Mechanical engineers design, develop, and support the manufacture of machinery and devices to transmit power or to convert energy from thermal to mechanical form in order to power the modern world and its machines. Traditionally, mechanical engineers have designed and tested devices, such as heating and air-conditioning systems, machine tools, internal combustion engines, and steam power plants. Today, they also play primary roles in the development of new technologies in a variety of fields—energy conversion, solar energy utilization, environmental control, prosthetics, transportation, manufacturing, robotics, and new-materials development.

Industrial engineers design and analyze systems that include people, equipment, and materials and their interactions and performance in the workplace. An industrial engineer collects this information and evaluates alternatives to make decisions that best advance the goals of the enterprise. Industrial engineers work in manufacturing firms, hospitals, banks, public utilities, transportation, government agencies, insurance companies, and construction firms. Among the projects they undertake are design and implementation of a computer-integrated supply chain or manufacturing system, facilities planning for a variety of industries, design of a robotics system in a manufacturing environment, long-range corporate planning, development and implementation of a quality-control system, simulation analyses to improve processes and make operational decisions, design of healthcare operations to enhance patient safety and improve efficiency, productivity, and development of computer systems for information control.

Missions of the Department
The mission of the Department of Mechanical and Industrial Engineering is to educate persons for professional and technical excellence: to perform research to advance the science and practice of engineering; to engage in service activities that advance the department, the university, and the profession; and to instill in ourselves and our students habits and attitudes that promote ethical behavior, professional responsibility, and careers that advance the well-being of society.

Academic Programs
The Department of Mechanical and Industrial Engineering (MIE) offers comprehensive research and educational programs for both Master of Science (MS) and Doctor of Philosophy (PhD) students. Our cutting-edge and vibrant doctoral programs include PhDs in industrial engineering, mechanical engineering, and an interdisciplinary PhD (hosted in the College of Engineering). Our MS degree programs are offered in both traditional mechanical and industrial engineering, as well as data analytics engineering, energy systems, engineering management, human factors, operations research, and robotics. These extensive programs and concentrations allow for the selection of a degree that meets a wide variety of personal and professional goals. Graduate students work with our world-renowned faculty to achieve research experience and their career goals and have opportunities to participate in the graduate cooperative education program.

Graduate Certificate Options
Students enrolled in a master’s degree have the opportunity to also pursue one of the many engineering graduate certificate options in addition to or in combination with the MS degree. Students should consult their faculty advisor regarding these options (https://www.northeastern.edu/graduate/programs/#/certificate/engineering/leadership/---/---/).

Gordon Institute of Engineering Leadership Option
Students have the opportunity to pursue the Gordon Engineering Leadership Program (https://www.northeastern.edu/graduate/program/graduate-certificate-in-engineering-leadership-5272/) in combination with the MS degree.

Engineering Business
Students have the opportunity to pursue the Galante Engineering Business Certificate (https://www.northeastern.edu/graduate/program/galante-engineering-business-certificate-14806/) in combination with several MS degrees.

Programs
Doctor of Philosophy (PhD)
- Industrial Engineering (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/industrial-engineering-phd/)
- Mechanical Engineering (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/mechanical-engineering-phd/)

Master of Science (MS)
- Advanced and Intelligent Manufacturing (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/advanced-intelligent-manufacturing-ms/)
- Data Analytics Engineering (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/data-analytics-engineering-ms/)
- Human Factors (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/human-factors-mshf/)

Master of Science in Industrial Engineering (MSIE)
- Industrial Engineering (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/industrial-engineering-msie/)

Master of Science in Engineering Management (MSEM)
- Engineering Management (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/engineering-management-msem/)

Master of Science in Energy Systems (MSEneS)
- Energy Systems (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/energy-systems-msenes/)
- Energy Systems—Academic Link Program (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/energy-systems-msenes-academic-link-program/)

Master of Science in Mechanical Engineering (MSME)
- Mechanical Engineering with Concentration in General Mechanical Engineering (http://catalog.northeastern.edu/graduate/engineering/
Graduate Certificate

- Mechanical Engineering with Concentration in Materials Science (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/mechanical-engineering-concentration-material-science-msme/)
- Mechanical Engineering with Concentration in Thermofluids (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/mechanical-engineering-concentration-thermofluids-msme/)
- Mechanical Engineering with Concentration in Mechatronics (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/mechanical-engineering-concentration-mechatronics-msme/)
- Mechanical Engineering with Concentration in Thermofluids (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/mechanical-engineering-concentration-thermofluids-msme/)
- Mechanical Engineering with Concentration in Mechanics and Design (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/mechanical-engineering-concentration-mechanics-design-msme/)
- Mechanical Engineering with Concentration in Mechanics and Design (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/mechanical-engineering-concentration-mechanics-design-msme/)

Master of Science in Operations Research (MSOR)

- Operations Research (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/operations-research-msor/)

Graduate Certificate

- Data Analytics Engineering (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/data-analytics-engineering-graduate-certificate/)
- Energy Systems (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/energy-systems-graduate-certificate/)
- Energy Systems Management (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/energy-systems-management-graduate-certificate/)
- Engineering Business (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/engineering-business-graduate-certificate/)
- Engineering Economic Decision Making (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/engineering-economic-decision-making-graduate-certificate/)
- Lean Six Sigma (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/lean-six-sigma-graduate-certificate/)
- Renewable Energy (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/renewable-energy-graduate-certificate/)
- Software Engineering Systems (http://catalog.northeastern.edu/graduate/engineering/multidisciplinary/software-engineering-systems-graduate-certificate/)
- Sustainable Energy Systems (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/sustainable-energy-systems-graduate-certificate/)
- Supply Chain Engineering Management (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/supply-chain-engineering-management-graduate-certificate/)
- Technology Systems Management (http://catalog.northeastern.edu/graduate/engineering/mechanical-industrial/technology-systems-management-graduate-certificate/)

Courses

Energy Systems Courses

Search ENSY Courses using FocusSearch (http://catalog.northeastern.edu/class-search/?subject=ENSY)

ENSY 5000. Fundamentals of Energy System Integration. (4 Hours)

Presents fundamental issues of successfully integrating and implementing energy systems. Exposes students to combined heat and power strategies (cogeneration system), strategies of incorporating renewable with nonrenewable energy sources, thermoeconomics, and carbon sequestration techniques. Includes energy, exergy, and thermoeconomic cost factors in the presented case studies. Explores the effects of public policy, regulations, and financial operations on selecting energy technology. Students are given case studies to illustrate the complexity of implementing energy systems and are expected to complete a major project involving proposing an energy system. Emphasizes that successful implementation of energy systems requires both a technical and an economic solution. Requires calculus-based physics and chemistry.

ENSY 5050. Fundamentals of Thermal Science 1. (4 Hours)

Introduces and reviews thermodynamic properties such as temperature, pressure, energy, enthalpy, and entropy. Defines work and heat interactions and calculates the amount of energy transferred during thermodynamic processes. Introduces the first and second laws of thermodynamics and concepts of thermodynamic equilibrium. Discusses mass, energy, and entropy balance relations as well as conversion devices, such as turbine, compressors, pumps, valves, and energy exchangers. Studies simple power plants, refrigeration, heat (energy) pumps, and stationary gas turbine systems. Presents and reviews fundamentals of calculus, such as limit, differentiation, integration, power series, vector spaces, and multivariable functions needed for thermodynamic analysis.

