methods, available computational tools, and field design. Learning objectives will be assessed through homework, class exams, and the conduct of the group projects.

Mechanical Engineering Technical Electives

Students must take at least one approved non-core Mechanical Engineering course labeled as “Mechanical Engineering Technical Elective” in the example course sequence. The course must be an approved 24-xxx course (9-credit minimum) at the 300 level or above to fulfill the technical elective requirement. 24-291 Environmental Systems on a Changing Planet and 24-292 Renewable Energy Engineering are the only 200 level courses that may be used as a Mechanical Engineering Technical Elective.

Students can also take mechanical engineering graduate courses to fulfill the technical elective requirement. However, students must have the appropriate prerequisites and the instructor must approve taking the course. Undergraduates do not have priority for graduate level courses. Students can find a list of graduate courses we offer on the Carnegie Mellon Schedule of Classes https://enr-apps.as.cmu.edu/open/SOC/SOCServlet (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet). Course offerings are variable, please check the Schedule of Classes (above) to see the most current list of classes.

Students cannot use research or project courses to fulfill the technical elective requirement. However, these courses, with limitations, will count as free elective units. Up to 27 units of project/research may be counted in the free electives. Project/research courses that do not fulfill the technical elective requirements are:

- 24-391/ 24-392 Mechanical Engineering Project
- 24-491/ 24-492 Department Research Honors
- 39-xxx CIT series courses

Free Electives

A Free Elective is defined as any graded course offered by any academic unit of the university (including research institutes such as the Robotics Institute (http://www.ri.cmu.edu) and the Software Engineering Institute (http://www.sei.cmu.edu)). Free electives offer students the opportunity to add additional majors and minors, pursue additional interests or deepen their experience in Mechanical Engineering. Typically, once the core requirements are completed, there remain about 45 units of free electives to reach the minimum of 382 to complete the degree.

Up to 9 units of Student Taught Courses (StuCo) and Physical Education courses, or other courses taken as Pass/Fail, may also be used toward Free Electives.

Guidance on Engineering Electives

The Mechanical Engineering department offers several elective courses for undergraduates seeking further knowledge and experience in specialty areas of mechanical engineering. These courses (with approval) can fulfill for your Mechanical Engineering Technical Elective, Free Electives, and/or additional major or minor requirements.

Robotics and Automation

Fundamental Courses
- 24-356 Introduction to Vibrations with Applications
- 24-451 Feedback Control Systems
- 24-677 Special Topics: Linear Control Systems
- 24-760 Special Topics: Robot Dynamics and Analysis
- 24-773 Multivariable Linear Control
- 24-776 Non Linear Control

Application Courses
- 24-614 Microelectromechanical Systems
- 24-671 Electromechanical Systems Design
- 24-673 Soft Robots: Mechanics, Design and Modeling
- 24-753 Special Topics: Robotic Materials: Designs, Principles & Mechanics
- 24-774 Special Topics: Advanced Control Systems Integration
- 24-775 Special Topics: Robot Design and Experimentation
- 24-778 Mechatronic Design

Energy, Environment, and Thermal Fluid Systems

Fundamental Courses
- 24-711 Fluid Dynamics
- 24-718 Computational Fluid Dynamics
- 24-721 Advanced Thermodynamics
- 24-722 Energy System Modeling
- 24-730 Advanced Heat Transfer

Application Courses
- 24-292 Renewable Energy Engineering
- 24-421 Internal Combustion Engines
- 24-425 Combustion and Air Pollution Control
- 24-428 Computational Analysis of Transport Phenomena
- 24-623 Molecular Simulation of Materials
- 24-626 Air Quality Engineering
- 24-628 Energy Transport and Conversion at the Nanoscale
- 24-629 Direct Solar and Thermal Energy Conversion
- 24-631 Thermal Design
- 24-643 Energy Storage Materials and Systems

Product Design and Development

Fundamental Courses
- 24-651 Materials Selection for Mechanical Engineers
Autonomous Systems and Machine Learning

Fundamental Courses
24-451 Feedback Control Systems 12
24-480 Special Topics: Artificial Intelligence and Machine Learning for Engineering 9
24-677 Special Topics: Linear Control Systems 12
24-704 Probability and Estimation Methods for Engineering Systems 12
24-786 Special Topics: Bayesian Machine Learning for Scientists and Engineers 12
24-787 Machine Learning and Artificial Intelligence for Engineers 12
24-789 Special Topics: Deep Learning for Engineers 12

Application Courses
24-774 Special Topics: Advanced Control Systems Integration 12
24-775 Special Topics: Robot Design and Experimentation 12
24-784 Special Topics: Trustworthy AI Autonomy 12

Computational Engineering

Fundamental Courses
24-780 Engineering Computation 12
24-783 Advanced Engineering Computation 12
24-785 Engineering Optimization 12

Application Courses
24-658 Image-Based Computational Modeling and Analysis 12
24-681 Computer-Aided Design 12
24-718 Computational Fluid Dynamics 12
24-755 Finite Elements in Mechanics I 12
24-781 Engineering Computation Project 12

Engineering Mechanisms and Materials

Fundamental Courses
24-634 Structural Design 12
24-635 Structural Analysis 9
24-652 Mechanical Behavior of Engineering Materials 12
24-653 Special Topics: Materials and Their Processing 12
24-751 Introduction to Solid Mechanics I 12

Application Courses
24-643 Energy Storage Materials and Systems 12
24-650 Applied Finite Element Analysis 12
24-751 Introduction to Solid Mechanics I 12
24-684 Special Topics: Nanoscale Manufacturing Using Structural DNA Nanotechnology 12
24-755 Finite Elements in Mechanics I 12
24-753 Special Topics: Robotic Materials: Designs, Principles & Mechanics 12

Quality Point Average Requirements
To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.00 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student’s final transcript will be calculated based on all grades in all courses taken, including freshman year. The Mechanical Engineering Department requires that students attain a quality point average of 2.00 or higher for all required Mechanical Engineering core courses.

