Mechanical and Industrial Engineering

Chair
• Ching-Long Lin

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

The Department of Mechanical and Industrial Engineering offers distinct undergraduate and graduate degrees and research programs in industrial engineering and in mechanical engineering. It also is the administrative home of the undergraduate Certificates in Wind Energy and Naval Hydrodynamics.

Industrial Engineering

Industrial engineering is concerned with analysis, design, and implementation of systems through optimal use of resources—human, material, energy, information, and financial. Systems may range from small units to extremely large operations. In order to accomplish these activities, the industrial engineer must be skilled in mathematics, physical sciences, management, and human relations as well as manufacturing, computer systems, economics, optimization, human behavior, and systems analysis and design.

Industrial engineers have many opportunities for employment and service in industrial, government, research, and public service organizations. Employment opportunities are among the most varied in the engineering field. Industrial engineers hold positions as advisors to management or may participate directly in management decisions. Representative job titles include industrial engineer, manufacturing engineer, systems analyst, quality specialist, operations research analyst, internal consultant, human factors specialist, supervisor, and manager. Industrial engineers are employed by manufacturing and energy firms, wind turbine manufacturers, government agencies, and service organizations such as airlines, banks, hospitals, health care groups, and consulting companies.

Mechanical Engineering

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.

Certificate in Naval Hydrodynamics

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

Certificate in Wind Energy

The Departments of Mechanical and Industrial Engineering and Electrical and Computer Engineering and the Department of Geographical and Sustainability Sciences (College of Liberal Arts and Sciences) administer the undergraduate certificate program in wind energy; see Certificate in Wind Energy 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, Mechanical and Industrial Engineering (College of Engineering), Economics (Tippie College of Business), Geographical and Sustainability Sciences (College of Liberal Arts and Sciences), 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 Certificate in Transportation Studies (Graduate College) in the Catalog.

Programs

Undergraduate Programs of Study

 Majors
• Major in Industrial Engineering (Bachelor of Science in Engineering)
• Major in Mechanical Engineering (Bachelor of Science in Engineering)
Graduate Programs of Study

Majors

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

Facilities

Design for Manufacturing Laboratory

The Design for Manufacturing Laboratory is used by students in industrial engineering and in mechanical engineering. The laboratory provides students with experience in CAD/CAM systems. It is equipped with 4-axis CNC mills (Haas and Tornmach), 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.

Industrial Engineering

The following facilities and laboratories are used by undergraduate and graduate students. For information about laboratories affiliated with core courses coordinated by other College of Engineering departments, see those departments' Catalog sections.

Active Learning Facility

The Active Learning Facility (ALF) is designed to encourage group interaction in a small classroom setting. The reconfigurable classroom is equipped with nine tables and 20 HP workstations. It is used for industrial engineering courses and for small groups working together on computer assignments.

Biomanufacturing Laboratory

The Biomanufacturing Laboratory teaches students about emerging processes and techniques in cell-biomaterial interactions and gives them hands-on laboratory experience. Work in the lab is interdisciplinary, spanning engineering, medicine, biology, and biotechnology. The lab provides facilities for engineered living tissue systems. Next generation manufacturing tools are used to build biologically inspired structures intended to replace diseased or damaged organs and tissues. Lab research projects and activities focus primarily on design, modeling, and fabrication of tissue replacement parts; tissue scaffolds and medical devices; and cell and organ printing. Diverse software and hardware are available to support bioadditive manufacturing platforms.

Cognitive Systems Laboratory

The Cognitive Systems Laboratory is devoted to examining the safety, performance, and user acceptance implications of technology insertion into complex systems. The lab has networked computers, a video editing workstation, a process control simulation, and a low-cost driving simulator. The simulator is equipped with five cameras, instrumentation to record all driver activity, and an eye tracking system. The Cognitive Systems Laboratory shares the driving simulator and an instrumented vehicle with the Operator Performance Laboratory. The equipment supports class projects, system development, and undergraduate and graduate research.

Design Project Laboratory

The Design Project Laboratory is equipped with standard computers and videoconferencing facilities. It supports senior design project courses.

GROK Lab

The GROK Lab develops technologies to help scientists and doctors improve their understanding and control of complex systems such as robots, distributed sensor networks, and augmented-reality systems. The lab designs and builds software, electronic circuits, and mechanical devices that create or modify complex systems and that extend scientists’ understanding of how to make these systems perform their intended tasks better.

