# Mechanical Engineering (ME)

## Courses

**ME 1990. Elective. (1-4 Hours)**
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

**ME 2340. Introduction to Material Science. (4 Hours)**
Introduces the materials science field, which emphasizes the structure-processing property-performance relationships for various classes of materials including metals, ceramics, polymers, electronic materials, and magnetic materials. Topics include crystallography, structure of solids, imperfections in crystals, mechanical properties, dislocation theory, slip, strengthening mechanisms, phase equilibrium, phase transformations, diffusion, thermal and optical physical properties, and electrical and magnetic properties. Issues associated with materials selection, including economic and environmental consequences of materials choices, are also addressed. Laboratory experiments, with written memo and report submissions, are required. Includes individual and team-based projects.

**Prerequisite(s):** (CHEM 1151 with a minimum grade of D- or CHEM 1161 with a minimum grade of D- or CHEM 1211 with a minimum grade of D- ); (ENGL 1102 with a minimum grade of C or ENGL 1111 with a minimum grade of C or ENGW 1102 with a minimum grade of C or ENGW 1111 with a minimum grade of C or ENGW 1114 with a minimum grade of C )
**Corequisite(s):** ME 2341
**Attribute(s):** NUpath Writing Intensive

**ME 2341. Lab for ME 2340. (1 Hour)**
Accompanies ME 2340. Covers topics from the course through various activities.

**Corequisite(s):** ME 2340

**ME 2350. Statics. (4 Hours)**
Introduces the vector representation of force and moment, the equivalent force systems, free body diagrams, and equations of equilibrium. Discusses centroids and center of gravity of rigid bodies. Examines applications to beams, trusses, and pin-connected frames and elementary concepts of friction. Discusses variation of internal forces and moments for beams and cable systems. Theory of dry friction is implemented in simple machine elements. Introduces the concepts of virtual work and potential energy. Includes a design project that demonstrates the fundamental concepts of equilibrium.

**Prerequisite(s):** (PHYS 1151 with a minimum grade of D- or PHYS 1161 with a minimum grade of D- or PHYS 1171 with a minimum grade of D- ); MATH 1342 with a minimum grade of D-

**ME 2355. Mechanics of Materials. (4 Hours)**
Discusses concepts of stress and strain; transformation of stress and strain at a point; stress-strain relations material properties; second moments of cross-sectional areas; stresses and deformations in simple structural members due to axial torsional, and flexural loading for statically determinate and indeterminate cases; design of beams under combined loading; and stability of structures and buckling of columns with various supports. Laboratory experiments and written reports are required.

**Prerequisite(s):** ME 2350 with a minimum grade of D- or CIVE 2221 with a minimum grade of D-
**Corequisite(s):** ME 2356

**ME 2356. Lab for ME 2355. (1 Hour)**
Accompanies ME 2355. Covers topics from the course through various activities.

**Corequisite(s):** ME 2355

**ME 2380. Thermodynamics. (4 Hours)**
Defines and calculates thermodynamic properties such as energy, entropy, temperature, and pressure. Work and heat interactions are defined. The first and second laws of thermodynamics and concepts of thermodynamic equilibrium are introduced. Conservation of energy and mass and the entropy balance relation are discussed for open and closed systems. Irreversibility, energy, and the energy balance relation are introduced and applied in analyzing thermodynamic systems. Fundamentals of thermodynamics are used to model power generation and refrigeration systems. Covers thermodynamics of nonreacting gas mixtures with applications to air-water vapor mixtures for air-conditioning systems.

**Prerequisite(s):** MATH 2321 with a minimum grade of D- ; (PHYS 1151 with a minimum grade of D- or PHYS 1161 with a minimum grade of D- )
**Corequisite(s):** ME 2381

**ME 2381. Recitation for ME 2380. (0 Hours)**
Accompanies ME 2380. Offers demonstrations and and opportunities for problem solving.

