Mechanical Engineering

Chair

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Undergraduate major: mechanical engineering (BSE)

Graduate degrees: MS in mechanical engineering; PhD in mechanical engineering

Faculty: https://engineering.uiowa.edu/me-people

Website: https://engineering.uiowa.edu/me

The Department of Mechanical Engineering offers distinct undergraduate and graduate degrees and research programs in mechanical engineering. It also is the administrative home of the undergraduate Certificate in Naval Science and Technology and the undergraduate and graduate Certificates in Artificial Intelligence, Modeling and Simulation in Engineering.

Mechanical engineering is broadly concerned with the energy, manufacturing, and design of machines. Mechanical engineers conceive, plan, design, and direct the manufacture, distribution, and operation of a wide variety of devices, machines, and systems—including complex human-machine systems—for energy conversion, biofuel production, environmental control, materials processing, transportation, materials handling, and other purposes. Major subspecialties of mechanical engineering include thermal-fluids engineering and mechanical systems engineering.

Thermal-fluid phenomena occur in many engineering systems and devices such as aircraft; automobiles; off-road vehicles; ships; gas turbines; heat exchangers; material processes; heating, ventilating, air-conditioning, and refrigerating systems; hydraulic and wind turbines; airbag inflators; fuel cells; biofuel processes; environmental control devices; and biomedical systems.

Machines and mechanical systems are the foundations of human technology. Mechanical systems are found in mechanical engineering systems and devices such as manufacturing equipment, medical equipment, ground vehicles, heavy equipment, farm equipment, aircraft, ships, home appliances, packaging machinery, wind turbine blades and gearboxes, robots, and biomedical systems.

Mechanical engineers find a wide variety of career opportunities in industry, government, and education. Mechanical engineers form an integral part of most industries, including aerospace firms, energy companies, automobile manufacturers, health care providers, food- and metal-processing industries, petroleum refineries, electronic and computer manufacturers, heavy construction and agricultural vehicle manufacturers, wind turbine manufacturers, thermal comfort equipment firms, farm equipment firms, and consulting companies.

Certificates

Artificial Intelligence, Modeling and Simulation in Engineering

The Department of Mechanical Engineering offers the undergraduate and graduate certificate programs in Artificial Intelligence, Modeling and Simulation in Engineering; see Artificial Intelligence, Modeling and Simulation in Engineering in the catalog.

Naval Science and Technology

The Department of Mechanical Engineering offers the undergraduate certificate program in Naval Science and Technology; see the Certificate in Naval Science and Technology in the catalog.

Programs

Undergraduate Program of Study

Major

- Major in Mechanical Engineering (Bachelor of Science in Engineering)

Graduate Programs of Study

- Master of Science in Mechanical Engineering
- Doctor of Philosophy in Mechanical Engineering

Facilities

Undergraduate Instruction

Departmental Instructional Facilities

The Department of Mechanical Engineering maintains six laboratories for undergraduate student learning, which consist of the Advanced Manufacturing Laboratory; the Control, Automation, and Robotics Laboratory; the Engineering Manufacturing Laboratory; the Ralph and Barbara Stephens Experimental Engineering Laboratory; the Laboratory for Machine Intelligence (under development); and two design project laboratories developed to facilitate collaboration on senior design projects and communication with project sponsors.

Advanced Manufacturing Laboratory

The Advanced Manufacturing (AM) Laboratory supports the elective mechanical engineering undergraduate course ME:4116 Manufacturing Processes Simulations and Automation. The laboratory includes a variety of machine tools and instruments for students to practice nontraditional material processes and controls. Facilities and instrumentation include a three-axis CNC laser cutter (Bodor laser), an ultrasonic metal seam welder (Branson), an ultrasonic metal spot welder (Branson), and a 25-programmable logic controller (Divelbiss). The facility uses the latest software technology, such as Abaqus, MATLAB, and EZ Ladder.

Control, Automation, and Robotics Laboratory

The Control, Automation, and Robotics (CAR) Laboratory is located in the Seamans Center for the Engineering Arts and Sciences and is managed by the Department of Mechanical Engineering. It provides students with experience in advanced control, robotics, and autonomous systems. The lab is equipped with one industrial 6-axis robotic arm, two Kuka mobile robots (KMR iiwa and KMP) with collaborative robotic arms, a desktop computer, two Roboception cameras, one co-act and one suction gripper, and four Quanser rotary servo base units. The facility has the latest software technology, such as LabVIEW and KUKA.Sim. The Quanser units are used in the laboratory assignments in ME:3600 Control of

Mechanical Engineering Systems, while the robotic systems are used in ME:4140 Modern Robotics and Automation. In fall 2019, two control laboratories were developed based on two Quanser base units. The control laboratories were developed and tested in CAR and set up to accommodate a large class size. Later, two additional base units and three accessory modules were purchased to expand the control laboratories. In addition, the robotics systems are used in ME:4111 Scientific Computing and Machine Learning and ME:4150 Artificial Intelligence in Engineering to assist in the instruction of relevant course materials. The CAR laboratory is also used by students who have permission to work in the lab on honors and research projects.