The lab has a variety of software development platforms and manufacturing tools, including CNC machines and supplies for casting and molding, as well as a suite of equipment for circuit design, testing, and assembly. The GROK lab has developed technologies used by NASA to control robots exploring South America and Mars. Its most recent projects have focused on using distributed sensor networks to track the activities of health care workers and on developing training simulators for orthopedic surgeons.

Intelligent Systems Laboratory

The Intelligent Systems Laboratory provides facilities for research in computational intelligence leading to applications in industry, service organizations, and healthcare. Research in the lab is funded by government agencies and industrial corporations. Solutions to practical problems and enhancement of engineering education are emphasized. Most of the lab’s recent projects concentrate on development of software tools for product development, manufacturing, and health care applications.

The Intelligent Systems Laboratory is furnished with the latest computer technology to support research on numerous computing platforms. Diverse software is available for modeling, design, and construction of intelligent systems—for example, data mining software, neural networks, expert systems, and simulation software.

Operator Performance Laboratory

Research in the Operator Performance Laboratory (OPL) focuses on determining human performance in a variety of situations, with particular emphasis on driving and flight deck environments. Much of the research is performed in the field using a state-of-the-art instrumented vehicle that is equipped with five cameras, eye movement equipment, two computers, video equipment, and a suite of sensors. The OPL also features a scale Boeing 737-400 fixed-base flight simulator with six channels of visuals. The flight simulator is equipped with a remote eye-tracking device that allows the activation of selected virtual controls in the flight deck. A specially designed stimulus presentation booth is used for color research and for photometry applications. Computer models of operator performance are designed based on the data obtained in the laboratory and field research.
Mechanical Engineering

Mechanical Engineering 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.

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 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.

Experimental Fluid Mechanics Laboratory
The Experimental Fluid Mechanics Laboratory acquaints students with ongoing research in fluid mechanics and hydraulics. The lab focuses on literature, experiments, numerical simulations, audio-video aids, and links to educational and scientific internet sites. Students using the lab develop an understanding of basic flow mechanisms and become familiar with the latest developments in experimental techniques and instrumentation.

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.

Mechanical Engineering 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.

Courses

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Industrial Engineering Courses

IE:0000 Industrial Engineering Internship/Co-op 0 s.h.
Industrial 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 Cooperative Education Program.

IE: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.

IE:2000 Industrial Engineering Sophomore Seminar 0 s.h.
Curriculum and profession; ethics and professionalism in classroom and workplace. Requirements: sophomore or transfer standing in engineering.

IE:2500 Engineering Economy 3 s.h.
Basic concepts of engineering economy; time value of money, cash flow equivalence, depreciation, tax considerations, continuous cash flows, cost accounting overview; main analysis techniques—present worth, uniform annual cost, rate of return, benefit/cost ratio, replacement and break-even analysis. Corequisites: STAT:2020.

IE:3000 Professional Seminar: Industrial Engineering 0 s.h.
Professional aspects of industrial engineering presented through lectures and discussions by guest speakers, field trips, films, panel discussions. Requirements: junior standing.

IE:3149 Information Visualization 3 s.h.
Instruments for reasoning about quantitative information; analyzing and communicating statistical information; main typologies of data graphics (data-maps, time-series, space-time narrative, relational diagrams, graphs and methods for dimensionality reduction); language for discussing data visualizations combined with knowledge of human perception of visual objects; how to visualize information effectively by using statistical methods, knowledge of human perception, and basics of data graphics. Prerequisites: STAT:2020.

IE:3300 Manufacturing Systems 3 s.h.
Manufacturing and logistics systems, supply chain management, MRP/ERP systems, lean manufacturing, concurrent engineering, value stream mapping and six sigma. Offered spring semesters. Prerequisites: IE:3700 and ENGR:2760. Same as ME:4131.

IE:3350 Process Engineering 4 s.h.
Methodologies, algorithms, and tools for processing modeling, analysis, and reengineering; modeling issues in product and component design, product and process modularity, quality, reliability, agility. Offered spring semesters. Prerequisites: IE:3700.

IE:3400 Human Factors 3 s.h.
Design of human-machine systems; development of optimum work environments by applying principles of behavioral science and basic knowledge of human capacities and limits. Offered fall semesters. Prerequisites: PSY:1001.