**Corequisite(s):** ME 2380

**ME 2990. Elective. (1-4 Hours)**
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

**ME 3455. Dynamics. (4 Hours)**
Treats the kinematics and kinetics of particles by using force, mass and acceleration, and energy and momentum methods. Investigates kinematics of rigid bodies in general plane motion. Introduces mass moment of inertia; kinetics of rigid bodies by using force-mass-acceleration, work and energy, and impulse and momentum methods; and free and forced vibration of undamped and damped one-degree-of-freedom systems.

**Prerequisite(s):** (ME 2350 with a minimum grade of D- or CIVE 2221 with a minimum grade of D- ); MATH 2341 with a minimum grade of D-
**Corequisite(s):** ME 3456

**ME 3456. Lab for ME 3455. (1 Hour)**
Accompanies ME 3455. Covers topics from the course through various activities.

**Corequisite(s):** ME 3455

**ME 3460. Robot Dynamics and Control. (4 Hours)**
Covers fundamental components and mechanisms of robotic systems and their multidisciplinary nature. Introduces the robot's kinematics, dynamics, and control. Presents a quick overview of forward and inverse kinematics, robot dynamics, as well as path planning and control techniques. Topics also include dynamic modeling and analysis of mechanically, electrically, and magnetically driven hydraulic and pneumatic drives; kinematics and motion analysis of linkages; as well as sensing technologies (e.g., position, linear and angular displacements, velocity and acceleration, force and torque sensors) used in robotic systems. Presents kinematics and control of automatic machinery and manufacturing processes, automatic assembly, and inspection robotic systems as representative examples.

**Prerequisite(s):** CS 3650 with a minimum grade of D- or MATH 2331 with a minimum grade of D- or MATH 2341 with a minimum grade of D-

**ME 3465. Introduction to Flight. (4 Hours)**
Presents the fundamentals of aerospace engineering at the introductory level. Covers historical developments and background associated with aerospace engineering in parallel with technical discussions. Introduces thermodynamic analyses of flowing gasses and derivations of the governing equations accompanying the anatomy of airplanes and space vehicles. Studies basics of fluid dynamics such as continuity, momentum and energy equations, and isentropic flows. Discusses shapes, designs, characteristics, and usage of different aerodynamic shapes and their corresponding lift, drag, and momentum coefficients. Explores the elements of airplane performance in level flight, takeoff, and landing. Covers the introduction to the dynamics of flight, stability, and control of the airplanes and astronautic vehicles. Designed for students interested in an introductory course in aerospace engineering and the fundamentals and historical traditions of aerodynamics of flight.

**Prerequisite(s):** MATH 2321 with a minimum grade of D- ; (PHYS 1151 with a minimum grade of D- or PHYS 1161 with a minimum grade of D- ); ME 2380 with a minimum grade of D-

**ME 3470. Aeronautical Propulsion. (4 Hours)**
Introduces basics for the analysis and design of aircraft engines and reviews the history of gas turbine engines. Introduces general conservation laws of mass, energy, and momentum for compressible flows and application to quasi-one-dimensional internal flows and shock waves in external flows. Reviews thrust and thermodynamic performance of the engines. Discusses designing parameters of the inlets in detail. Uses the principles of chemical equilibrium to calculate the composition of combustion products in a chemical reaction to find flame temperature and energy release, which drive the design of combustors and afterburners. Introduces physics and aerodynamics of compressors and turbines, and reviews basics of gas turbine blades cooling.

**Prerequisite(s):** ME 2380 with a minimum grade of D-

**ME 3475. Fluid Mechanics. (4 Hours)**
Studies fundamental principles in fluid mechanics. Topics include hydrostatics (pressure distribution, forces on submerged surfaces and buoyancy); Newton's law of viscosity; dimensional analysis; integral forms of basic laws (conservation of mass, momentum, and energy); pipe flow analysis; differential formulation of basic laws including Navier-Stokes equations; and the concept of boundary layer and drag coefficient. Includes a team-based independent project.