Design Project Laboratories

The department also maintains two design project laboratories to support student teamwork on capstone design projects: the Design Lab and the MEDP/PEDE room. The Design Lab supports students taking the ME:4086 Mechanical Engineering Design Project and ME:4186 Enhanced Design Experience sequence in the Program for Enhanced Design Experience (PEDE) and Virtual International Project Teams (VIPT), whereas the MEDP/PEDE room is occupied by students completing the single-semester ME:4086 Mechanical Engineering Design Project (MEDP) course, as well as for PEDE and VIPT students. The Design Lab contains four workstations with large monitors for collaborative design and analysis activities, as well as tables and chairs for group discussions. An integrated teleconferencing room is enclosed with glass windows so students can communicate with project sponsors. The teleconferencing room contains a 4K LED smart TV connected to a desktop computer, as well as a video camera, microphone, speaker, and speakerphone for video conferencing and phone calls. The MEDP/PEDE room contains six computer workstations with four large computer monitors and two large TV monitors. There are four additional tables without workstations, two mobile whiteboards, and a sofa and mobile chairs for project design and collaborative activities.

Engineering Manufacturing Laboratory

The Engineering Manufacturing Laboratory is located in the Seamans Center for the Engineering Arts and Sciences. The laboratory provides students with experience in advanced CAD/CAM systems. It is managed by the Department of Mechanical Engineering and the Department of Industrial and Systems Engineering. The lab is equipped with three-axis CNC mills (Haas and Tormach), a CNC router (Techno-CNC), a CNC lathe (Haas), a drill press, a plastic injection molder, thermoforming machine, a band saw, a disc sander, a bench grinder, polishing wheel, hand drill, sandblasting cabinet, a press, and a three-in-one shear/break/roll machine. The facility has the latest software technology, such as Creo Parametric and Rhinoceros 4.0. The machinery is used in laboratory assignments in ME:2300 Manufacturing Processes. The room is extensively used near the end of each semester for the course project. It is also used by students who have permission to work in the lab on their honors and research projects.

Ralph and Barbara Stephens Experimental Engineering Laboratory

The Ralph and Barbara Stephens Experimental Engineering Laboratory supports required mechanical engineering undergraduate courses ME:3351 Engineering Instrumentation and ME:4080 Experimental Engineering.

Laboratory for Machine Intelligence

The Laboratory for Machine Intelligence provides an interactive environment for students to develop knowledge and skills in the design and use of smart and autonomous systems. Data analysis, control, and artificial intelligence concepts are integrated with innovative mechatronic systems through hands-on active learning. The lab is designed to empower students with the skills and theoretical tools needed to design, develop, and optimize intelligent machines capable of engaging in a broad range of tasks and complex environments. Systems to be studied in this lab include legged robots as well as land, air, and marine vehicles, non-locomotor machines, and medical assistive devices.

Collegiate Instructional Facilities

Fluid Mechanics Laboratories

The College of Engineering and IIHR—Hydroscience and Engineering have a long history of excellence in fluid mechanics education dating back to the 1920s, when IIHR developed the fluids laboratory as a hands-on learning environment for fluids-related disciplines within the College of Engineering. The long success of the institute's education program is due in large part to a new curriculum emphasizing scientific principles rather than merely practice in manipulating equipment.

IIHR is now modernized, expanded, and was relocated to the laboratory facilities, which were distributed throughout IIHR research facilities at the south end of the campus to the new Seamans Center Annex, where it occupies a 3,300 square foot laboratory suite. The laboratory suite comprises three distinct but connected laboratory spaces. The Fluids Fundamentals Laboratory houses experiments that directly support formal laboratory instruction in College of Engineering courses. Through the lab-development project, existing experimental facilities were modernized, refurbished, and installed, and additional experiments were developed. The laboratory has a large, reconfigurable open space in which different experiments and furnishings can be set up to support a variety of instructional activities.

The Fluids Workshop is the venue through which students can advance to independent and inquiry-driven, course-related, and extracurricular projects. The lab also supports the activities of College of Engineering student organizations. Advanced measurement instrumentation, computational hardware, and resources for developing experiments are available to students in the lab. Tables around the perimeter of the room contain additional PCs and Linux workstations for numerical computations, data analysis, and visualization.

The Advanced Measurements Laboratory houses major facilities supporting both instructional and inquiry-driven student activities. It contains three facilities that have been upgraded and relocated through this project: the vertical wind tunnel, the visualization water channel, and a towing tank whose functionality has been expanded to also serve as an open channel flume. The laboratory, which is also designed to facilitate the safe use of laser-based instrumentation, is located behind the two front laboratories and is accessible from both rooms.