Pursuant to university rules, students can repeat a course in which a grade below C was attained in order to achieve the QPA requirement. When a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student’s QPA. For all required Mechanical Engineering core courses, the highest grade obtained between the original and the repeated class will be used to calculate the Mechanical Engineering QPA.

Credit Overload Policy
Mechanical Engineering students can register for a maximum of 54 units per semester. A student can request additional units from the Undergraduate Education Committee based on their QPA. The policy is outlined in the Mechanical Engineering Undergraduate Handbook (https://www.mech.engineering.cmu.edu/education/undergraduate-education/undergraduate-handbooks.html).

Double Majors and Minors
Mechanical Engineering students may pursue double majors and minors in a variety of subjects, taking advantage of the free elective courses to satisfy the requirements for the major or minor. The College of Engineering has added designated minors to promote flexibility and diversity among engineering students. Common double majors for Mechanical Engineering students include Engineering and Public Policy, Biomedical Engineering and Robotics.

A complete description of majors and minors in engineering can be found on the College of Engineering website (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/majors-minors.html).

Internships and Co-operative Education Program
The Mechanical Engineering Department considers experiential learning opportunities important educational options for its undergraduate students. Students in Mechanical Engineering are encouraged to undertake professional internships during summer breaks.

Another option is cooperative education, which provides a student with an extended period of exposure with a company. All co-ops must be at least 6 consecutive months in length, and must be a full-time, paid position with a single company.

Study Abroad
In today’s global society, a study abroad experience can be an integral part of an undergraduate engineering education. An academic experience abroad is encouraged and assistance is provided for course choices and curriculum sequencing. The Mechanical Engineering department offers scholarships for international experiences to support and encourage students to take advantage of study and work abroad experiences.

Integrated Master's/Bachelor's Program (IMB)
Interested undergraduates may plan a course of study that leads to both the Bachelor's and Master's in Mechanical Engineering. Beyond eight semesters, at least one semester of full-time graduate student status is required. Please refer to the Integrated Master's/Bachelor's Degree Program section in the most recent Master of Science in Mechanical Engineering Handbook (https://www.mech.engineering.cmu.edu/education/graduate-programs/handbooks.html) for additional information.

Full-Time Faculty
AMIR BARATI FARIMANI, Assistant Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2018-
MARK BEDIOLLION, Teaching Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016–

SARAH BERGMBREAT, Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2018–

JACK LEE BEUTH, Professor of Mechanical Engineering - Ph.D., Harvard University; Carnegie Mellon, 1992–

JONATHAN CAGAN, George Tallman and Florence Barrett Ladd Professor of Engineering - Ph.D., University of California at Berkeley; Carnegie Mellon, 1990–

MAARTEN P. DE BOER, Professor of Mechanical Engineering - Ph.D., University of Minnesota; Carnegie Mellon, 2007–

ESTEFANIA GOMEZ, Special Faculty of Mechanical Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–

NOELIA GRANDE GUTIERREZ, Assistant Professor of Mechanical Engineering - Ph.D., Stanford University; Carnegie Mellon, 2021–

DIANA HAIDAR, Assistant Teaching Professor of Mechanical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 2017–

ENI HALILAJ, Assistant Professor of Mechanical Engineering – Ph.D., Brown University; Carnegie Mellon, 2018–

AARON M. JOHNSON, Assistant Professor of Mechanical Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2016–

LEVENT BURAK KARA, Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2007–


SHAWN LITSTER, Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2008–

CARMEL MAJIDI, Clarence H. Adamson Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2011–

JONATHAN A. MALEN, Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2009–

CHRISTOPHER MCCOMB, Associate Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–

ALAN J.H. MCGAUGHEY, Trustee Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

JEREMY J. MICHALEK, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

O. BURAK OZDOGANLAR, Ver Planck Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–

RAHUL PANAT, Russell V. Trader Career Development Associate Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2017–

SNEHA PRABHA NARRA, Assistant Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–

ALBERT PRESTO, Research Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2012–

YOED RABIN, Professor of Mechanical Engineering – D.Sc., Technion-Israel Institute of Technology; Carnegie Mellon, 2000–

ALLEN L. ROBINSON, David and Susan Coulter Head of Mechanical Engineering; Raymond J. Lane Distinguished University Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1998–

EDWARD STEPHEN RUBIN, Alumni Chair Professor of Environmental Engineering and Science – Ph.D., Stanford University; Carnegie Mellon, 1969–

SHENG SHEN, Professor of Mechanical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2011–

KENJI SHIMADA, Theodore Ahrens Professor of Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1996–

SATBIR SINGH, Teaching Professor of Mechanical Engineering – Ph.D., University of Wisconsin at Madison; Carnegie Mellon, 2012–

PAUL S. STEIF, Associate Department Head and Professor of Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1983–