**Prerequisite(s):** MATH 2321 with a minimum grade of D- ; ME 2380 with a minimum grade of D-

**ME 3480. International Applications of Fluid Mechanics. (4 Hours)**
Studies fundamental principles in fluid mechanics in an international setting. Students have an opportunity to travel to a foreign locale to develop theoretical understanding while experiencing the issues that affect applications of fluids engineering in a culture and environment different from their own. Topics include hydrostatics (pressure distribution, forces on submerged surfaces, and buoyancy); Newton's law of viscosity; dimensional analysis; integral forms of basic laws (conservation of mass, momentum, and energy); pipe flow analysis; differential formulation of basic laws including Navier-Stokes equations; and the concept of boundary layer and drag coefficient. Includes a team-based independent project that focuses on applications that allow students to delve into issues that affect engineering and technology development in their host country.

**Prerequisite(s):** MATH 2321 with a minimum grade of D- ; ME 2380 with a minimum grade of D-

**ME 3990. Elective. (1-4 Hours)**
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

**ME 4505. Measurement and Analysis with Thermal Science Application. (4 Hours)**
Introduces basic measurements and data analysis techniques. Offers students an opportunity to become familiar with various types of measurement systems and to set up and perform experiments according to a given procedure. Covers basic measurement methods of rotational frequency; temperature, pressure, and power; and analog-to-digital conversion techniques and data acquisition. Data analysis topics include statistical analysis of data, probability and inherent uncertainty, basic measurement techniques, primary and secondary standards, system response characteristics, and computerized data acquisition methods. Includes experiments in thermodynamics, fluid mechanics, and heat transfer. Topics include cycle performance, flow discharge coefficient and heat transfer coefficient measurements, and psychometric applications in the air-conditioning field.

**Prerequisite(s):** ME 2380 with a minimum grade of D-
**Corequisite(s):** ME 4506
**Attribute(s):** NUpath Analyzing/Using Data

**ME 4506. Lab for ME 4505. (1 Hour)**
Accompanies ME 4505. Covers topics from the course through various activities.

**Corequisite(s):** ME 4505

**ME 4508. Mechanical Engineering Computation and Design. (4 Hours)**
Highlights the role of finite element analysis in product development. Introduces the theory of finite elements in elastic/plastic, static, and transient problems. Emphasis is on solid modeling in design using available commercial finite element software. Also covers other numerical techniques such as finite difference schemes in the solution of systems of partial differential equations, and numerical solution to systems of linear and nonlinear equations.

**Prerequisite(s):** (ME 2355 with a minimum grade of D- ; MATH 2341 with a minimum grade of D- ) or (BIOE 2350 with a minimum grade of D- ; (GE 2361 with a minimum grade of D- or MATH 2341 with a minimum grade of D- ))

**ME 4520. Mechanical Vibration. (4 Hours)**
Covers concepts in mechanical vibration analysis. Topics include basic concepts of vibrations, vibration problems vs.dynamic problems, linear vs. nonlinear vibrations, vibrational elements, harmonic motion; free vibration of undamped SDOF systems, stability, Rayleigh's energy method, free vibration of viscously damped SDOF systems, free vibration of damped SDOF systems with Coulomb and hysteretic damping; harmonically forced SDOF systems, harmonic motion of base and rotating unbalance, forced vibrations of Coulomb-damped and hysteresis-damped SDOF systems, general (nonperiodically) forced vibrations; free and forced vibrations of 2 DOF systems, damped vibrations, general eigenvalue problem, vibration measuring instruments; tuned vibration absorbers, passive and active vibration absorbers, vibration-control systems (passive, semiactive, and active), modal analysis software, and illustrative examples.

**Prerequisite(s):** MATH 2341 (may be taken concurrently) with a minimum grade of D- ; ME 3455 (may be taken concurrently) with a minimum grade of D-

**ME 4550. Mechanical Engineering Design. (4 Hours)**
Explores development of the mechanical design process and its open-ended nature. Reviews fundamentals of stress and theories of failure including fatigue considerations in the analysis of various machine components. Treatment is given to shafts, springs, screws, connections, lubrications, bearings, gears, and tolerances. Includes team-based design projects that involve modeling and the design process.

**Prerequisite(s):** ME 2355 with a minimum grade of D-

**ME 4555. System Analysis and Control. (4 Hours)**
Presents the theoretical backgrounds for the analysis and design of simple feedback control systems, differential equations, and Laplace transforms. Treats system modeling, linear approximations, transfer functions, and block diagrams; and transient and frequency response and stability-frequency domain and root locus methods. Other topics may include linear systems with time lag and relay servomechanisms with small nonlinearities.