The fluids laboratories support formal laboratory activities for several courses taken by students in the biomedical, civil and environmental, and mechanical engineering departments, including ENGR:2510 Fluid Mechanics, CEE:3371 Principles of Hydraulics and Hydrology, CEE:5380 Fluid Flows in

Environmental Systems, ME:4125 Biomimetic Fluid Dynamics, and ME:4176 Experimental Naval Hydrodynamics.

Additionally, it has been used as a resource in many other courses, including BME:4920 Biomedical Engineering Senior Design II, ECE:4890 Electrical and Computer Engineering Senior Design 2, ME:4080 Experimental Engineering, ME:4086 Mechanical Engineering Design Project, ME:4098 Individual Investigations: Mechanical Engineering, and ME:4186 Enhanced Design Experience.

Graduate Facilities

Fluid Mechanics

The program in fluid mechanics is conducted in close collaboration with IIHR—Hydroscience and Engineering. The equipment available to graduate students includes several wind tunnels and hydraulic flumes, an environmental flow facility, a towing tank, two special low-temperature flow facilities for the investigation of ice phenomena, hot-wire and laser anemometer systems, particle-image velocimetry systems, and computer-based data acquisition systems. Facilities available in the department include a flow visualization and imaging system with a charge-coupled devices (CCD) camera and a low-speed wind tunnel. IIHR and College of Engineering shops provide the necessary support. In addition to using in-house workstations and computers, the department's faculty members and students make extensive use of supercomputers at national centers.

Mechanical Systems

Computer-based simulation research activities in the mechanical systems area are carried out mainly in the Iowa Technology Institute. It maintains a variety of high-performance computer systems in support of its technology research and development efforts. General computing services are supported by a number of Linux and Windows application servers connected to centralized file servers. Computer-aided design/computer-aided engineering (CAD/CAE), software development, virtual prototyping, and virtual environment development applications are hosted on numerous high-performance workstations. Standard desktop, multimedia, and office productivity applications are hosted on a network of more than 40 workstations.

Thermal Sciences

Facilities for research in the thermal sciences and systems consist of a low-pressure combustion chamber, a high-pressure continuous flow combustion chamber, a high-pressure chamber for atomization study, a test rig for heat transfer to near supercritical fluids, a diffusion flame test rig, an enclosed laminar flame test rig, air atomization spray apparatus, test stands for melting and solidification studies, various optical measurement systems, and two fuel cell test rigs. Laser-based diagnostics (e.g., laser-induced fluorescence, imaging, and laser Doppler anemometry) are available for solidification, turbulent flow, heat transfer, and combustion studies. Flow visualization and imaging by CCD camera are available for the study of complex fluid motion, heat convection, and combustion flows.

Courses

Mechanical Engineering Courses

ME:2020 Mechanical Engineering Program Seminar **0 s.h.**
Introduction to the mechanical engineering profession and curriculum; ethics and professionalism in classroom and workplace; mentorship program and professional societies; visits to laboratories and local companies.

ME:2200 Introduction to Mechanical Engineering Design **2 s.h.**
Solid modeling, assemblies, drawings, and Geometric Dimensioning and Tolerancing (GD&T); basic engineering design process; introduction to engineering standards, product liability, and ethics. Prerequisites: ENGR:1100.

ME:2300 Manufacturing Processes **3 s.h.**
Study of fundamental manufacturing processes used in engineering practice. Topics include machining, casting, forming, joining, additive manufacturing, and more. Emphasis on the relationships between material properties, manufacturing process selection, and product quality. Introduction to process planning, metrology, and basic computer-aided manufacturing (CAM) concepts. Corequisites: ENGR:2720 and (ME:2200 or BME:2710).

ME:3045 Heat Transfer **3 s.h.**
Principles of heat transfer by conduction, convection, radiation; analytical and numerical methods of solution; applications to engineering problems. Prerequisites: MATH:3550 and ENGR:2510 and ENGR:1300.

ME:3052 Mechanical Systems **4 s.h.**
Topics in mechanical behavior and failure of materials; materials selection in design; stress and deflection analysis; static failure theories; fatigue and durability in design; fracture, statistical, and reliability considerations; introduction to finite element analysis using commercial software packages; standards, product liability, engineering ethics. Prerequisites: ENGR:2750. Corequisites: ENGR:2720 and ME:2300 and STAT:2020.

ME:3091 Professional Seminar: Mechanical Engineering **0 s.h.**
Professional aspects of mechanical engineering: presentations, student/faculty interaction, professional society involvement, panel discussions, plant trip. Prerequisites: ME:2020.

ME:3351 Engineering Instrumentation **2 s.h.**
Basic elements of measuring circuits (bridges, voltage dividers, shunts, transformers); laboratory instrumentation (oscilloscopes, multimeters, power supplies, signal generators); amplifiers; frequency response principles; sensors; data acquisition, signal processing, filtering using Labview. Prerequisites: PHYS:1612 and ENGR:2120.

ME:3600 Control of Mechanical Engineering Systems **3 s.h.**
Introduction to fundamental control theory and robot manipulators. Prerequisites: MATH:2560 and ENGR:2710.