ENSY 5060. Fundamentals of Thermal Science 2. (4 Hours)

Studies fundamental principles in fluid mechanics and thermal systems analysis. Topics include hydrostatics (pressure distribution, forces on submerged surfaces, and buoyancy); Newton's law of viscosity; integral forms of basic laws (conservation of mass, momentum, and energy); pipe flow analysis; concept of boundary layer; and drag coefficient. Presents Navier-Stokes equations as differential forms of conservative properties. Introduces theories of thermal energy transport, including conduction, convection, and thermal radiation; the design of thermal systems; and fundamentals of calculus, such as linear algebra, vector fields, and curvilinear coordinate systems required for introducing concepts of fluid dynamics and heat transfer. Discusses surface and volume integrals, conservative vector fields, and surface flux. Green's, divergence, and Stokes theorems are introduced for vector and scalar fields.

Prerequisite(s): ENSY 5050 with a minimum grade of C-

ENSY 5100. Hydropower. (4 Hours)

Covers fundamentals of hydropowered development projects and their relevant design parameters. Emphasizes harnessing the hydro-energy potentials of both natural and man-made reservoirs. Reviews hydro- and electromechanical equipment and civil structure. Addresses selection procedure and design parameters of the equipment and structure.
ENSY 5200. Energy Storage Systems. (4 Hours)
Explores the various energy storage technologies, their working, and their practical applications. Focuses on the state-of-the-art review of current and most recent technologies. Offers students an opportunity to explore various innovations in the field of energy storage that can be helpful for fulfilling our current energy storage needs. Covers many different energy storage systems such as mechanical, chemical, electrochemical, thermal, thermochemical, etc.

ENSY 5300. Electrochemical Energy Storage. (4 Hours)
Covers the basics of electrode kinetics and thermodynamics as applied to electrochemical energy storage systems, as well as batteries and capacitors for traction and stationary power. Discusses the chemical structure of electrodes and electrolytes and practical battery construction.

ENSY 5400. Power Plant Design and Analysis. (4 Hours)
Reviews the fundamental laws of thermodynamics and balance equations for mass, energy, exergy, and entropy. Studies thermochemistry, chemical equilibrium, fuels and combustion, steam power plant cycle, gas turbine systems, thermo-economics, nuclear power plants, and energy recovery.

ENSY 5500. Smart Grid. (4 Hours)
Covers fundamentals of smart electric power grid. Covers definition, design criteria, and technology. Smart grid can be defined as the application of information processing and communications to the power grid. Seeks to motivate development of the smart grid, evaluating options for adding sensing, communications, computation, intelligence, control, and automation to various parts of the electric system. Topics include automation, or lack thereof, in existing power systems; generation; transmission; distribution; and smart grid definition.

ENSY 5585. Wind Energy Systems. (4 Hours)
Introduces wind energy and its applications. Integrates aerodynamics of wind turbine design with the structures needed to support them. Covers types of wind turbines, their components, and related analyses; airfoil aerodynamics; concepts of lift, drag, pitching moment, circulation, angle of attack, and stall; laminar and turbulent boundary layers and separation concepts; fundamental conservation equations; Bernoulli’s, Euler’s, and Navier-Stokes equations and their applications; Betz limit; computational fluid dynamics and its application for flow over typical airfoils; compressibility and elements of one-dimensional gas dynamics; wind resource; wind climatology and meteorological data; turbine tower and structural engineering aspects of turbines; vibration problems; aeroelastic phenomena in turbines; small wind turbines and vertical axis wind turbines; and introduces environmental and societal impacts and economic aspects.

ENSY 5600. Fundamentals of Solar Photovoltaic Energy Conversion. (4 Hours)
Focuses on the principles and working fundamentals of photovoltaic (PV) energy conversion, while emphasizing currently available solar technologies. Studies the semiconductor processes and advanced characterization theories. Examines design, fabrication, characterization of the PV modules, and different generations of solar cells and their properties. Advanced topics include thin film cells, compound semiconductors multijunction, multiband cells, spectral conversion, and introduces organic devices. Offers insight about the energy consumption crisis, sustainable energy sources, PV system components, and solar markets. Also discusses issues relating to PV systems, economics, and sustainability.

ENSY 5700. Renewable Energy Development. (4 Hours)
Examines a unique blend of technological and commercial aspects of renewable energy development focused on solar and storage projects with a strong focus on distributed projects. Topics include an introduction to the Independent System Operator New England and generation markets; site selection and layout development; tilt and orientation calculations; shading analysis and interrow spacing requirements; energy production modeling; solar string designs; DC/AC ratios; National Electrical Code requirements/compliances; and wind load analysis. Introduces battery energy storage system sizing analysis and requirements for behind-the-meter and front-of-meter projects, as well as renewable portfolio standards and carbon analysis. Offers an overview of financial modeling and basic tax equity structures. Discusses case studies requiring substantial class participation to uncover practical aspects of project development.

ENSY 5800. Applications of Artificial Intelligence in Energy Systems. (4 Hours)
Covers fundamentals of artificial intelligence (AI) used in engineering applications for energy systems. Introduces a brief treatment of AI methods. Examines several AI methods, including search algorithms, decision making under uncertainty, graphical methods, and machine learning. Discusses a more thorough treatment for how AI is used for engineering applications in energy systems. Application areas include power generation, electric grid, renewables, and energy storage. Focuses on practical considerations, including economic opportunity, verification and validation, risks, and nontechnical challenges.

Prerequisite(s): ENSY 5000 with a minimum grade of C-

ENSY 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

ENSY 7374. Special Topics in Energy Systems. (4 Hours)
Offers topics of interest to the staff member conducting the course for advanced study. May be repeated without limit.

ENSY 7440. Energy Systems Engineering Leadership Challenge Project 1. (4 Hours)
Offers students an opportunity to develop and present a plan for the demonstration of a marketable technology product or prototype with an energy systems focus. Constitutes the first half of a thesis-scale project in technology commercialization. Requires work/training with a sponsoring organization or employer to improve a process or develop a project that is of significant value to the organization and demonstrates a quantifiable market impact while enhancing the student's technological and engineering depth and fostering the student's leadership development.

ENSY 7442. Energy Systems Engineering Leadership Challenge Project 2. (4 Hours)
Continues ENSY 7440, a thesis-scale project in technology commercialization. Offers students an opportunity to demonstrate their development of a marketable technology product or prototype with an energy systems focus and to produce a written documentary report on the project to the satisfaction of an advising committee. Requires work/training with a sponsoring organization or employer to improve a process or develop a project that is of significant value to the organization and demonstrates a quantifiable market impact while enhancing the student's technological and engineering depth and fostering the student's leadership development.

Prerequisite(s): ENSY 7440 with a minimum grade of C-
EMGT 6305. Financial Management for Engineers. (4 Hours)
Examines the issues and processes of short-term financing on industrial firms, financial analysis of cases, supplemented by readings to develop familiarity with sources and uses of working capital as well as the goals and problems involved in its management. Also covers the analysis necessary for such long-term financial decisions as issuance of stock or bonds; contracting of leases or loans, and financing of a new enterprise; mergers, capital budgeting, the cost of capital, and the valuation of a business. Examines financial statement ratio analysis along with the use of the capital asset pricing model as it relates to risk and return. Explores leverage and capital structure and international managerial finance in the examination of the overall financial policy decision-making process.

EMGT 6600. Engineering Team Performance. (4 Hours)
Offers students an opportunity to obtain foundational knowledge of team performance and learn the practical application of principles to enable them to develop practical skills in managing engineering and other technical team development initiatives. Teaming is a critical technique used to make a positive impact on personal and organizational performance and is essential for engineering and other technical disciplines. Designed to help students understand why and how team skills are critical to organizational success, learn how to use team skills to more effectively achieve engineering and technical goals as well as to organize and influence others to work more effectively, and to apply cognition to develop higher-performing teams.

