Mechanical Engineering

Chair
• Ching-Long Lin

Undergraduate major: mechanical engineering (B.S.E.)
Graduate degrees: M.S. in mechanical engineering; Ph.D. in mechanical engineering
Faculty: https://me.engineering.uiowa.edu/people
Website: https://me.engineering.uiowa.edu

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 Hydrodynamics.

Mechanical engineering is broadly concerned with 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

Naval Hydrodynamics
The Department of Mechanical Engineering offers the undergraduate certificate program in Naval Hydrodynamics; see the Certificate in Naval Hydrodynamics in the Catalog.

Related Certificate: Transportation Studies
The Transportation Studies Program offers the Certificate in Transportation Studies. The program focuses on the varied and complex problems of transportation and on interdisciplinary approaches to addressing them. The Departments of Civil and Environmental Engineering, Industrial and Systems Engineering, Mechanical Engineering (College of Engineering), Economics (Tippie College of Business), and the School of Urban and Regional Planning (Graduate College) participate in the program.

The certificate is coordinated by the School of Urban and Regional Planning; see the Certificate in Transportation Studies in the Catalog.

Programs

Undergraduate Program of Study
Major
• Major in Mechanical Engineering (Bachelor of Science in Engineering)

Graduate Programs of Study
Majors
• Master of Science in Mechanical Engineering
• Doctor of Philosophy in Mechanical Engineering

Facilities

Undergraduate Instruction

Engineering Core
The laboratories for fluid flows and transport processes contain a wind tunnel; a water flume; a water table; four water channels with porous media; three air-jet tables; various air, water, and oil flow devices; and facilities for numerous small-scale experiments to demonstrate the principles of mass, momentum, and energy transfer.

For information about laboratories affiliated with core courses coordinated by other College of Engineering departments, see the departments' Catalog sections.

Computational Fluids Laboratory
The Computational Fluids Laboratory is equipped with 20 computers running ANSYS Fluent software used in fluid mechanics courses.

Control Automation Robotics Laboratory
The new Control Automation Robotics (CAR) Laboratory has a KUKA KR 6 and a KUKA KMR iiwa omniMove robotics. Students who are interested in learning how to program and control an industrial robot can enroll in ME:4113 Control of Mechanical Engineering Systems. Modern Robotics and Automation (ME:4140) is another course that uses the CAR lab.

Design Project Laboratory
The Design Project Laboratory supports all senior design project courses. It is equipped with eight mid-level workstations as well as a high-end workstation, which enables students to manipulate full design models and interactive Cisco Webex sessions with companies using the analysis software during the session. Research versions of ANSYS Fluent and ProE, standard computers, and videoconferencing facilities also are available.
Fluids Laboratories
The fluid laboratories comprise a trio of rooms. The Fluids Fundamentals Lab includes recently built equipment and ones that have been around for decades. The Advanced Measurements Lab includes some of the larger experimental devices, such as a wind tunnel and a towing tank. The third laboratory, the Fluids Workshop, is a space in which students can perform their experiments. The new laboratories held their open house in January 2019. Four courses with a total of approximately 170 students currently hold classes in the lab.

Ralph and Barbara Stephens Experimental Engineering Laboratory
The Ralph and Barbara Stephens Experimental Engineering Laboratory supports the required undergraduate courses ME:3351 Engineering Instrumentation and ME:4080 Experimental Engineering. The lab is equipped with varied instruments and test rigs that help students learn basic measurement principles and laboratory procedures. It also offers sensors for measurement of displacement, mass, temperature, pressure, velocity and flow rate, heat flux, force, torque, and so forth.

Solidification Laboratory
The Solidification Laboratory supports research in fundamental aspects of solidification and their application in casting of metals. Research in the lab ranges from basic experimental and computational studies of microstructure evolution to modeling and simulation of a wide variety of industrial metal casting processes. Collaboration with the casting industry has resulted in custom-made software for process control, new capabilities in commercially available casting simulation software, and strategies for yield improvement and defect prevention. Facilities include numerous state-of-the-art computer workstations and experimental test setups.

Thermal and Heat Transfer Laboratory
The Thermal and Heat Transfer Laboratory is equipped with data acquisition systems to process data online. It also provides facilities for experiments in heat transfer measurements.