IE:3450 Ergonomics 3 s.h.
Ergonomic design of jobs and products in an industrial and consumer market setting; principles of good design, examples of poor design; consequences of poor job and product design; principles of work sampling, usability studies, performance rating, sizing and planning of workstations, hand tool design, ergonomic design in transportation; related group project.

IE:3500 Information Systems Design 3 s.h.
Structure and design of computer-based information systems; concepts of information systems, decision making; computer hardware, software, data structures; methods for determining system requirements; designing, implementing, evaluating, managing information systems; applied projects. Prerequisites: ENGR:1300.

IE:3600 Quality Control 3 s.h.
Basic techniques of statistical quality control; application of control charts for process control variables; design of inspection plans and industrial experimentation; modern management aspects of quality assurance systems. Offered fall semesters. Prerequisites: STAT:2020 or (STAT:3100 and STAT:3101 and STAT:3200). Same as CEE:3142, STAT:3620.

IE:3610 Stochastic Modeling 3 s.h.

IE:3700 Operations Research 3 s.h.
Operations research models and applications; emphasis on deterministic model (linear programming, duality). Offered fall semesters. Prerequisites: MATH:2550. Corequisites: STAT:2020.

IE:3750 Digital Systems Simulation 3 s.h.
Simulation modeling and analysis; emphasis on construction of models, interpretation of modeling results; input and output analysis; hands-on usage of ARENA simulation software, manufacturing, health care, and service. Offered spring semesters. Prerequisites: IE:3610 and IE:3700.

IE:3760 Applied Linear Regression 3 s.h.
Regression analysis with focus on applications; model formulation, checking, selection; interpretation and presentation of analysis results; simple and multiple linear regression; logistic regression; ANOVA; hands-on data analysis with computer software. Prerequisites: STAT:2020 or STAT:2010. Same as IGPI:3200, STAT:3200.

Independent projects in industrial engineering for undergraduate students, including laboratory study, an engineering design project, analysis and simulation of an engineering system, computer software development, CAD/CAM applications, or research.
**IE: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 ME:4113.

**IE: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: ENGR:2760. Same as ME:4116.

**IE:4172 Big Data Analytics** 3 s.h.
Principles of data mining and machine learning in context of big data; basic data mining principles and methods—pattern discovery, clustering, ordering, analysis of different types of data (sets and sequences); machine learning topics including supervised and unsupervised learning, tuning model complexity, dimensionality reduction, nonparametric methods, comparing and combining algorithms; applications of these methods; development of analytical techniques to cope with challenging and real "big data" problems; introduction to MapReduce, Hadoop, and GPU computing tools (Cuda and OpenCL). Prerequisites: STAT:2020. Requirements: basic programming skills in C, C++, Java, or Python; knowledge of Matlab, Octave, or R; and knowledge of a word processor. Recommendations: IE:3760 and CS:4400 and CS:3330 and MATH:2550.

**IE:4175 Safety Engineering** 3 s.h.
Systems safety principles and methods, occupational safety, product safety and liability, accident investigation and prevention methods and analysis, hazard analysis, and standards and regulations.

**IE:4550 Wind Power Management** 3 s.h.
Principles of wind power production, wind turbine design, wind park location and design, turbine and wind park control, predictive modeling, integration of wind power with a grid.

**IE:4600 Industrial Engineering Design Project** 1-4 s.h.
Projects involving product and related operational system design in an industrial or service organization; associated entrepreneurial or intrapreneurial planning. Corequisites: IE:3300 and IE:3350 and IE:3400 and IE:3450 and IE:3500 and IE:3600 and IE:3750, if not taken as prerequisites.

**IE:4620 Design of Experiments for Quality Improvement** 3 s.h.
Development of skills necessary to efficiently and effectively design and analyze experiments for quality improvement; topics include experiment planning, design, and statistical analysis of the results; experimentation is beneficial in all phases of industrial processes including new product design, process development, and manufacturing process improvement; students develop successful experiments that can lead to reduced development lead time, enhanced process performance, and improved product quality. Prerequisites: STAT:2020. Requirements: junior (third year) standing.

**IE:4650 Mechatronics Engineering for Smart Device Design** 3 s.h.
Introduction to basic mechatronics system components and design principles using mechatronics to meet functionality requirements of products, processes, and systems; lab-oriented assignments and team-based projects presented with innovative case studies in diverse application domains; labs require students to use a micro-controller kit to finish hardware development assignments; for students who plan to have a career in areas such as product development, robotics, design and manufacturing automation, technology management and innovations. Prerequisites: ENGR:2120 and ENGR:2760. Same as ME:4650.