EMGT 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

EMGT 7374. Special Topics in Engineering Management. (4 Hours)
Offers topics of interest to the staff member conducting this class for advanced study. May be repeated without limit.

EMGT 7945. Master's Project. (4 Hours)
Offers theoretical or experimental work under individual faculty supervision.

EMGT 7962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

EMGT 7978. Independent Study. (1-4 Hours)
Offers theoretical or experimental work under individual faculty supervision. May be repeated without limit.

EMGT 7990. Thesis. (1-8 Hours)
Offers analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. Requires first-year students to attend a graduate seminar program that introduces the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Requires successful completion of the seminar program. May be repeated without limit.

EMGT 7996. Thesis Continuation. (0 Hours)
Continues thesis work conducted under the supervision of a departmental faculty member.

Industrial Engineering Courses
Search IE Courses using FocusSearch (http://catalog.northeastern.edu/class-search/?subject=IE)
IE 5137. Computational Modeling in Industrial Engineering. (4 Hours)
Builds computational models for industrial engineering applications. Offers students an opportunity to learn how to identify the problem, split it into subsystems, develop mathematical models of each sub-system, and implement in Python. Selected problems are specific to industrial engineering applications with examples of inventory systems, queuing systems, production planning and control, supply chain management, transportation, network flows, forecasting, scheduling, Monte Carlo simulation, regression analysis, sensitivity analysis, and decision support systems in data science and machine learning to test and learn from models. Students also have an opportunity to learn how to use Python libraries to implement the corresponding data structures and algorithms.

Prerequisite(s): GE 1111 with a minimum grade of D- or GE 1502 with a minimum grade of D- or graduate program admission

IE 5374. Special Topics in Industrial Engineering. (4 Hours)
Offers topics of current interest in industrial engineering. May be repeated up to two times.

IE 5390. Structured Data Analytics for Industrial Engineering. (4 Hours)
Covers fundamental knowledge and skills for using structured data analytics for IE applications. Offers students an opportunity to learn data cleaning and preparation, as well as analytics of data sets, and coding in VBA (writing macros and creating GUI), both as a driver of spreadsheet formulas and as a stand-alone programming language. A final project involves the development and presentation of a structured data analytics application that addresses industrial engineering concepts.

Prerequisite(s): (IE 4515 with a minimum grade of D- or OR 6205 with a minimum grade of C-); (IE 3412 with a minimum grade of D- or IE 6200 with a minimum grade of C-)

IE 5400. Healthcare Systems Modeling and Analysis. (4 Hours)
Discusses the key functions of healthcare operations management, such as patient and process flow, process improvement, facility layout, staffing and scheduling, capacity planning, and resource allocation. Focuses on analysis, design, management, and control of health systems and processes that are necessary to provide clinical care. The applications of systems engineering methods, such as optimization, simulation, and queuing models, are discussed through papers and case studies in different care settings (e.g., hospitals, emergency departments, surgery departments, and outpatient clinics) for different diseases (e.g., diabetes, cancer, mental health, cardiovascular disease). Uses spreadsheet tools to model and solve simulation and optimization problems. Requires equivalent course work if prerequisites are not met.

Prerequisite(s): IE 4515 with a minimum grade of D- or OR 6205 with a minimum grade of D- or graduate program admission

IE 5500. Systems Engineering in Public Programs. (4 Hours)
Introduces the design, development, analysis, and application of mathematical modeling for addressing public programs and societal needs. Systems engineering and mathematical models form the basis for decision making in both public and private applications. Focusing on societal applications, offers students an opportunity to discover how to incorporate public objectives and characteristics of large systems in the development of models and policies. Examines applications in the operation of public programs (e.g., public health systems, government programs) and public safety (e.g., security, emergency preparedness, and disaster response). Modeling techniques include game theory, data envelopment analysis, cost-benefit analysis, simulation, differential equations, and stochastic optimization. Requires equivalent course work if prerequisites are not met.

Prerequisite(s): (IE 4515 with a minimum grade of D- or OR 6205 with a minimum grade of C-); (IE 3412 with a minimum grade of D- or MATH 3081 with a minimum grade of D- or IE 6200 with a minimum grade of C-)

IE 5617. Lean Concepts and Applications. (4 Hours)
Covers the fundamentals of lean thinking and how to apply this knowledge to practical problems. Lean thinking is imperative for organizations aspiring to stay competitive in global markets. It calls for process changes to eliminate waste, shorten product delivery time, improve product quality, and curtail costs, while improving customer satisfaction. Offers students an opportunity to learn concepts, a kit of process improvement tools, implementation methods, and best practices for lean workforce development. Makes extensive use of active learning exercises and simulations, and case studies from different disciplines, to help students learn how lean principles are applied in manufacturing and also in less traditional areas such as knowledge work and healthcare systems.

Prerequisite(s): (IE 4515 with a minimum grade of D- or MATH 3081 with a minimum grade of C-); (IE 3412 with a minimum grade of D- or IE 6200 with a minimum grade of C-)

IE 5618. Recitation for IE 5617. (0 Hours)
Accompanies IE 5617. Provides small group demonstrations, exercises, and team activities.

Corequisite(s): IE 5617

IE 5630. Biosensor and Human Behavior Measurement. (4 Hours)
Emphasizes the measurement of human behavior in complex human-machine interaction. Topics include introduction of complex human-machine interactions; research methods in complex human-machine interactions; various kinds of human psychophysiological signals/cues, including physiological cues, facial expressions, eye-gaze movement, head movement, contextual cues; human cues and behavior relationship; transducers and measurement for these human cues/signals; basic principles of biosensors; general classification of biosensors; current technologies for building biosensors; conventional transducers and new technologies including micro-/nanotechnology; general systematic design process for biosensors; application of biosensors to understand human behavior in human-machine interactions. Also introduces the latest relevant research advancements in sensor fusion, affective computing, and emotion recognition.
IE 5640. Data Mining for Engineering Applications. (4 Hours)
Introduces data mining concepts and statistics/machine learning techniques for analyzing and discovering knowledge from large data sets that occur in engineering domains such as manufacturing, healthcare, sustainability, and energy. Topics include data reduction, data exploration, data visualization, concept description, mining association rules, classification, prediction, and clustering. Discusses data mining case studies that are drawn from manufacturing, retail, healthcare, biomedical, telecommunication, and other sectors.

Prerequisite(s): IE 3412 with a minimum grade of D- or MATH 3081 with a minimum grade of D- or IE 6200 with a minimum grade of C-

IE 6200. Engineering Probability and Statistics. (4 Hours)
Studies fundamental concepts of probability. Topics include events, sample space, and discrete and continuous random variables; density functions, mass functions, cumulative probability distributions, and moment generating functions; expectation of random variables; common discrete and continuous probability distributions including binomial, Poisson, geometric, uniform, exponential, and normal; multivariate probability distributions, covariance, and independence of random variables; sampling and descriptive statistics; and parameter estimation, confidence intervals, and hypothesis testing. Also introduces analysis of variance. Requires knowledge of multivariate calculus.

IE 6300. Manufacturing Methods and Processes. (4 Hours)
Focuses on manufacturing and its relationship to design and computers. Examines the relationship between design and various aspects of manufacturing. Covers manufacturing systems, manufacturing processes, bill of materials, group technology, mechanical tolerancing, QC, SPC, QPC, TQM, process planning and CAPP, NC part programming, supply chain management, production scheduling, JIT, lean manufacturing, flexible manufacturing systems, CIM cells, and manufacturing control via, say, programmable logic controllers.