Graduate Facilities
Fluid Mechanics
The program in fluid mechanics is conducted in close collaboration with IIHR—Hydroscience & 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 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 CCD (charge-coupled devices) 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 Center for Computer-Aided Design (CCAD). CCAD 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 applications servers connected to centralized file servers. 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, an 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 and heat convection, and combustion flows.

Shared Laboratory
Design for Manufacturing Laboratory
The Design for Manufacturing Laboratory is used by students in mechanical engineering and in industrial and systems engineering. The laboratory provides students with experience in CAD/CAM systems. It is equipped with 4-axis CNC mills (Haas and Tormach), CNC router (Techno-CNC), CNC metal lathe (Haas and Techno-CNC), drill press, plastic injection molder, thermoforming machine, band saw, disc sander, bench grinder, polishing wheel, hand drill, sandblasting cabinet, press, foot shear, and welding station. The lab has the latest software technology, such as Pro/ENGINEER and Rhinoceros.

Courses
Mechanical Engineering Courses

ME:0000 Mechanical Engineering Internship/Co-op 0 s.h.
Mechanical engineering students participating in the Cooperative Education Program register in this course during work assignment periods; registration provides a record of participation in the program on the student's permanent record. Requirements: admission to the Cooperative Education Program.

ME:1000 First-Year Seminar 0-1 s.h.
Small discussion class taught by a faculty member; topics chosen by instructor; may include outside activities (e.g., films, lectures, performances, readings, visits to research facilities). Requirements: first- or second-semester standing.

ME:2020 Mechanical Engineering Sophomore 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. Requirements: sophomore or transfer standing.
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.
Fundamentals of design, engineering graphics, and manufacturing processing; computer graphics using Pro/ENGINEER for CAD and CAM; typical industrial processes including casting, welding, machining, and forming; laboratory exercises and projects. Corequisites: ENGR:2720 and (ME:2200 or BME:2710).

ME:3040 Thermodynamics II 3 s.h.
Power and refrigeration cycles; mixtures of gases, psychometric mixtures; availability; thermodynamics of combustion and chemical equilibrium. Prerequisites: ENGR:2130.

ME:3045 Heat Transfer 3 s.h.

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. Requirements: junior standing.

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 3-D 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: ENGR:2760 or ME:2200. 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 and ME:3040.

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.

ME:4086 Mechanical Engineering Design Project 2-3 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 0 s.h.
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: ME:3052 and ENGR:2750. 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:2710 and MATH:2550. Requirements: junior standing. Same as CEE:4512.

ME:4113 Control of Mechanical Engineering Systems 3 s.h.
How to model simple engineering systems, apply time and frequency domain analysis techniques, and design control systems; application of these techniques using MATLAB; writing differential equations describing engineering systems and determine time domain response to a wide range of inputs; use of state-variable equations to model engineering systems and determine their time response to a wide range of inputs; describe advantages of feedback control; analyze performance of control systems; determine stability of control systems using Root-Locus, Bode, and Nyquist methods; design feedback control systems using frequency domain and state-variable methods. Prerequisites: MATH:2550 and MATH:2560 and ENGR:2710. Same as ISE:4113.
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 ENGR:2760. Same as ISE:4116.

ME:4117 Finite Element Analysis 3 s.h.
Trusses and frames; Rayleigh-Ritz methods; 2-D and 3-D 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 or (MATH:2550 and MATH:2560 and ENGR:2710).

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: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:4175 Computational Naval Hydrodynamics 3 s.h.
Simulations based on relevant vessels and propellers will be used to introduce the use of computational fluid dynamics for the analysis of surface and underwater marine craft performance, while also introducing naval hydrodynamics concepts related to resistance, propulsion, maneuvering, and seakeeping; an educational version of the naval hydrodynamics code REX will be freely distributed and used in the class. Prerequisites: ENGR:2510.

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:5113 Mathematical Methods in Engineering 3 s.h.

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: MATH:2560.