ME:4024 Product Design and Realization 3 s.h.
Design principles and methods to develop 3D part models and assemblies; emphasis on use of mechanical engineering design principles and functional requirements through the complete design process using PTC Creo Parametric; for students with a basic knowledge of computer-aided design (CAD). Prerequisites: ME:2200 or ME:2300. Corequisites: ENGR:2750.

ME:4048 Energy Systems Design 4 s.h.
Principles and design of energy conversion systems, including solar, wind, and geothermal power systems; design of thermal-fluid system components, modeling and simulation of systems, optimization techniques; design projects. Prerequisites: ME:3045.

ME:4055 Mechanical Systems Design 3 s.h.
Kinematics of mechanisms, dynamics and vibration of machines, cam and gear, machine elements, computer-aided analysis of machines. Prerequisites: ENGR:2710 and ME:3052.

ME:4080 Experimental Engineering 4 s.h.
Principles of physical measurements; standards calibration, estimation of error; static and dynamic performance of measuring systems; laboratory experience, experiment planning, report writing. Prerequisites: ME:3351 and ME:3045 and ME:3052.

ME:4086 Mechanical Engineering Design Project 3 s.h.
Application of mechanical, thermal, fluid systems design; student or team design projects initiated at various levels in the design process and carried through to higher levels; emphasis on synthesis, written and oral communication. Corequisites: ME:4048 or ME:4055.

ME:4098 Individual Investigations: Mechanical Engineering arr.
Individual projects for mechanical engineering undergraduate students; laboratory study; engineering design project; analysis, synthesis, simulation of an engineering system; computer software development, research.

ME:4110 Computer-Aided Engineering 3 s.h.
Computational engineering modeling and simulation, geometric modeling, grid generation, finite-element and finite-volume methods, uncertainty analysis, optimization, engineering applications. Prerequisites: ENGR:2750. Corequisites: ME:3052. Same as CEE:4515.

ME:4111 Scientific Computing and Machine Learning 3 s.h.
Numerical methods in scientific computing; root problems and optimization; linear algebraic equations; eigenvalue problems; numerical differentiation and integration; interpolation and curve-fitting; initial value and boundary value problems; machine learning in regression, classification, and clustering problems; Python programming and packages. Prerequisites: MATH:2560. Same as CEE:4511.

ME:4112 Engineering Design Optimization 3 s.h.
Engineering design projects involving modeling, formulation, and analysis using optimization concepts and principles; linear and nonlinear models, optimality conditions, numerical methods. Prerequisites: ENGR:2110 and MATH:2550. Requirements: junior standing. Same as CEE:4512.

ME:4116 Manufacturing Processes Simulations and Automation 3 s.h.
Material processing, metal cutting theories, forming, micro/nano fabrication, programmable logic controller, computer numerical controllers, discrete control system, DC and AC servo motors, Command generation. Prerequisites: ME:2300 or ISE:2360. Same as ISE:4116.

ME:4117 Finite Element Analysis 3 s.h.
Trusses and frames; Rayleigh-Ritz methods; 2D and 3D elasticity problems; heat transfer, thermo-mechanical coupling; transient problems; use of commercial software for applications in analysis and design of mechanical engineering systems. Prerequisites: ENGR:2750.

ME:4120 Advanced Linear Control Systems 3 s.h.
Overview of system modelling and classical control design tools and methods, and bridges those with state-space approach for analysis and control of linear systems in the time domain; topics include linearization, root locus, Bode diagrams, Nyquist criteria, robustness margins, lead-lag compensators, observability and controllability, state-space realizations, internal stability and input-output stability, pole-placement, observers and reduced order observers, separation principle, performance limitations, linear quadratic regulator and its guaranteed margins, and optimal estimation. Prerequisites: ME:3600.

ME:4125 Biomimetic Fluid Dynamics 3 s.h.
Study and development of engineered systems that mimic the structure and function of biological systems; overview of the fluid dynamic principles that govern locomotion by swimming or flapping flight; equations of motion, fundamentals of aerodynamics; analytical models of force generation for swimming and flight; parameters governing effective locomotion; experimental and numerical studies to understand the present state of the art, challenges, and important questions. Prerequisites: ENGR:2510.

ME:4140 Modern Robotics and Automation 3 s.h.
Introduction to basics of robotics and automation; mechanical design development and manufacturing of smart and automated devices, components, and systems; principles of robotic motion and kinematics; introduction to process automation through system requirement identification, equipment integration, sensors, actuation, and logical control; fundamentals of design, analysis, and manufacturing to meet functionality requirements of products, devices, and systems using the principles of mechatronics to develop smart and automated products. Prerequisites: ENGR:2710.

ME:4145 Industrial Internet of Things (IIoT) 3 s.h.
Introduction to process automation through system requirement identification, equipment integration, sensors, actuation, and logical control; fundamentals of design, analysis, and manufacturing to meet functionality requirements of products, devices, and systems using principles of mechatronics to develop smart and automated products; integration of advanced networking and monitoring into device control and automaton. Corequisites: ME:3351.