IE 6500. Human Performance. (4 Hours)
Explores a wide range of human-machine systems. Focuses on human performance, human system integration, evaluation, and applications and how they can improve productivity, efficiency, safety, and quality of work life. Involves designing of machines, operations, jobs, and work environments in systems so that they are compatible with human capabilities, characteristics, and limitations. Discusses a variety of human-machine systems and interactions, including transportation, healthcare, human-computer, human-robot, consumer products, and service industries.

IE 6600. Computation and Visualization for Analytics. (4 Hours)
Offers students an opportunity to learn how to use visualization tools and techniques for data exploration, knowledge discovery, data storytelling, and decision making in engineering, healthcare operations, manufacturing, and related applications. Covers basics of Python and R for data mining and visualization. Introduces students to static and interactive visualization charts and techniques that reveal information, patterns, interactions, and comparisons by focusing on details such as color encoding, shape selection, spatial layout, and annotation.

IE 6700. Data Management for Analytics. (4 Hours)
Covers the theory and applications of database management to support data analytics, data mining, machine learning, and artificial intelligence. Discusses the fundamental concepts and emerging technologies in database design and modeling, database systems, data storage, and the evolving world of data warehousing and data governance. Presents a balanced theory-practice focus and covers relational databases, NoSQL databases, data integration, data quality, data governance, big data, and data processing for analytics.

IE 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

IE 7200. Supply Chain Engineering. (4 Hours)
Presents modern quantitative techniques for designing, analyzing, managing, and improving supply chains using deterministic and probabilistic models. Topics include a macro view of supply chains, demand forecasting, aggregate planning, sequencing and scheduling, inventory analysis and control, materials requirement planning, pricing and revenue management, contracts decisions, transportation decisions, location and distribution decisions, supplier selection methods, and global supply chains.

Prerequisite(s): (IE 6200 with a minimum grade of C- or MATH 7241 with a minimum grade of C); OR 6205 with a minimum grade of C-

IE 7215. Simulation Analysis. (4 Hours)
Covers elementary queueing models, simulation and modeling, simulation model design, a survey of simulation languages with one language covered in detail, input data analysis and distribution fitting, model verification and validation, output analysis and transient/steady-state response, terminating/nonterminating systems, model experimentation and optimization, random number/random variate generation, and variance reduction techniques.

Prerequisite(s): IE 6200 with a minimum grade of C or MATH 7241 with a minimum grade of C

IE 7270. Intelligent Manufacturing. (4 Hours)
Covers advanced and emerging topics in manufacturing. Discusses fundamentals of digital and cyber-physical manufacturing including machine communication protocols, control architectures, agent-based and holonic systems, cloud-based and service-oriented manufacturing, and applications of artificial intelligence in manufacturing.

Prerequisite(s): IE 6200 with a minimum grade of C-

IE 7275. Data Mining in Engineering. (4 Hours)
Covers the theory and applications of data mining to support data analytics, data mining, machine learning, and artificial intelligence. Discusses the fundamental concepts and emerging technologies in database design and modeling, database systems, data storage, and the evolving world of data warehousing and data governance. Presents a balanced theory-practice focus and covers relational databases, NoSQL databases, data integration, data quality, data governance, big data, and data processing for analytics.

Prerequisite(s): IE 6200 with a minimum grade of C or MATH 7241 with a minimum grade of C
IE 7280. Statistical Methods in Engineering. (4 Hours)
Discusses statistical models for analysis and prediction of random phenomena. Topics include review of descriptive statistics and hypothesis testing, linear models, both regression and ANOVA. Introduces design of experiments. Covers experiments with single and multiple factors of interest, and considers experiments with high-order experimental restrictions.

Prerequisite(s): IE 6200 with a minimum grade of C or MATH 7241 with a minimum grade of C

IE 7285. Statistical Quality Control. (4 Hours)
Designed to study the fundamental concepts of quality planning and improvements. Studies analysis and application of modern statistical process control methods including cusum, EWMA, multivariate, and modified control charts. Covers inspection error and design of sampling plans. Topics include software quality assurance, and study of the concepts of Deming, Ishikawa, Feigenbun, and Taguchi’s approach in quality planning, organization, and improvement.

Prerequisite(s): IE 6200 with a minimum grade of C or MATH 7241 with a minimum grade of C

IE 7290. Reliability Analysis and Risk Assessment. (4 Hours)
Studies principles of the methods of risk assessment and reliability analysis including fault trees, decision trees, and reliability block diagrams. Discusses classical, Bayesian, and median rank methods for analysis of components and systems reliability. Presents various factors that determine the stress and strength of components and their impact on system reliability. Uses practical applications, examples, and problems to cover a broad range of engineering fields, such as mechanical, electrical, industrial, computer, structures, and automatic control systems.

Prerequisite(s): IE 6200 with a minimum grade of C or MATH 7241 with a minimum grade of C

IE 7315. Human Factors Engineering. (4 Hours)
Offers students an opportunity to acquire the necessary knowledge and skills to recognize and analyze existing or potential human factors problems and to identify, design, and possibly implement feasible solutions. Includes introduction to human factors and ergonomics; engineering anthropometry and biomechanics; physiology related to human factors and workstation design; cognition and information processing; decision making, attention, and workload; human error and accidents; human-machine interface design; controls and displays; and human factors applications in transportation, aerospace, consumer product design, and so forth.

IE 7374. Special Topics in Industrial Engineering. (4 Hours)
Offers topics of interest to the staff member conducting this class for advanced study. May be repeated without limit.

IE 7440. Industrial Engineering Leadership Challenge Project 1. (4 Hours)
Offers students an opportunity to develop and present a plan for the demonstration of a marketable technology product or prototype with an industrial-engineering focus. Constitutes the first half of a thesis-scale project in technology commercialization. Requires work/training with a sponsoring organization or employer to improve a process or develop a project that is of significant value to the organization and demonstrates a quantifiable market impact while enhancing the student’s technological and engineering depth and fostering the student’s leadership development.

IE 7442. Industrial Engineering Leadership Challenge Project 2. (4 Hours)
Continues IE 7440, further developing a thesis-scale project in technology commercialization. Offers students an opportunity to demonstrate their development of a marketable technology product or prototype with an industrial engineering focus and produce a written documentary report on the project to the satisfaction of an advising committee. Requires work/training with a sponsoring organization or employer to improve a process or develop a project that is of significant value to the organization and demonstrates a quantifiable market impact while enhancing the student’s technological and engineering depth and fostering the student’s leadership development.

Prerequisite(s): IE 7440 with a minimum grade of C-

IE 7615. Neural Networks and Deep Learning. (4 Hours)
Covers the theory and applications of neural networks in engineering. Reviews basics of machine learning, discusses important neural network architectures, and presents neural network training methods and algorithms. The specific neural network models covered in this course include feedforward neural networks such as deep learning architectures, radial basis function networks, support vector machines, self-organizing feature maps, and recurrent networks. Discusses neural network applications in several areas including manufacturing, healthcare, medicine, business, and diagnostics and prognostics.

IE 7945. Master’s Project. (4 Hours)
Offers theoretical or experimental work under individual faculty supervision.

IE 7962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

IE 7978. Independent Study. (1-4 Hours)
Offers theoretical or experimental work under individual faculty supervision. An independent study must be petitioned and approved by the academic advisor. The petition must clearly state the reason for taking the course; a brief description of goals; as well as the expected outcomes, deliverables, and grading scheme. Master’s degree students in thesis or project options are not eligible to take independent study.