ME:5115 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 ME:4113 or CBE:4105 or ECE:3600.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ME:5120</td>
<td>Vehicle System Dynamics</td>
<td>3 s.h.</td>
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<tr>
<td>ME:5143</td>
<td>Computational Fluid and Thermal Engineering</td>
<td>3 s.h.</td>
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<td>ME:5145</td>
<td>Intermediate Heat Transfer</td>
<td>3 s.h.</td>
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<td>ME:5146</td>
<td>Modeling of Materials Processing</td>
<td>3 s.h.</td>
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<tr>
<td>ME:5149</td>
<td>Propulsion Engineering</td>
<td>3 s.h.</td>
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<tr>
<td>ME:5150</td>
<td>Intermediate Mechanics of Deformable Bodies</td>
<td>3 s.h.</td>
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<tr>
<td>ME:5154</td>
<td>Intermediate Kinematics and Dynamics</td>
<td>3 s.h.</td>
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<tr>
<td>ME:5159</td>
<td>Composite Materials</td>
<td>3 s.h.</td>
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<tr>
<td>ME:5162</td>
<td>Experimental Methods in Fluid Mechanics and Heat Transfer</td>
<td>3 s.h.</td>
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<tr>
<td>ME:5167</td>
<td>Composite Materials</td>
<td>3 s.h.</td>
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<tr>
<td>ME:5195</td>
<td>Contemporary Topics in Mechanical Engineering</td>
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<tr>
<td>ME:5210</td>
<td>Intermediate Thermodynamics</td>
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<td>ME:6191</td>
<td>Graduate Seminar: Mechanical Engineering</td>
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<tr>
<td>ME:6198</td>
<td>Individual Investigations: Mechanical Engineering</td>
<td>arr.</td>
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<td>ME:6199</td>
<td>Research: Mechanical Engineering</td>
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<td>ME:6214</td>
<td>Analytical Methods in Mechanical Systems</td>
<td>3 s.h.</td>
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<td>ME:6215</td>
<td>Finite Element II</td>
<td>3 s.h.</td>
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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:6245 Diffusive Transport 3 s.h.
Diffusive transport of heat, mass, and momentum; phenomenological laws and analogies; analytical and numerical solution techniques; inverse heat conduction; multiphase and multicomponent systems. Prerequisites: ME:5145. Same as CBE:6145.

ME:6247 Contact Mechanics 3 s.h.
Varied aspects of contact mechanics and engineering applications, including stationary contacts, sliding, rolling, impact, and fretting fatigue; emphasis on theoretical basis of solutions of contact mechanics problems; mathematical methods of solving contact problems using Green's function method; complex potentials and integral transform methods. Prerequisites: ME:5113 and ME:5150.

ME:6255 Multiscale Modeling 3 s.h.
Computational modeling of engineering materials ranging from molecular to continuum scales, molecular dynamics and Monte Carlo methods, nanoscale continuum modeling, scale-coupling methods. Prerequisites: ME:5143 or CEE:4533. Same as CEE:7549.

ME:6258 Computational Ship Hydrodynamics 3 s.h.
Introduction to computation of problems in three main areas of ship hydrodynamics: resistance and propulsion, seakeeping, and maneuvering; focus on issues of simulating operating ships, modeling methods, and numerical techniques used to approach ship hydrodynamics. Prerequisites: ME:5160. Corequisites: ME:5143.

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 3 s.h.
Compressible flow behavior; 1-D unsteady flow and appropriate use of x-t diagrams; 2-D flows and use of the method of characteristics; Burgers' Equation and its properties.

ME:6275 Advanced Heat Transfer 3 s.h.
Conservation laws, forced and natural convection; surface and gaseous radiation; analytical and numerical methods; applications. Prerequisites: ME:5145.

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:6300 Control of Networked Autonomous Systems 3 s.h.
Introduction to state-of-the-art research in networked autonomous robotic systems; graph theory based network models, decentralized control, multi-agent cooperation, and mobile sensor networks. Corequisites: ME:5115 or ME:5114.

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 discipilnes 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: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 Computational Solid Mechanics 3 s.h.
Advanced computational methods for nonlinear and dynamic analysis of solids, structures; new space- and time-discretization methods for problems, including highly nonlinearities, large deformation, contact/impact conditions. 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:7259 Mechanical Design in Structures 3 s.h.
Discrete and continuum variational equilibrium equations, discrete design sensitivity analysis for static responses and eigenvalues, interactive design workstation, continuum sizing design sensitivity analysis for static responses and eigenvalues, design sensitivity analysis of structural dynamics, differentiability theory, shape optimal design, shape design sensitivity analysis, design sensitivity of nonlinear structural systems. Prerequisites: CEE:4533 and ME:5113 and ME:5150.

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:7267 Multiphase Flow and Transport 3 s.h.
Thermodynamic and mechanical aspects of interfacial phenomena and phase transitions; nucleation, phase-change, species transport, particulate flows, liquid-vapor systems, solidification, porous media. 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.

Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for Ph.D. in mechanical engineering.