**Prerequisite(s):** ME 3455 with a minimum grade of D- or (BIOE 2350 with a minimum grade of D- ; BIOE 3380 with a minimum grade of D- )

**ME 4565. Introduction to Computational Fluid Dynamics. (4 Hours)**
Introduces numerical methods applied to solve fluid flow problems. Includes basic mathematics and physics related to computational fluid dynamics (CFD), together with practical assignments that use commercial CFD packages. Emphasizes finite difference and finite volume methods. Other topics include mathematical properties of partial differential equations, accuracy and stability analysis of numerical solution, CFD verification and validation, application to variety of fluid dynamics problems, grid generation, and turbulence modeling.

**Prerequisite(s):** (ME 3475 with a minimum grade of D- or ME 3480 with a minimum grade of D- or BIOE 3310 with a minimum grade of D- ); (MATH 2341 with a minimum grade of D- or GE 2361 with a minimum grade of D- )

**ME 4570. Thermal Systems Analysis and Design. (4 Hours)**
Introduces theories of thermal energy transport, including conduction, convection, and thermal radiation, and the design of thermal systems. Solution methods are developed for steady-state and transient conduction problems including thermal circuit analogies, internal energy sources and extended surfaces. Convective heat transfer mechanisms are introduced and correlations to evaluate the heat transfer coefficient are discussed. Methodologies for calculating the thermal radiation heat transfer between surfaces are introduced. These theories are integrated with thermodynamics and fluid mechanics in the design of thermal systems, including heat exchangers. Includes an open-ended design project and students are expected to use computational methods throughout the course.

**Prerequisite(s):** ME 2380 with a minimum grade of D- ; (ME 3475 with a minimum grade of D- or ME 3480 with a minimum grade of D- )

**ME 4670. Internal Combustion Engine. (4 Hours)**
Presents the concepts and theories of operation of internal combustion engines based upon the fundamental engineering sciences of thermodynamics, gas dynamics, heat transfer, and mechanics. Discusses the design and operating characteristics of conventional spark-ignition, compression-ignition, Wankel, and stratified charge. Explores the relationship between vehicle load and engine load through differential and transmission gear-ratio selections. Includes laboratory experiments.

**Prerequisite(s):** ME 2380 with a minimum grade of D- ; (ME 3475 with a minimum grade of D- or ME 3480 with a minimum grade of D- )

**ME 4699. Special Topics in Mechanical Engineering. (4 Hours)**
Focuses on an advanced mechanical engineering project agreed upon between the student and instructor. May be repeated without limit.

**ME 4970. Junior/Senior Honors Project 1. (4 Hours)**
Focuses on in-depth project in which a student conducts research or produces a product related to the student’s major field. Combined with Junior/Senior Project 2 or college-defined equivalent for 8-credit honors project. May be repeated without limit.

**ME 4971. Junior/Senior Honors Project 2. (4 Hours)**
Focuses on second semester of in-depth project in which a student conducts research or produces a product related to the student’s major field. May be repeated without limit.

**Prerequisite(s):** ME 4970 with a minimum grade of D-

**ME 4990. Elective. (1-4 Hours)**
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

**ME 4991. Research. (4 Hours)**
Offers an opportunity to conduct research under faculty supervision. May be repeated once.

**Attribute(s):** NUpath Integration Experience

**ME 4992. Directed Study. (1-4 Hours)**
Offers theoretical or experimental work under the direction of members of the department on a chosen topic. Course content depends on instructor. May be repeated without limit.

**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 software 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 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 5520. Fundamentals and Applications of Optics and Photonics. (4 Hours)**
Introduces the basic knowledge and recent development in the field of optics and photonics. Explains the property of light from four perspectives: geometric optics, wave optics, electromagnetic optics based on Maxwell’s equations, as well as quantum mechanics. Discusses the interactions between light and materials, ranging from bulk to nano and molecular level. Presents representative applications, particularly in the domain of mechanical engineering, which include imaging and microscopy, photolithography, 3D laser printing, solar desalination, radiative cooling, optical tweezers to manipulate micro/nano objects, and solar sails for spacecraft propulsion.