IE 7990. Thesis. (1-8 Hours)
Offers analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. Requires first-year students to attend a graduate seminar program that introduces the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Requires successful completion of the seminar program. May be repeated without limit.

IE 7996. Thesis Continuation. (0 Hours)
Continues thesis work conducted under the supervision of a departmental faculty member.

IE 8960. Candidacy Preparation—Doctoral. (0 Hours)
Offers students an opportunity to prepare for the PhD qualifying exam under faculty supervision. Intended for students who have completed all required PhD course work and have not yet achieved PhD candidacy; students who have not completed all required PhD course work are not allowed to register for this course. May be repeated once.

IE 8986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.
IE 9000. PhD Candidacy Achieved. (0 Hours)
Indicates successful completion of program requirements for PhD candidacy.

IE 9986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

IE 9990. Dissertation Term 1. (0 Hours)
Offers dissertation supervision under individual faculty supervision.

Prerequisite(s): IE 9900 with a minimum grade of S

IE 9991. Dissertation Term 2. (0 Hours)
Offers dissertation supervision by members of the department.

Prerequisite(s): IE 9990 with a minimum grade of S

IE 9996. Dissertation Continuation. (0 Hours)
Offers continuing dissertation supervision under individual faculty supervision.

Prerequisite(s): IE 9991 with a minimum grade of S or Dissertation Check with a score of REQ

### Materials Engineering Courses

Search MATL Courses using FocusSearch (http://catalog.northeastern.edu/class-search/?subject=MATL)

MATL 5380. Particulate Materials Processing. (4 Hours)
Covers the processing of metallic and ceramic materials from particulate form. Includes particulate fabrication, characterization, handling, and consolidation for alloys, ceramics, and composites. Other topics include the principles of sintering in the absence and presence of liquid, advanced materials processing by rapid-solidification powder metallurgy, and the processing and structures of advanced ceramics.

Prerequisite(s): ME 2340 with a minimum grade of B or graduate program admission

MATL 6250. Soft Matter. (4 Hours)
Introduces the relatively young field of soft matter, which encompasses the physical description of various states of soft materials including liquids, colloids, polymers, foams, gels, granular materials, and a number of biological materials. Soft matter (also known as “soft condensed matter” or “complex fluids”) is less ordered than metals and oxides (hard condensed matter) and is more subject to thermal fluctuations and applied forces. Focuses on critical thinking, problem diagnosis, estimation, statistical analysis, and data-based decision making. Includes many in-class demonstrations from colloidal assembly to emulsion stability to cellular apoptosis. Highlights applications such as industrial processing, life sciences, and environmental remediation. Requires graduate study in related field or permission of instructor.

Introduces students to materials, devices, and mechanisms for clean and sustainable energy while providing a broad overview of energy storage and energy harvesting. Offers examples related to materials and devices used in energy storage and harvesting and delves into the principles that underlie the performance of advanced electrochemical storage and harvesting systems, for example solar energy and mechanical energy. Also covers efficient energy usage, such as energy-efficient lighting and building. Beyond course content, assignments provide students with opportunities to practice concise writing and peer review of abstracts, deliver scientific presentations, and explore optimum ways to present technical information. Students should have some prior knowledge of materials science, electrochemistry, and/or semiconductor physics.

MATL 6285. Structure, Properties, and Processing of Polymeric Materials. (4 Hours)
Provides an introduction to the organic chemistry of polymers, the effects of chemical composition on structure, melting point, and degradation, and the thermodynamics of polymers. Other topics include the mechanical properties of polymers, analysis and testing, the effects of processing on structures and properties, and the processing of industrial polymers, with applications.

MATL 6290. Fundamentals of Nanostructured Materials. (4 Hours)
Covers fundamentals of 1D and 2D nanomaterials such as carbon nanotubes, graphene, nanowires, 2D atomic crystals (transition metal dichalcogenides), nanostructured graphites and their novel physical properties, and related nanotechnology. Draws from various textbooks and from seminal scientific journal articles that paved the new era of nanomaterials and nanotechnology in the past couple of decades. Includes lab demonstrations and assignments for some nanomaterials synthesis and characterization. An introduction to materials science and engineering, solid-state physics, chemistry of materials, or any related materials engineering background is strongly recommended.

MATL 6962. Elective. (1–4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

MATL 7350. Mechanical Behavior and Strengthening Mechanisms. (4 Hours)
Covers dislocation theory and includes such topics as crystalline defects, elastic properties of dislocation, movement of dislocations, multiplication, intersection, annihilation, dislocations in crystalline materials, and dislocation arrays and crystal boundaries. Examines application of dislocation theory to microplasticity, dynamic recovery and recrystallization, strengthening mechanisms, and high-temperature deformation. Requires knowledge of materials science.

MATL 7355. Thermodynamics of Materials. (4 Hours)
Covers fundamentals of materials thermodynamics that encompass the first, second, and third laws, entropy, enthalpy, and free energy. Emphasis is on phase stability and equilibria, phase diagram computation with applications to phases in metals, alloys, and ionic compounds. Requires knowledge of thermodynamics course and materials science course.
MATL 7360. Kinetics of Phase Transformations. (4 Hours)
Focuses on the different types of phase transformations that occur in materials in relation to theory and practice. Topics include the diffusion equations, mechanisms of diffusion in crystalline solids, random walk theory, ionic conduction, high-diffusivity paths, diffusional and nondiffusional phase transformations, and microstructural evolution in material processing.
Prerequisite(s): MATL 7355 with a minimum grade of C-

MATL 7365. Properties and Processing of Electronic Materials. (4 Hours)
Focuses on electronic principles and the processing techniques underlying the processing/structure/property relationships of materials. Covers metals and alloys, semiconductors, and insulators. Topics include electronic structures, band theory, thermal, electrical, and magnetic properties; and processing methods including film deposition.

MATL 7374. Special Topics in Materials Engineering. (4 Hours)
Offers topics of interest to the staff member conducting this class for advanced study. May be repeated without limit.

MATL 7395. Fundamentals of Solidification. (4 Hours)
Discusses fundamental aspects of the solidification of metals and alloys in both conventional and advanced solidification processing. Topics covered include the nucleation and growth of solids, the morphological stability of the solid/liquid interface, capillarity effects, cellular and dendritic solidification, effects of diffusion and convection, eutectic solidification, and the solidification of undercooled melts.
Prerequisite(s): MATL 7360 with a minimum grade of C-

MATL 7945. Master’s Project. (4 Hours)
Offers theoretical or experimental work under individual faculty supervision.

MATL 7962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

MATL 7978. Independent Study. (1-4 Hours)
Offers theoretical or experimental work under individual faculty supervision. May be repeated without limit.

MATL 7990. Thesis. (1-8 Hours)
Offers analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. Requires first-year students to attend a graduate seminar program that introduces the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Requires successful completion of the seminar program. May be repeated without limit.

MATL 7996. Thesis Continuation. (0 Hours)
Offers continuing master’s thesis supervision under individual faculty supervision.