**IE:4900 Introduction to Six Sigma** 3 s.h.
Six Sigma techniques for the DMAIC cycle (Define, Measure, Analyze, Improve, Control); what is needed for data collection (process inputs and outputs, measurement tools), conduct analysis (hypothesis testing, process capability studies), and conduct process improvement studies (design of experiments, response surface methodology); overview of Six Sigma, process and project management skills; application of the DMAIC model to a real-life improvement projection (a "learn-by-doing" approach). Prerequisites: IE:3600.

**IE:5000 Graduate Seminar: Industrial Engineering** 1 s.h.
Recent advances and research in industrial engineering presented by guest lecturers, faculty, students. Requirements: graduate standing.

**IE:5860 Health Informatics I** 3 s.h.
Technological tools that support health care administration, management, and decision making. Same as HMP:5370, IGPI:5200, MED:5300, SLIS:5900.

**IE:5995 Contemporary Topics in Industrial Engineering** arr.
New topics or areas of study not offered in other industrial engineering courses; topics based on faculty/student interest.

**IE:5998 Individual Investigations: Industrial Engineering** arr.
Individual projects for industrial engineering graduate students: laboratory study, engineering design, analysis and simulation of an engineering system, computer software development, research. Requirements: graduate standing.

**IE:5999 Research: Industrial Engineering M.S.**
**Thesis** arr.
Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for M.S. with thesis in industrial engineering. Requirements: graduate standing.
IE:6211 Human Factors in Healthcare Systems  3 s.h.
Solving human factors problems in health care work systems; cognitive systems engineering, interface design, health care productivity, patient safety; specific research including decision making, information transfer, and communication; discrete event and dynamic systems simulation modeling; human computer interaction; health information technology/systems; usability; business models of organizational, technical, and social elements of health care systems.

IE:6220 Cognitive Engineering  3 s.h.
Cognitive engineering principles; decision making and judgment; distributed cognition; cognitive work; human system interaction; cognitive work analysis; situated action and ecological models; mental models and representation; cognitive engineering methods and applications.

IE:6232 Advanced Computer-Aided Design and Manufacturing  3 s.h.
In-depth study of CAD and manufacturing (CAD/CAM); review of CAD/CAM, computer graphics, NURBS modeling (curves/surfaces, solid modeling, design data exchange); computational geometry for product development; heterogeneous object modeling, rapid prototyping (RP) and layered manufacturing, computer-aided path planning, CAD applications (computer-aided tissue engineering, biomedical imaging and processing, biomanufacturing); related lab projects and assignments. Requirements: knowledge of one programming language (C, C++, C#, VB, or Java).

IE:6300 Innovation Science and Studies  3 s.h.
Innovative typology and sources, classical innovation models, measuring innovation, innovation discovery from data, evolutionary computation in innovation, innovation life cycle.

IE:6350 Computational Intelligence  3 s.h.
Concepts, models, algorithms, and tools for development of intelligent systems; data mining, expert systems, neural networks for engineering, medical and systems applications. Prerequisites: IE:3700. Same as NURS:6900.

IE:6410 Research Methods in Human Factors Engineering  3 s.h.
Logic and methods for research and for analysis and evaluation of complex human-machine systems; advanced techniques for enhancement of human interaction with advanced information technology; emphasis on cognitive task analysis techniques for innovative design, understanding of how technology affects safety, performance, user acceptance.

IE:6420 Human/Computer Interaction  3 s.h.
Development of projects using human factors principles in the design of computer interfaces.

IE:6440 Airborne Design of Experiments  3 s.h.
Issues in design of airborne human factors research, and techniques applicable to ground transportation research; statistical, human factors, flight mechanics, and organizational principles in flight test engineering; basic understanding of systematic approach to human factors flight testing, development of test points and test apparatus, flight envelope, proper briefing techniques, mission execution, and after-action review; securing, synchronizing, and analyzing data.

IE:6450 Human Factors in Aviation  3 s.h.
Measuring, modeling, and optimizing human visual performance; display design for optimal legibility, research in visibility, legibility, conspicuity, and camouflage; visibility model development.

IE:6460 The Design of Virtual Environments  3 s.h.
Development of techniques for designing and creating three-dimensional representations of information for simulation, scientific visualization, and engineering; emphasis on human factors issues, software.