ME:4150 Artificial Intelligence in Engineering 3 s.h.
Artificial intelligence, computational intelligence, data science and engineering, machine intelligence, digital manufacturing and design, intelligent machining, fault diagnosis, autonomy, robotics; applications in mechanical engineering. Prerequisites: ME:4111.

ME:4153 Fundamentals of Vibrations 3 s.h.
Vibration of linear discrete and continuous mechanical and structural systems; harmonic, periodic, and arbitrary excitation; modal analysis; applications. Prerequisites: ENGR:2750. Same as CEE:4532.

ME:4160 Engines and Power Plants 3 s.h.
Fundamental principles of thermodynamics applied to areas of particular interest in mechanical engineering; power plants and refrigeration cycles, internal combustion engine cycles, gas mixtures and combustion, mixing processes and pollutant formation, and hybrid power systems. Prerequisites: ENGR:2130.

ME:4176 Experimental Naval Hydrodynamics 3 s.h.
Introduction to experimental methods for measurement of propeller thrust performance and resistance of surface vessels and underwater marine craft; present and expand on fundamental concepts related to fluid mechanics, measurement methods, and uncertainty analysis in a context that focuses on naval science and technology challenges; students work with models of relevant vessels and propellers in a dedicated towing tank facility. Prerequisites: ENGR:2510.

ME:4186 Enhanced Design Experience 2-3 s.h.
Experience working in teams on industry-sponsored design and product development projects scheduled for production; emphasis on practical experience with the complete design process, from conceptualization through prototyping, evaluation, testing, and production; written and oral communication. Prerequisites: ME:4086.

ME:4200 Modern Engineering Materials for Mechanical Design 3 s.h.
Overview of design approaches for different engineering materials (i.e., metals, polymers, ceramics); topics include manufacturing processes, smart and advanced functionalities for applications in emerging engineering fields, theoretical models describing mechanical behavior, failure mechanisms, and design criteria; introduction to composite materials; computer lab activities focus on finite element method (FEM) simulations of materials with different mechanical properties. Prerequisites: ME:3052.

ME:4235 Health Monitoring of Structural and Mechanical Systems 3 s.h.
Structural analysis, vibration analysis, experimental modal analysis, health monitoring, damage detection, measurements, and physical and numerical testing of structural and mechanical systems. Prerequisites: ENGR:2750. Same as BME:4135, CEE:4135.

ME:5113 Mathematical Methods in Engineering 3 s.h.
Linear ordinary differential equations, series solutions of differential equations, special functions, Laplace transforms, Fourier series, matrices, linear systems, eigenvalue problems, second-order partial differential equations. Prerequisites: MATH:2550 and MATH:2560. Same as CBE:5140, CEE:5513.

ME:5114 Nonlinear Control in Robotic Systems 3 s.h.
Nonlinear analysis and control systems theory; focus on Lyapunov-based analysis methods and associated design techniques; introduction to definitions of stability for autonomous and nonautonomous systems leading to a Lyapunov framework, and based on the developed Lyapunov-based analysis tools, basic and advanced design tools for contemporary engineering problems are presented, including state-of-the-art techniques. Prerequisites: ME:3600 or ME:4120 or CBE:4105 or ECE:3600.

ME:5120 Vehicle System Dynamics 3 s.h.
Introduction to principles and basic procedures used in analysis of vehicle system dynamics and design; topics include tire mechanics, longitudinal and cornering tire force characteristics, steady-state and transient vehicle cornering responses, vehicle stability control, ride comfort, suspension design, off-road vehicle mobility, tire-soil interaction, and vehicle performance evaluations. Prerequisites: ENGR:2710.

ME:5125 Hand-Built Robot: Mechatronics and Machine Learning for Mobile Robots 3 s.h.
Process of building, programming, and training a mobile robotic arm with computer vision and machine learning techniques for object identification and sorting in an unstructured environment; integration of hands-on activities involving hardware, control, communication, and software layers through the Roboto Operating System (ROS); implementation on commercial robotic systems using two Unitree legged robots (quadruped and humanoid); competition to autonomously collect and sort items; use of Linux and Python. Prerequisites: ME:3600.

ME:5143 Computational Fluid and Thermal Engineering 3 s.h.
Governing equations of fluid flow and heat transfer; basic numerical techniques for solution of the governing equations; estimation of accuracy and stability of the approximations; boundary conditions; grid generation; applications to flows and heat transfer in engineering systems; familiarity with software for analysis and design of thermo-fluids systems. Prerequisites: ME:3045.

ME:5145 Intermediate Heat Transfer 3 s.h.
Steady and unsteady conduction; forced and natural convection; surface and gaseous radiation; condensation and evaporation; analytical and numerical methods and applications. Prerequisites: ME:3045.