ME 5240. Computer Aided Design and Manufacturing. (4 Hours)
Covers basic aspects of computer graphics and CAD/CAM. Topics include hardware and software concepts, generic structure of CAD/CAM and its modules, and CAD/CAM database structure. Also covers the parametric representations of curves, surfaces, solids, and features that are widely used in existing commercial CAD/CAM systems. Discusses geometrical transformations, CAD/CAM data exchange formats, prototyping techniques, and PDM. Presents applications such as mass properties calculations, assemblies, mechanical tolerancing, simulation, finite element mesh generation, process planning and CAPP, CNC part programming, and Web-based CAD/CAM.
Prerequisite(s): GE 1110 with a minimum grade of B or GE 1501 with a minimum grade of B or graduate program admission

ME 5245. Mechatronic Systems. (4 Hours)
Covers integration of electronic/electrical engineering, computer technology, and control engineering with mechanical engineering to provide a self-contained, modern treatment of mixed systems along with their computer simulation and applications. Topics include mixed-systems integration; sensors, actuation systems; brief overview of dynamic systems modeling, response characterization, and closed-loop controllers; interfacing; data presentation systems and processes; microprocessors; real-time monitoring and control; and applications of mechatronic systems. The course also offers numerous MATLAB/ Simulink examples of select mechatronic systems and devices along with open-ended design projects and assignments.
Prerequisite(s): ME 4555 with a minimum grade of C or ME 5659 with a minimum grade of C

ME 5250. Robot Mechanics and Control. (4 Hours)
Covers kinematics and dynamics of robot manipulators, including the development of kinematics equations of manipulators, the inverse kinematics problem, and motion trajectories. Employs Lagrangian mechanics to cover dynamics of manipulators for the purpose of control. Covers control and programming of robots, steady state errors, calculations of servoparameters, robot vision systems and algorithms, as well as imaging techniques and the concept of mobile robots.
Prerequisite(s): ME 4555 with a minimum grade of D- or graduate program admission

ME 5374. Special Topics in Mechanical Engineering. (4 Hours)
Offers topics of current interest in mechanical engineering.

ME 5554. Robotics Sensing and Navigation. (4 Hours)
Examines the actual sensors and mathematical techniques for robotic sensing and navigation with a focus on sensors such as cameras, sonars, and laser scanners. These are used in association with techniques and algorithms for dead reckoning and visual inertial odometry in conjunction with GPS and inertial measurement units. Covers Kalman filters and particle filters as applied to the SLAM problem. A large component of the class involves programming in both the ROS and LCM environments with real field robotics sensor data sets. Labs incorporate real field sensors and platforms. Culminates with both an individual design project and a team-based final project of considerable complexity.
Prerequisite(s): (MATH 3081 with a minimum grade of D- or EECE 3468 with a minimum grade of D-; EECE 2160 with a minimum grade of D- or EECE 2210 with a minimum grade of D-) or graduate program admission
ME 5600. Materials Processing and Process Selection. (4 Hours)
Covers the fundamentals and usage of processes and techniques for bulk, thick film, thin film, and patterned structures. Covers techniques for improvement of mechanical or functional properties, for reliability, or for operation in harsh environments. Includes case studies for which processes are selected based on efficacy, material input, and cost. Systems studied include biocompatible implants and materials for the telecommunication, semiconductor, energy, and aerospace industries.

Prerequisite(s): ME 2340 with a minimum grade of D- or graduate program admission

ME 5650. Advanced Mechanics of Materials. (4 Hours)
Covers stress, strain, and deformation analysis of simple structures including beams, plates, and shells. Topics include classical theory of circular and rectangular plates; combined effects of bending and in-plane forces; buckling of plates; effects of shear deformation and of large deflections; membrane theory of shells; analysis of cylindrical shells; introduction to energy methods with applications to beams, frames, and rings; Ritz method; and the concept of stability as applied to one and two degree-of-freedom systems buckling of bars, frames, and rings. Permission of instructor required for undergraduate students.

ME 5653. Inelasticity. (4 Hours)
Introduces models suitable for rate-independent and rate-dependent plasticity, creep, viscoplasticity, viscoelasticity, and damage. Emphasizes the interdisciplinary nature of nonlinear constitutive theories. Offers students an opportunity to understand the phenomenological aspects of nonlinear and time-dependent material behavior and to obtain the ability to develop and use mathematical models that describe inelastic deformation behavior.

Prerequisite(s): ME 2355 with a minimum grade of D- or graduate program admission

ME 5655. Dynamics and Mechanical Vibration. (4 Hours)
Covers dynamic response of discrete and continuous media. Topics include work and energy, impulse and momentum, Lagrangian dynamics, free and forced response to periodic and transient excitations, vibration absorber, free and forced response of multiple degree-of-freedom systems with and without damping, method of modal analysis, vibrations of continuous media such as extensional, torsional, and bending vibrations of bars, and approximate methods of analysis. Permission of instructor required for undergraduate students.

ME 5657. Finite Element Method. (4 Hours)
Focuses on numerical techniques for solving engineering problems. Topics include introduction to the finite element method; methods of approximations and variational methods; Rayleigh-Ritz method and Galerkin formulation; interpolation functions; truss, beam, plate, shell, and solid elements; stiffness matrix and assembly of element equations; application of finite element method in fluid and heat transfer problems; linear, nonlinear, and transient problems; numerical integration and methods of solving systems of equations for static and dynamic problems; and use of a finite element general-purpose commercial package. Permission of instructor required for undergraduate students.

ME 5659. Control Systems Engineering. (4 Hours)
Covers concepts in design and control of dynamical systems. Topics include review of continuous-time system modeling and dynamic response; principles of feedback, classical and modern control analyses, and design techniques such as root locus, frequency response (e.g., Bode plots and Nyquist Criteria), and state-space feedback; dynamic analysis, design, and control of electromechanical systems; block diagram algebra or signal-flow graphs, effects of poles and zeros on system response characteristics; principles of controllability, observability, observer design, and pole placement techniques; introduction to adaptive and learning control and digital implementation of control algorithms.

ME 5665. Musculoskeletal Biomechanics. (4 Hours)
Using a three-part format, emphasizes the quantitative analysis of human musculoskeletal system statics and dynamics, including, in part I, gait analysis and estimation of the complex loads on human joint systems. Investigates how the form of connective tissue and bone is derived from function in part II, including a quantitative analysis of the material properties of bone, ligament, tendon, and cartilage. Working in groups in part III, students select and investigate a relevant, current topic in musculoskeletal biomechanics and present their findings to the class. Requires prior completion of an undergraduate course in biomechanics (Northeastern's BIOE 2350 or equivalent). Permission of instructor required for undergraduate students.
ME 5685. Solar Thermal Engineering. (4 Hours)
Develops a model for the hourly direct and diffuse radiation under a cover of scattered clouds and the transmission and absorption of this radiation by passive and active systems. Considers the design of air heating systems and the storage of the collected energy by a pebble bed, and considers elements of heater exchanger design. Makes a study of the economics of a domestic water and/or space heating system using f-chart analysis. Requires prior completion of ME 4570 or equivalent.

ME 5690. Gas Turbine Combustion. (4 Hours)
Offers students an opportunity to obtain an understanding of the basic physical, chemical, and aerodynamic processes associated with combustion in gas turbine engines and their relevance to combustor design and performance in applications ranging from aeronautical to power generation. Topics include the history and evolution of gas turbine engines, thermodynamic cycles, conventional and alternative aviation fuels, combustion fundamentals, fuel injection and atomization, advanced wall cooling techniques, mechanisms of combustion noise and approaches to noise control, and design and performance for ultra-low emissions.

Prerequisite(s): ME 4570 with a minimum grade of D- or graduate program admission

ME 5695. Aerodynamics. (4 Hours)
Focuses on topics of practical importance in applications of fluid mechanics to external flows over bodies. Covers compressible flow analysis in order to use the concepts of sound speed and Mach number and to design subsonic and supersonic nozzles, diffusers, and airfoils. Introduces normal and oblique shock waves and the Prandtl-Meyer expansion applied to supersonic flows over bodies and surfaces. Discusses Rayleigh and Fanno flows. Studies and applies the Bernoulli equation and potential flow theory to external flow analyses and the theory of lift generation on airfoils.