IE:6480 Unmanned Aircraft Systems  3 s.h.
Applications and research in unmanned aircraft systems (UAS) with focus on engineering aspects; new era of aviation and how UAS are fast emerging as a disruptive technology in aviation; applications ranging from film production, photography, precision agriculture, remote sensing, and infrastructure inspections to military applications; problem space of UAS from a variety of angles including engineering controls design, data links, UAS types, human factors, regulatory aspects.

IE:6600 Linear Programming  3 s.h.
Mathematical programming models; linear and integer programming, transportation models, large-scale linear programming, network flow models, convex separable programming. Requirements: calculus and linear algebra. Same as IGPI:6600, MSCI:6600.

IE:6720 Nonlinear Optimization  3 s.h.
Mathematical models, theory, algorithms for constrained and unconstrained nonlinear optimization; optimality conditions and aspects of duality theory; applications of nonlinear optimization in data analytics and machine learning.

IE:6750 Stochastic Optimization  3 s.h.
General tools and approaches used in decision making under uncertainties; modeling of uncertainties and risk, changes that uncertainties bring to the decision process, difficulties of incorporating uncertainties into optimization models, common techniques for solving stochastic problems.

IE:6760 Pattern Recognition for Financial Data  3 s.h.
Modeling and harvesting useful information and patterns for financial data; topics include basic concepts of financial data, financial data visualization, modeling and forecasting of financial time series, seasonal models, volatility models, value at risk, principal component analysis, and factor models.

IE:6780 Financial Engineering and Optimization  3 s.h.
Quantitative methods of modeling various financial instruments (i.e., stocks, options, futures) and tools for measurement and control of risks inherent to financial markets; fundamentals of interest rates; options and futures contract valuation, including weather and energy derivatives; risk management and portfolio optimization; emphasis on modeling and solution techniques based on optimization and simulation approaches traditional to industrial engineering and operations research. Recommendations: basic knowledge of probability and statistics, numerical methods, and optimization.

IE:6790 Reliability Theory and Applications  3 s.h.
Fundamental topics in reliability engineering, including system reliability modeling, statistical inference of lifetime data, basic preventive maintenance models; statistics and random process models, and online monitoring and change detection techniques. Prerequisites: MATH:2550 and STAT:2020.

IE:7995 Advanced Topics: Industrial Engineering  arr.
Discussion of current literature in industrial engineering.

IE:7998 Special Topics in Industrial Engineering  arr.
Mechanical Engineering Courses

ME:0000 Mechanical Engineering Internship/Co-op 0-1 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:2300 Fundamentals of Design and Manufacturing 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.

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 ENGR:2760 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:4024 Mechanical Engineering Design and Parametric Modeling 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. Corequisites: ENGR:2750 ME:3045.

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 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: ME:3052 and ENGR:2750. Same as CEE:4515.

ME:4111 Numerical Calculations 3 s.h.
Development of algorithms for functional approximations, numerical differentiation and integration; solution of algebraic and differential equations, with emphasis on digital computations; initial and boundary value problems. 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: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 IE:4113.

ME:4115 Finite Element I 3 s.h.
One- and two-dimensional boundary value problems; heat flow, fluid flow, torsion of bars; trusses and frames; isoparametric mapping; higher order elements; elasticity problems; use of commercial software. Prerequisites: ENGR:2750. Same as CEE:4533, IGPI:4115.

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: ENGR:2760. Same as IE:4116.

ME:4120 State-Space Methods for Linear Control Systems arr.
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: 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:4131 Manufacturing Systems 3 s.h.
Manufacturing and logistics systems, supply chain management, MRP/ERP systems, lean manufacturing, concurrent engineering, value stream mapping and six sigma. Offered spring semesters. Prerequisites: IE:3700 and ENGR:2760. Same as IE:3300.

ME:4142 Wind Turbine Aerodynamics 3 s.h.
Fluid mechanics of wind turbines and wind farms; engineering methodologies to design wind turbine blades; evaluation of rotor wakes; interaction between machines; effects of topography on wind turbine and wind farm performance. Prerequisites: ENGR:2510.

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:4164 Fundamentals of Wind Turbines arr.
Application of fundamental principles of thermodynamics, fluid mechanics, and mechanical systems to wind turbine engineering; fundamentals of horizontal-axis wind turbines, wind energy conversion to useful work; wind turbine aerodynamics, performance, design of components; overview of wind resource and historical development of wind turbines; introduction to wind turbine installation and wind farm operation.