ME:5149 Propulsion Engineering 3 s.h.
Opportunity to develop basic understanding and knowledge of rocket and airbreathing propulsion systems; relevant terminology and analysis techniques, parameteric cycle analysis for ideal engines, off-design analysis methods, problem-solving methodology. Prerequisites: ENGR:2130. Requirements: graduate standing.

ME:5150 Intermediate Mechanics of Deformable Bodies 3 s.h.
Application of equilibrium analyses, strain-displacement relations, and constitutive relationships to practical structural systems and elementary plane elasticity problems. Prerequisites: ENGR:2750. Same as CEE:5540.

ME:5154 Intermediate Kinematics and Dynamics 3 s.h.
Kinematic and dynamic analysis of mechanical systems; computational kinematics, Lagrangian dynamics, principle of virtual work in dynamics, constrained dynamics, spatial dynamics. Prerequisites: ENGR:2710.

ME:5159 Fracture Mechanics 3 s.h.
Three-dimensional stress states, definition and criteria for failure, nominal and local yield phenomena, linear elastic and elastic plastic fracture mechanics, plane stress and plane strain fracture toughness, J-Integral, crack opening displacement, environmental assisted cracking, fatigue crack growth, fail safe, and damage tolerant design. Prerequisites: ENGR:2750. Corequisites: ME:3052. Same as CEE:5549.

ME:5160 Intermediate Mechanics of Fluids 3 s.h.
Basic concepts and definitions; pressure distribution in a fluid; governing equations and boundary conditions; integral and differential analysis; dimensional analysis and similarity; experimental analysis; laminar and turbulent internal and external flows; potential flows; engineering applications. Prerequisites: ENGR:2510. Same as CEE:5369.

ME:5167 Composite Materials 3 s.h.
Mechanical behavior of composite materials and their engineering applications; composite constituents (fibers, particles, matrices) and their properties and behavior; macromechanical behavior of composite laminae; micromechanical predictions of composite overall properties; classical lamination theory; composite beams and plates. Prerequisites: ENGR:2750. Same as CEE:5137.

ME:5170 Data-Driven Analysis in Engineering Mechanics 3 s.h.
Exposure to machine learning approach of problem solving; modular course structure containing four or five modules, each concentrating on a particular class of problem; theories and techniques relevant to a class of problems taught in corresponding module. Prerequisites: ENGR:2750 and ME:4111.

ME:5179 Continuum Mechanics arr.
Mechanics of continuous media; kinematics of deformation, concepts of stress and strain; conservation laws of mass, momentum and energy; constitutive theories; boundary and initial value problems. Prerequisites: ENGR:2750 or ENGR:2510. Same as CEE:5179.

ME:5195 Contemporary Topics in Mechanical Engineering arr.
New topics in fluid and thermal sciences and mechanical systems not covered in other courses; topic and coverage determined by student/faculty interest. Requirements: junior standing.

ME:5210 Intermediate Thermodynamics 3 s.h.
Fundamental principles of thermodynamics as applied to phase equilibrium; properties of fluids, first and second law, variable composition systems, behavior of real fluids, mathematical techniques for solution thermodynamics. Requirements: CBE:3105 or ME:4160 or graduate standing. Same as CBE:5110.

ME:5300 Uncertainty Quantification and Design Optimization 3 s.h.
Analytical and computational methods for uncertainty quantification for a design optimization of mechanical and structural systems; brief review of probability theory, second-moment analysis, reliability analysis, robust design optimization, and reliability-based design optimization; use of commercially available software suites. Prerequisites: ENGR:2750 and STAT:2020. Corequisites: ME:3052.

ME:6115 Cooperative Autonomous Systems 3 s.h.
How to enable ground, marine, and aerial robotic platforms to perform cooperative tasks autonomously in complex real-world environments; theoretical topics include numerical approximation, optimal control, nonlinear analysis and control, game theory, and graph theory; project-based activities in a laboratory environment; focus on design and implementation of motion planning, tracking, collision avoidance, and cooperative control algorithms for autonomous vehicles. Prerequisites: ME:3600 or ME:4120 or CBE:4105 or ECE:3600.

ME:6120 Mechatronics, Measurement, and Wearable Robotics 3 s.h.
From accelerometers in phones, heart rate monitors in watches, fitness trackers, and smart clothing to robotic surgery and assistive devices, wearable sensors and robotics are increasingly all around us; introduction to different sensors, signals, and processing techniques needed to study movement; practical applications and scientific principles of sensors and actuators; work with real-world data; development of key research skills in literature review and experiment design through theoretical, programming, and hands-on coursework, presentations, and projects. Prerequisites: ME:3351 and ME:3600 and ME:5154.

ME:6130 Novel Artificial Muscles and Sensors for Evolving Robotics 3 s.h.
Overview of novel smart materials-based actuators (i.e., artificial muscles) and sensors used in modern robotics (i.e., soft robotics, bio-inspired robotics, assistive robotics); evolution from conventional actuators/sensors to novel actuators/sensors based on smart, flexible, and compliant materials; working mechanism, theoretical models, manufacturing, and applications for each type of artificial muscle/sensor; lab demonstrations and activities involve manufacturing and testing of some artificial muscles and smart sensors.