**Prerequisite(s):** (PHYS 1155 with a minimum grade of D or PHYS 1165 with a minimum grade of D ) or graduate program admission

**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.

**ME 5620. Fundamentals of Advanced Materials. (4 Hours)**
Offers a deep dive into the interdisciplinary field of materials science that addresses the discovery, design, and prediction of new materials, with an emphasis on solids. Offers students an opportunity to gain knowledge and practice in issues of materials science. Consists of fundamentals, properties (emphasis on electronic properties), applications, and advanced topics. Provides specific readings from the literature assigned to support the in-class lectures. Offers a variety of opportunities to practice and demonstrate comprehension and learning.

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

**ME 5630. Nano- and Microscale Manufacturing. (4 Hours)**
Introduces students to nano- and microscale manufacturing of applications in electronics, energy, materials, and life sciences. Offers students an opportunity to understand conventional fabrication approaches to making today's consumer electronics (top-down). Presents new and emerging bottom-up manufacturing approaches, including additive manufacturing for making electronics and other applications.

**ME 5640. Additive Manufacturing. (4 Hours)**
Discusses fundamentals, process characteristics, and practical applications of various additive manufacturing (AM) processes. Covers digital workflow for AM, implications of AM on design, material for AM and material properties, energy sources and interaction with materials, AM processes, process characteristics and capabilities, process models, design of experiments and Taguchi methods for AM process parameter optimization, postprocessing of AM parts, process defects, and the Ansys AM module.

**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 5654. 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.

**Prerequisite(s):** ME 4550 with a minimum grade of B- 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 1. (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 5658. Continuum Mechanics. (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 4550 with a minimum grade of B- or graduate program admission

**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 designs, and pole placement techniques; introduction to adaptive and learning control and digital implementation of control algorithms.

**ME 5661. Composite Materials. (4 Hours)**
Discusses the structure, composition, deformation, and failure analysis of composite materials. Topics include introduction to composite materials, constitutive relations and mechanical properties of particulate reinforced composites, anisotropic lamina and cellular composites, and micromechanical models of laminated composites; mechanical behaviors and properties of cellular composites and sandwich composites; and their design, manufacturing, computational modeling, and mechanical experimental characterizations.

**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 5680. Applications of Concentrating Solar Thermal Technologies. (4 Hours)**
Focuses on the analysis of concentrating solar thermal technologies at the design and system levels. Discusses simulation techniques to calculate the performance of concentrating solar power (CSP) technologies, including comparisons to other solar systems in terms of efficiency and cost. Includes topics involving solar systems designs of heliostats, concentrating dishes, and troughs. Presents geometric optics and convolution techniques and integrates them with incident solar predictions to calculate the performance of CSP systems. Covers the control and tracking systems required to maximize performance; the thermal effects that occur at the high solar energy fluxes and high temperatures in CSP systems; and the potential advantages in energy generation, energy storage, and biogas manufacturing and means to predict them.

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

**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 5700. Multiphase Transport. (4 Hours)**
Introduces multiphase flow and heat transfer. Presents insights of multiphase transport systems, tools to analyze the system in different scenarios, and exposes students to research frontiers and real-world applications. Topics include the fundamental principles governing the multiphase systems, capillary effect involving drops and bubbles, the dynamics of particles dispersed in fluid, phase change and heat transfer, and applications of multiphase systems. Discusses research topics at the frontier in this area.

**Prerequisite(s):** (ME 4570 with a minimum grade of D or CHME 3312 with a minimum grade of D ) or graduate program admission

**ME 5976. Directed Study. (1-4 Hours)**
Offers students an opportunity to conduct theoretical or experimental work under the direction of members of the department on a chosen topic. Course content depends on instructor. May be repeated up to 11 times for a maximum of 12 semester hours.