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:4650 Mechatronics Engineering for Smart Device Design 3 s.h.
Introduction to basic mechatronics system components and design principles using mechatronics to meet functionality requirements of products, processes, and systems; lab-oriented assignments and team-based projects presented with innovative case studies in diverse application domains; labs require students to use a micro-controller kit to finish hardware development assignments; for students who plan to have a career in areas such as product development, robotics, design and manufacturing automation, technology management and innovations. Prerequisites: ENGR:2120 and ENGR:2760. Same as IE:4650.

ME:5113 Mathematical Methods in Engineering 3 s.h.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME:5114</td>
<td>Nonlinear Control in Robotic Systems</td>
<td>3 s.h.</td>
<td>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.</td>
</tr>
<tr>
<td>ME:5120</td>
<td>Vehicle System Dynamics</td>
<td>3 s.h.</td>
<td>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.</td>
</tr>
<tr>
<td>ME:5143</td>
<td>Computational Fluid and Thermal Engineering</td>
<td>3 s.h.</td>
<td>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.</td>
</tr>
<tr>
<td>ME:5145</td>
<td>Intermediate Heat Transfer</td>
<td>3 s.h.</td>
<td>Steady and unsteady conduction; forced and natural convection; surface and gaseous radiation; condensation and evaporation; analytical and numerical methods and applications. Prerequisites: ME:3045.</td>
</tr>
<tr>
<td>ME:5146</td>
<td>Modeling of Materials Processing</td>
<td>3 s.h.</td>
<td>Manufacturing processes for metals, polymers, semiconductors; processing by casting, solidification, crystal growth, polymer molding and extrusion, welding, heat treating, application of optical (laser) and electromagnetic energy; processes that use momentum, heat, mass transfer principles; measurement and instrumentation for materials processing; current topics in materials processing. Corequisites: ME:3045.</td>
</tr>
<tr>
<td>ME:5149</td>
<td>Propulsion Engineering</td>
<td>3 s.h.</td>
<td>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: ME:3040. Requirements: graduate standing.</td>
</tr>
<tr>
<td>ME:5150</td>
<td>Intermediate Mechanics of Deformable Bodies</td>
<td>3 s.h.</td>
<td>Application of equilibrium analyses, strain-displacement relations, and constitutive relationships to practical structural systems and elementary plane elasticity problems. Prerequisites: ENGR:2750. Same as BME:5660, CEE:5540.</td>
</tr>
<tr>
<td>ME:5154</td>
<td>Intermediate Kinematics and Dynamics</td>
<td>3 s.h.</td>
<td>Kinematic and dynamic analysis of mechanical systems; computational kinematics, Lagrangian dynamics, principle of virtual work in dynamics, constrained dynamics, spatial dynamics. Prerequisites: ENGR:2710.</td>
</tr>
<tr>
<td>ME:5159</td>
<td>Fracture Mechanics</td>
<td>3 s.h.</td>
<td>3-D 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: BME:4910 or ME:4055 or ME:5150. Same as CEE:5549.</td>
</tr>
<tr>
<td>ME:5160</td>
<td>Intermediate Mechanics of Fluids</td>
<td>3 s.h.</td>
<td>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:2750. Same as CEE:5369.</td>
</tr>
<tr>
<td>ME:5162</td>
<td>Experimental Methods in Fluid Mechanics and Heat Transfer</td>
<td>3 s.h.</td>
<td>Hands-on experience in methodology of conducting experiments in fluid mechanics and heat transfer from design to data acquisition and processing; essential theoretical elements, experimental methodologies, data acquisition systems, uncertainty analysis; wide variety of instruments for fundamental and applied experimentation; work in small groups; design, implement, test, and report an experiment in area of interest. Same as CEE:5372.</td>
</tr>
<tr>
<td>ME:5167</td>
<td>Composite Materials</td>
<td>3 s.h.</td>
<td>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 or ENGR:2510. Same as CEE:5179.</td>
</tr>
<tr>
<td>ME:5179</td>
<td>Continuum Mechanics</td>
<td>arr.</td>
<td>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.</td>
</tr>
<tr>
<td>ME:5195</td>
<td>Contemporary Topics in Mechanical Engineering</td>
<td>arr.</td>
<td>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.</td>
</tr>
<tr>
<td>ME:5210</td>
<td>Intermediate Thermodynamics</td>
<td>3 s.h.</td>
<td>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:3040 or graduate standing. Same as CBE:5110.</td>
</tr>
<tr>
<td>ME:5236</td>
<td>Optimization of Structural Systems</td>
<td>3 s.h.</td>
<td>Advanced topics; optimization of structural topology, shape, and material; finite dimensional dynamic response optimization, sensitivity analysis, distributed parameter systems; projects. Same as BME:5720, CEE:5236.</td>
</tr>
<tr>
<td>ME:5360</td>
<td>Control Theory</td>
<td>3 s.h.</td>
<td>State space approach; controllability, observability, canonical forms, Luenberger observers, feedback control via pole placement, stability, minimal realization and optimal control. Prerequisites: ECE:3600. Same as ECE:5600.</td>
</tr>
</tbody>
</table>
ME:5362 Computer-Based Control Systems 3 s.h.
Discrete and digital control systems; application of computers in control; sampling theorem; discrete time system models; analysis and design of discrete time systems; control design by state variable and input/output methods; advanced topics in digital controls; lab. Prerequisites: ECE:5600. Same as ECE:5640, IGPI:5641.