ME:6191 Graduate Seminar: Mechanical Engineering 1 s.h.
Presentation and discussion of recent advances and research in mechanical engineering by guest lecturers, faculty, students.

ME:6198 Individual Investigations: Mechanical Engineering arr.
Individual project in mechanical engineering, for department graduate students; laboratory study, engineering design project, analysis and simulation of an engineering system, computer software development, research.

ME:6199 Research: Mechanical Engineering MS Thesis arr.
Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for MS with thesis in mechanical engineering.

ME:6214 Analytical Methods in Mechanical Systems 3 s.h.
Vector and function spaces; functionals and operators in Hilbert spaces; calculus of variations and functional analysis with application to mechanics; Ritz and Galerkin methods. Prerequisites: ME:5113. Same as CEE:6310.

ME:6215 Finite Element II 3 s.h.
Computer implementation; plate and shell elements; mixed and hybrid formulations; nonlinear analysis; recent development; introduction to boundary element method. Prerequisites: CEE:4533. Same as CEE:6532, IGPI:6216.

ME:6216 Laser Materials Processing 3 s.h.
Proficient engineering background involved in laser processing and manufacturing; fundamentals and operation principles for various types of laser systems, laser optics, principles of laser-matter interactions, laser-induced thermal and thermo-mechanical effects; emerging areas of laser applications (e.g., microscale and nanoscale laser processing, ultrafast laser processing) and related energy transport analyses; video demonstrations. Prerequisites: ME:3045 and MATH:3550.

ME:6217 Advanced Modeling and Simulation for Manufacturing 3 s.h.
How materials often behave in a complicated manner involving deeply coupled effects among stress/stain, temperature, and microstructure during a manufacturing process; modeling and prediction of material processes based on a metallo-thermomechanical coupled analysis; focus on heat transfer modeling in material processes, fundamental mechanics aspects required for material processing analysis, and microstructural evolution modeling in material processes. Prerequisites: CEE:4533 and ME:3045.

ME:6240 Probabilistic Inference and Estimation for Mechanical Systems 3 s.h.
Theory and application of common techniques for probabilistic inference and estimation including types of estimators; Bayesian, Kalman, and Particle filtering; various motion and measurement models; and algorithms for simultaneous localization and mapping (SLAM). Prerequisites: ME:4120. Requirements: some level of exposure to probability and statistics, linear algebra, and 3D rigid body dynamics.

ME:6255 Multiscale Computational Science and Engineering 3 s.h.
Computational science and engineering methods at different spatial and temporal scales; molecular methods, including quantum mechanical calculation, molecular dynamics, and Monte Carlo methods; continuum methods, including finite element, peridynamics, and mesh-free particle methods; hierarchical and concurrent multiscale modeling; reinforcement learning methods and their applications; agent-based modeling; quantum computing and quantum algorithms; and artificial intelligence-assisted modeling and simulations. Prerequisites: ME:4117.

ME:6260 Viscous Flow 3 s.h.
Equations of viscous flow; classical analytical and numerical solutions; flow regimes and approximations; laminar boundary layers—equations, solution methods, applications; stability theory and transition; incompressible turbulent flow—mean-flow and Reynolds-stress equations, modeling, turbulent boundary layers and free shear flows. Requirements: for ME:6260—ME:5160; for CEE:6376—CEE:5369. Same as CEE:6376.

ME:6261 Multibody System Dynamics 3 s.h.
Introduction to principles of analytical and computational dynamics for rigid and flexible multibody systems; spatial kinematics and dynamics of rigid body systems, numerical solution procedures for multibody dynamics analysis, and flexible multibody dynamics. Prerequisites: ME:5154.

ME:6262 Inviscid Flow 3 s.h.
Derivation of governing equations for fluid flow; general theorems for motion of inviscid, incompressible flows; solution techniques for two- and three-dimensional irrotational flows; forces and moments acting on immersed bodies; vortex kinematics and dynamics; steady and unsteady aerodynamic theory. Prerequisites: ME:5160.

ME:6263 Compressible Flow arr.
Compressible flow behavior; 1D unsteady flow and appropriate use of x-t diagrams; 2D flows and use of the method of characteristics; Burgers' Equation and its properties.

ME:6278 Nonlinear Elasticity 3 s.h.
Nonlinear elasticity theory; modern applications in biomechanics; vectors and tensors, constitutive theory of elastic material, some exact solutions of boundary value problems, inverse deformation relations, stability of elastic material, theories of tissue adaptive response. Prerequisites: ME:5150. Requirements: elementary linear elasticity.

ME:6280 Optical Measurement Techniques in Experimental Fluid Dynamics 3 s.h.
Fundamental principles and applications for fluid dynamics; designing and performing measurements like particle image velocimetry (PIV), addressing challenges such as in vivo measurements and turbulent wall-shear stress, and discussing dvanced 3D techniques (e.g., Tomo-PIV, 4D-PTV). Prerequisites: ME:4080 and ME:5160.