ME 5978. Independent Study. (1-4 Hours)
Offers theoretical or experimental work under individual faculty supervision. May be repeated without limit.

ME 5984. Research. (1-4 Hours)
Offers an opportunity to conduct research under faculty supervision. May be repeated without limit.

ME 6200. Mathematical Methods for Mechanical Engineers 1. (4 Hours)
Focuses on linear algebra, vector analysis, ordinary, and partial differential equations with mechanical engineering applications. Topics include linear algebra, linear vector spaces, matrices, and eigenvectors; vector field theory, curvilinear coordinates, and integral theorems; power series methods for second order linear ODEs, special functions, Sturm-Liouville theory, and orthogonal function expansions including Fourier series; second order linear PDEs including the Laplace, diffusion, and wave equations and solution techniques such as separation of variables and orthogonal function decomposition.

ME 6201. Mathematical Methods for Mechanical Engineers 2. (4 Hours)
Focuses on partial differential equations with applications to mechanical engineering. Includes function spaces; Sturm-Liouville theory; eigenfunction expansions; special functions; potential theory; solution of elliptic, parabolic, and hyperbolic PDEs using separation of variables; eigenfunction expansions, transform methods, and numerical methods.

Prerequisite(s): ME 6200 with a minimum grade of C-

ME 6260. Introduction to Microelectromechanical Systems (MEMS). (4 Hours)
Provides an introduction to microelectromechanical systems including principles of sensing and actuation, microfabrication technology for MEMS, noise concepts, and packaging techniques. Covers a wide range of disciplines, from electronics to mechanics, material properties, microfabrication technology, electromagnetics, and optics. Studies several classes of devices including inertial measurement devices, pressure sensors, rf components, and optical MEMS. Devotes the last third of the semester largely to design projects, involving design of MEMS devices to specifications in a realistic fabrication process.

ME 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

ME 7210. Elasticity and Plasticity. (4 Hours)
Covers stress and strain analysis in continuous media. Analyzes Cartesian tensors using indicial notation; stress and strain concepts; point stress and strain; relation to tensor concepts; equations of equilibrium and compatibility; constitutive laws for elastic, general, axisymmetric, plane stress, and plane strain formulations and solutions; the relation of elasticity to structural mechanics theories; physical basis of plastic/inelastic deformation of solids; and constitutive descriptions of plasticity including yielding, hardening rules, Prandtl-Reuss constitutive laws, and viscoplasticity.

ME 7232. Theory of Plates and Shells. (4 Hours)
Covers the mechanics of plates using classical theory (cylindrical bending, rectangular plates, and circular plates) and plate theory with shear deformation. Includes combined effects of bending and in-plane forces, buckling of plates, moderately large deflections, membrane theory of shells, analysis of thin cylindrical shells of revolution, and general theory of thin elastic shells.

Prerequisite(s): ME 6200 with a minimum grade of C- or (ME 6200 with a minimum grade of C-; ME 6201 with a minimum grade of C-)

ME 7238. Advanced Finite Element Method. (4 Hours)
Focuses on advanced techniques for solving engineering problems with the finite element method. Topics include review of finite element method; solution of linear and nonlinear algebraic problems; solution of dynamics problems; solution of contact problems using penalty and Lagrange multiplier methods; solution of nonlinear beams, plates, and shells; finite element formulations of solid continua including Lagrangian and updated Lagrangian formulations, material nonlinearities, and use of a commercially available finite element package.

Prerequisite(s): ME 7210 with a minimum grade of C-; ME 5657 with a minimum grade of C-

ME 7247. Advanced Control Engineering. (4 Hours)
Reviews topics from modern control engineering and characteristics of nonlinear systems. Covers fundamentals of Lyapunov theory and stability analysis as well as nonlinear feedback control systems using the Lyapunov method. Includes an introduction to advanced topics: variable structure system control, adaptive control-system analysis and design, robust adaptive control, and optimal and digital control. Requires prior completion of ME 5659 or a graduate-level course in modern control.
ME 7255. Continuum Mechanics and Nonlinear FEM. (4 Hours)
Covers the stresses, strains, and displacements in general continuous media. Topics include vector and tensor calculus; definitions of stress, strain, and deformation; kinematics of a continuous medium; material derivatives; rate of deformation tensor, finite strain, and deformation; Eulerian and Lagrangian formulations; geometric measures of strain; relative deformation gradient, rotation, and stretch tensors; compatibility conditions; general principles; conservation of mass; momentum principles; energy balance; constitutive theories of materials (i.e., heat conduction, fluid mechanics, elastic solids, nonlinear elasticity, inelastic deformation of solids); variational principles; introduction to the nonlinear finite element formulations for solids, such as nonlinearities in solid mechanics, governing equations (strong form and weak form), finite element approximation, Newton-Raphson method, Lagrangian finite elements (total and updated Lagrangian approaches), and solution procedure.

Prerequisite(s): ME 7210 with a minimum grade of C-

ME 7270. General Thermodynamics. (4 Hours)
Examines fundamentals of equilibrium thermodynamics. Topics include work, energy, heat, temperature, available energy, entropy, first and second law of thermodynamics, simple systems, closed and open systems, availability loss and irreversibility, heat engines, multicomponent systems, mixtures of gases, chemical reactions, and chemical equilibrium.

Prerequisite(s): ME 7210 with a minimum grade of C-

ME 7275. Essentials of Fluid Dynamics. (4 Hours)
Offers a fundamental course in fluid dynamics designed to prepare the student for more advanced courses in the thermofluids curriculum while providing a strong background in fluid mechanics. Topics include Cartesian tensors; differential and integral formulation of the equations of conservation of mass, momentum, and energy; molecular and continuum transport phenomena; the Navier-Stokes equations; vorticity; inviscid incompressible flow, the velocity potential, and Bernoulli’s equation; viscous incompressible flow; the stream function; some exact solutions; energy equation including heat conduction and viscous dissipation, low Reynolds number flow, exact and approximate approaches to laminar boundary layers in high Reynolds number flows, stability of laminar flows and the transition to turbulence, and treatment of incompressible turbulent mean flow; and internal and external flows.

Prerequisite(s): ME 6200 with a minimum grade of C-

ME 7278. Complex Fluids. (4 Hours)
Covers the physical phenomena in complex fluids, including polymeric liquids, structured fluids, and cells and biofluids undergoing deformation and flow. Focuses on kinematics and material functions for complex fluids; techniques of viscometry, rheometry, and linear viscoelastic measurements for such fluids; mathematical expressions and constitutive laws describing rich and complex behavior of complex fluids under different flow conditions; continuum mechanics frame invariance and convected derivatives for finite strain viscoelasticity; differential and integral constitutive equations for viscoelastic fluids; the roles of non-Newtonian behavior, linear viscoelasticity, and time- and rate-dependent properties of a wide range of fluids, from cells and saliva, to oil and polymers, with examples on normal stresses; elastic recoil; stress relaxation in processing flows; molecular theories for dynamics of complex fluids; and more.

Prerequisite(s): ME 7275 with a minimum grade of C-

ME 7285. Heat Conduction and Thermal Radiation. (4 Hours)
Emphasizes analytical techniques in conduction and radiative transfer. Topics include formulation of steady- and unsteady-state one-dimensional and multidimensional heat conduction problems, solution techniques for linear problems including the method of separation of variables, Laplace transforms and integral transforms, approximate analytical methods, phase change problems, and nonlinear problems. Offers an introduction to thermal radiation heat transfer including the electromagnetic background of radiation, nature of thermal radiation, radiation intensity, black body intensity, and radiation through nonparticipating media. Discusses the fundamentals of radiation in absorbing, emitting, and scattering media including the equation of radiative transfer with methods of solution, pure radiative transfer in participating media, and interaction of radiation with conduction and/or convection. Requires undergraduate heat transfer course.