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.

Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for M.S. 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 thermomechanical 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:6246 Advanced Numerical Methods for Mechanical Systems 3 s.h.
Introduction to meshfree particle methods, extended finite element method, material stability analysis, thermal-mechanical coupling, and coupling of finite element/meshfree methods. Requirements: ME:4115 or ME:5143 or background in computational mechanics, computational chemistry, or computational physics.

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 arr.
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.
<table>
<thead>
<tr>
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<th>Description</th>
<th>Prerequisites/Disciplines</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME:6278</td>
<td>Nonlinear Elasticity</td>
<td>3 s.h.</td>
<td>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.</td>
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</tr>
<tr>
<td>ME:6534</td>
<td>Applied Optimal Design</td>
<td>3 s.h.</td>
<td>Optimal design problem formulation; optimality conditions; linear, quadratic, convex, and nonlinear programming; Lagrangian duality; numerical algorithms for unconstrained and constrained design problems, design sensitivity analysis, engineering applications. Prerequisites: CEE:5513. Same as CEE:6534.</td>
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<tr>
<td>ME:7248</td>
<td>Combustion Theory</td>
<td>3 s.h.</td>
<td>Laminar flame theory; turbulent combustion; spray combustion; thermal ignition; pollutant formation, oxidation; combustion diagnostics. Prerequisites: ME:5145 and ME:5160.</td>
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<tr>
<td>ME:7250</td>
<td>Advanced Fracture Mechanics</td>
<td>3 s.h.</td>
<td>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.</td>
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</tr>
<tr>
<td>ME:7256</td>
<td>Computational Solid Mechanics</td>
<td>3 s.h.</td>
<td>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.</td>
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<tr>
<td>ME:7257</td>
<td>Probabilistic Mechanics and Reliability</td>
<td>3 s.h.</td>
<td>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.</td>
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</tr>
<tr>
<td>ME:7259</td>
<td>Mechanical Design in Structures</td>
<td>3 s.h.</td>
<td>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.</td>
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</tr>
<tr>
<td>ME:7256</td>
<td>Interfacial Flows and Transport Processes</td>
<td>3 s.h.</td>
<td>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.</td>
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<tr>
<td>ME:7267</td>
<td>Multiphase Flow and Transport</td>
<td>3 s.h.</td>
<td>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.</td>
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<tr>
<td>ME:7268</td>
<td>Turbulent Flows</td>
<td>3 s.h.</td>
<td>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.</td>
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</tr>
<tr>
<td>ME:7269</td>
<td>Computational Fluid Dynamics and Heat Transfer</td>
<td>3 s.h.</td>
<td>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.</td>
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</tr>
<tr>
<td>ME:7295</td>
<td>Advanced Topics in Mechanical Systems</td>
<td>3 s.h.</td>
<td>Advanced contemporary topics in mechanical systems engineering not covered in other courses and determined by student/faculty interest.</td>
<td></td>
</tr>
<tr>
<td>ME:7299</td>
<td>Research: Mechanical Engineering Ph.D. Dissertation</td>
<td>arr.</td>
<td>Experimental and/or analytical investigation of an approved topic for partial fulfillment of requirements for Ph.D. in mechanical engineering.</td>
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</table>