ME:6320 Fluid-Structure Interactions 3 s.h.
Foundations of fluid-structure interactions (FSI) with focus on hydro-electric responses of flexible structures in dense fluids; structural dynamics and fluid dynamics are too often characterized as distinct disciples and this dichotomous mindset fails to recognize the important effects that dynamics fluid loads exert upon structural vibrations and vice-versa; students are equipped with knowledge to approach modern FSI problems; foundations of theoretical FSI, experimental methods, and computational approaches. Prerequisites: (ME:5160 or ME:4125) and (ME:4153 or ME:5154).

ME:6330 Thermo-Mechanics: Physics and Modeling of Materials Under Extreme Conditions 3 s.h.
Presentation of the physics of matter under extreme pressure, temperature, and stress, driven by increasing interest in supersonic and hypersonic flight, re-entry dynamics, energy delivery, propulsion, and nuclear technologies; understanding of why material behavior in these regimes is essential for engineering next-generation systems; from a physics and chemistry perspective, extreme conditions enable far-from-equilibrium material states that require understanding phenomena all the way from subatomic to macro-scales; connection of atomistic mechanisms to meso- and continuum-scale responses, emphasizing multiscale simulation. Prerequisites: ME:5160 and ME:5145 and ME:5150 and ME:5113.

ME:6725 Microfabrication and Thin Film Materials 3 s.h.
Microfabrication and nanofabrication techniques and thin film materials growth as foundations of modern electronic and optoelectronic devices; introduction to fabrication techniques, physics, and chemistry; growth and properties of thin film materials upon which fabrication is performed; hands-on experience with cleanroom processes; review of materials science, vacuum technology, micro- and nano-device structures, thin film deposition, plasma etching, patterning, characterization, and film nucleation, growth, structure, and properties. Prerequisites: (PHYS:2704 or ENGR:2130 or CHEM:1120) and (MATH:1560 or MATH:1860) and (PHYS:1612 or PHYS:2703) and CHEM:1110. Recommendations: background in thermal and statistical physics, introductory quantum mechanics, and introductory chemistry. Same as ECE:6725, PHYS:6725.

ME:7248 Combustion Theory 3 s.h.
Laminar flame theory; turbulent combustion; spray combustion; thermal ignition; pollutant formation, oxidation; combustion diagnostics. Prerequisites: ME:5145 and ME:5160.

ME:7250 Advanced Fracture Mechanics 3 s.h.
Fracture of modern engineering materials; linear-elastic fracture; computational methods; functionally graded materials; elastic-plastic fracture; multiscale fracture and fatigue crack initiation. Prerequisites: ME:5113 and (ME:5159 or CEE:4533). Same as CEE:7250.

ME:7256 Modern Nonlinear Finite Element Methods: Mechanics, Computation, and Differentiable Implementation 3 s.h.
Nonlinear finite element methods (FEM) for solid mechanics, emphasizing continuum theory, variational formulation, element technology, Newton-based solution algorithms, and differentiable implementations in automatic differentiation framework; perspective to enable gradient-based inverse analysis, uncertainty quantification, design optimization, and integration with machine learning workflows; rigorous understanding of nonlinear mechanics and practical experience constructing FEM solvers that are fully differentiable and extendable. Prerequisites: ME:5113 and CEE:4533.

ME:7257 Probabilistic Mechanics and Reliability 3 s.h.
Stochastic and reliability analysis of mechanical systems; computational methods for structural reliability; random eigenvalue problem; random field and stochastic finite element methods. Prerequisites: CEE:4533 and ME:5113.

ME:7266 Interfacial Flows and Transport Processes 3 s.h.
Physics of fluid interfaces and numerical techniques to simulate interface dynamics; interfacial flow coupled with thermal-fluid transport, from molecular interactions to continuum approximations; development of computer code segments to track and represent interface-flow interactions. Prerequisites: ME:5145 and ME:5160.

ME:7268 Turbulent Flows 3 s.h.
Origin; need for modeling, averages, Reynolds equations, statistical description; experimental methods and analysis; turbulence modeling; free shear layers and boundary layers; complex shearflows; development of computational strategies; recent literature on theory and applications, chaos phenomena. Prerequisites: ME:5160.

ME:7269 Computational Fluid Dynamics and Heat Transfer 3 s.h.
Development of numerical and algebraic approximations for elliptic, parabolic, hyperbolic partial differential equations; finite-volume, spectral, pseudo-spectral, Galerkin techniques; stability of numerical methods; CFL condition; stiff problems; adaptive grid generation and boundary-fitted coordinates; numerical solutions for one- and two-dimensional compressible and incompressible fluid flow and heat transfer problems. Prerequisites: ME:4111 and ME:5160.

ME:7299 Research: Mechanical Engineering PhD Dissertation arr.
Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for PhD in mechanical engineering.