**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 6250. Wearable Robotics. (4 Hours)**
Presents the design, control, and evaluation of prosthetics and exoskeletons based on core concepts in human movement, with special focus on assisting and rehabilitating pathological gait. Introduces the biological systems that enable human movement, biomechanical modeling and simulation, actuation design, control architectures, and key considerations for interfacing mechanical systems with the human body. Culminates with group projects in which teams either design, control, and analyze a wearable robotic system or write a perspective on a subtopic within the field of wearable robotics.

**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 6320. Mechanics of Soft Materials. (4 Hours)**
Covers the fundamental continuum mechanics theory of finite elastic deformation in soft materials formed by crosslinked polymer networks such as gels and elastomers, as well as the coupling effects from other physical fields (chemical, electrical, thermal, etc.) that enable novel functionalities. Emphasizes continuum mechanics, interfacing statistical mechanics, polymer physics, thermodynamics, and other chemical and physical disciplines. Lectures incorporate state-of-the-art research in mechanics of soft materials to offer students a broad and contemporary overview of the field.

**Prerequisite(s):** ME 6200 with a minimum grade of B

**ME 6340. Mechanics in New Engineering Frontiers. (4 Hours)**
Offered for graduate students who are interested in mechanics in emerging engineering frontiers including mechanical metamaterials, bio-inspired engineering, additive manufacturing, and smart and functional materials. Provides an overview of the new interdisciplinary fields and the application of mechanics in these fields. Also examines advanced theories in mechanics and their applications in new engineering frontiers. Mechanics together with modern engineering technologies including computer aided design, computer simulations, and 3D/4D printing serve as tools to explore engineering solutions. Students practice how to apply physical principles to engineering innovations.

**Prerequisite(s):** (ME 5650 with a minimum grade of B or ME 5654 with a minimum grade of B or ME 7210 with a minimum grade of B ); ME 6200 with a minimum grade of B

**ME 6360. Boundary Value Problems in Linear Elasticity. (4 Hours)**
Introduces the governing equations of linear isotropic elasticity and solves the boundary value problems associated with two-dimensional (planar) and three-dimensional elasticity. In two-dimensional elasticity, presents the use of Airy stress function in Cartesian and polar coordinates; asymptotic fields at discontinuities; forces and dislocations; contact and crack problems; and rotating and accelerating bodies. In three-dimensional elasticity, presents Galerkin and Papkovich-Neuber solutions; singular solutions; spherical harmonics; thermoelasticity; axisymmetric contact and crack problems; and axisymmetric torsion.

**Prerequisite(s):** ME 6200 with a minimum grade of B ; (ME 5650 with a minimum grade of B or ME 5654 with a minimum grade of B )

**ME 6420. Advanced Materials and Technologies in Manufacturing. (4 Hours)**
Provides integrated coverage of how material properties influence process selection, how processes enable new designs, and how sustainable processes can be developed. Offers practical knowledge of contemporary manufacturing techniques along with skills to evaluate interactions between materials, process mechanisms, equipment, automation, and environmentally responsible practices.

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

**ME 7238. Finite Element Method 2. (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 5654 with a minimum grade of C- ; ME 5657 with a minimum grade of C-

**ME 7247. Advanced Control Engineering. (4 Hours)**
Covers topics in modern control engineering, including optimal control, optimal filtering, robust/nonlinear control, and model predictive control. The main theme of the course is how uncertainty propagates through dynamical systems and how it can be managed in the context of a control system. Emphasizes modern tools from computational linear algebra and convex optimization. Uses MATLAB for implementation.

**Prerequisite(s):** EECE 5580 with a minimum grade of C- or EECE 5580 with a minimum grade of C- or EECE 7200 with a minimum grade of C- or ME 5659 with a minimum grade of C- or ME 5659 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.

**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.

**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 7976. Directed Study. (1-4 Hours)**
Offers independent work under the direction of members of the department on a chosen topic. Course content depends on instructor. May be repeated up to eight times for a maximum of 8 semester hours.

**ME 7986. Research. (0 Hours)**
Offers students an opportunity to conduct full-time research under faculty supervision.

**ME 7990. Thesis. (4 Hours)**
Offers analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree.

**Prerequisite(s):** ME 7945 with a minimum grade of C-

**ME 7996. Thesis Continuation - Half-Time. (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