Prerequisite(s): ME 6200 with a minimum grade of C-

ME 7290. Convective Heat Transfer. (4 Hours)
Focuses on the fundamental equations of convective heat transfer including heat transfer in incompressible external laminar boundary layers, integral boundary layer equations, laminar forced convection in internal flows, and turbulent forced convection in internal and external flows. Develops analogies between heat and momentum transfer including the Reynolds, Taylor, and Martinelli analogies. Covers natural convection, heat transfer in high-speed flow, and transient forced convection.

Prerequisite(s): ME 7275 with a minimum grade of C-

ME 7295. Multiscale Flow and Transport Phenomena. (4 Hours)
Covers the fundamentals of flow and transport phenomena in multiscale systems. Begins with an overview of momentum, energy, and mass transport phenomena, emphasizing microscale phenomena such as the slip flow regime. Introduces other driving forces and transport processes relevant to microscale flows, such as surface tension (capillarity) and electrokinetics. These basic concepts provide the preamble for the presentation of the more complex multiphase and porous flow transport behavior. This course material is supplemented with class projects and presentations by the students. Requires knowledge of thermodynamics, fluid mechanics, and heat transfer.

ME 7300. Combustion and Air Pollution. (4 Hours)
Deals with the formation of pollutants during combustion processes and their subsequent transformations in the atmosphere. Emphasis is on the effects of design and operating parameters of combustion devices on the nature and composition of exhaust gases, improvements, postcombustion treatment of effluent gases, atmospheric chemistry, and atmospheric transport of pollutants, smog formation, acid rain, ozone formation, and destruction.

ME 7305. Fundamentals of Combustion. (4 Hours)
Provides an advanced course that is a comprehensive treatment of the problems involved in the combustion of liquid, gaseous, and solid fuels in both laminar and turbulent flow. Discusses the fundamentals of chemical kinetics. Examines the equations for the transport of mass, momentum, and energy with chemically reacting gases. Topics include diffusion and premixed flames, combustion of droplets and sprays, and gasification and combustion of coal.

Prerequisite(s): ME 7270 with a minimum grade of C-
ME 7310. Computational Fluid Dynamics with Heat Transfer. (4 Hours)
Offers an advanced course in numerical methods applied to fluid flows with heat transfer. Topics include finite difference and finite volume methods for solving partial differential equations, with particular emphasis on the equations of fluid dynamics and heat transfer. Other topics include mathematical properties of partial differential equations, accuracy and stability analysis of numerical solutions, applications to a variety of fluid dynamics and heat transfer problems, grid generation, and an introduction to turbulence modeling. Requires knowledge of computer programming.

Prerequisite(s): ME 7275 with a minimum grade of C-

ME 7374. Special Topics in Mechanical Engineering. (4 Hours)
Offers topics of interest to the staff member conducting this class for advanced study. May be repeated without limit.

ME 7440. Mechanical Engineering Leadership Challenge Project 1. (4 Hours)
Offers students an opportunity to develop and present a plan for the demonstration of a marketable technology product or prototype with a mechanical engineering focus. Constitutes the first half of a thesis-scale project in technology commercialization. Requires work/training with a sponsoring organization or employer to improve a process or develop a project that is of significant value to the organization and demonstrates a quantifiable market impact while enhancing the student's technological and engineering depth and fostering the student's leadership development.

Prerequisite(s): ME 7440 with a minimum grade of C-

ME 7442. Mechanical Engineering Leadership Challenge Project 2. (4 Hours)
Continues ME 7440, a thesis-scale project in technology commercialization. Offers students an opportunity to demonstrate their development of a marketable technology product or prototype with a mechanical engineering focus and to produce a written documentary report on the project to the satisfaction of an advising committee. Requires work/training with a sponsoring organization or employer to improve a process or develop a project that is of significant value to the organization and demonstrates a quantifiable market impact while enhancing the student's technological and engineering depth and fostering the student's leadership development.

Prerequisite(s): ME 7440 with a minimum grade of C-

ME 7945. Master's Project. (4 Hours)
Offers theoretical or experimental work under individual faculty supervision.

ME 7962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

ME 7978. Independent Study. (1-4 Hours)
Offers theoretical or experimental work under individual faculty supervision. An independent study must be petitioned and approved by the academic advisor. The petition must clearly state the reason for taking the course; a brief description of goals; as well as the expected outcomes, deliverables, and grading scheme. Master's degree students in thesis or project options are not eligible to take independent study.

ME 7990. Thesis. (1-8 Hours)
Offers analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. Requires first-year students to attend a graduate seminar program that introduces the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Requires successful completion of the seminar program. May be repeated without limit.

ME 7996. Thesis Continuation. (0 Hours)
Continues thesis work conducted under the supervision of a departmental faculty member.

ME 8960. Candidacy Preparation—Doctoral. (0 Hours)
Offers students an opportunity to prepare for the PhD qualifying exam under faculty supervision. Intended for students who have completed all required PhD course work and have not yet achieved PhD candidacy; students who have not completed all required PhD course work are not allowed to register for this course. May be repeated once.

ME 8986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

ME 9000. PhD Candidacy Achieved. (0 Hours)
Indicates successful completion of program requirements for PhD candidacy.

ME 9986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

ME 9990. Dissertation Term 1. (0 Hours)
Offers dissertation supervision under individual faculty supervision.

Prerequisite(s): ME 9000 with a minimum grade of S

ME 9991. Dissertation Term 2. (0 Hours)
Offers dissertation supervision by members of the department.

Prerequisite(s): ME 9990 with a minimum grade of S

ME 9996. Dissertation Continuation. (0 Hours)
Offers continuing dissertation supervision under individual faculty supervision.

Prerequisite(s): ME 9991 with a minimum grade of S or Dissertation Check with a score of REQ

Mechanical and Industrial Engineering Courses
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MEIE 6800. Technical Writing and Professional Development. (0 Hours)
Offers students an opportunity to increase their professional communication skills through intensive verbal practice and technical writing application. Students work together in groups and individually to practice verbal and written communication that can increase their English competency and comfort level for work in the United States. Passing of the language assessment at the end of this course can be used to waive the TOEFL/IELTS requirements for co-op eligibility within the Department of Mechanical and Industrial Engineering. This course does not count toward graduation requirements.
MEIE 6830. Graduate Traineeship 1, Technical Writing and Communications. (2 Hours)
Focuses on technical writing. Covers writing and preparation tips for technical papers. Includes effective communications, such as Ph.D. proposal preparation and presentation, and technical seminar presentation tips.

MEIE 6850. Research Seminar in Mechanical and Industrial Engineering. (0 Hours)
Offers a research seminar presenting topics of current interest in a variety of areas in mechanical and industrial engineering. May be repeated without limit.

MEIE 6860. Graduate Traineeship 2, Research Ethics and Professional Development. (2 Hours)
Focuses on responsible conduct of research, research misconduct (plagiarism, falsification, and fabrication), research ethics, and professional and personal development. Offers optional modules on grant proposal preparation, academic career preparation, faculty and professional jobs search, research and teaching statements preparation, how to become an effective teacher, mentorship, entrepreneurship, and industry insights and real-world experiences.

Prerequisite(s): MEIE 6830 with a minimum grade of C-