MECHANICAL ENGINEERING

Degree Types: PhD, MS

The Department of Mechanical Engineering (https://www.mccormick.northwestern.edu/mechanical/graduate/) prepares graduates for careers in industry, research, and academia. With its collaborations across departments and institutions, the Department of Mechanical Engineering at Northwestern University educates the engineers of the future while conducting leading-edge research in robotics and autonomy, biosystems and health, AI and design, advanced manufacturing, micro/nanoengineering, energy and sustainability, and computational engineering.

Led by award-winning educators, our MS program is designed to provide students with advanced technical knowledge as well as exposure to research at the cutting edge of today's technology. Our MS degree puts graduates on the fast track for a career in a broad range of industries or serves as a springboard for PhD and post-doctoral studies.

The PhD program focuses on the discovery of new knowledge and technologies. Doctoral students are expected not only to pursue a rigorous course of study, but also to demonstrate scholarly distinction by advancing the state of knowledge in their chosen fields of research.

Additional resources:

- Department website (https://www.mccormick.northwestern.edu/mechanical/academics/graduate/)
- Program handbook(s)

Degrees Offered

- Mechanical Engineering BS/MS (https://catalogs.northwestern.edu/tgs/mechanical-engineering/mechanical-engineering-bach-mast/)
- Mechanical Engineering MS (https://catalogs.northwestern.edu/tgs/mechanical-engineering/mechanical-engineering-ms/)
- Mechanical Engineering PhD (https://catalogs.northwestern.edu/tgs/mechanical-engineering/mechanical-engineering-phd/)

Mechanical Engineering: MS

Learning objective(s)/Students should be able to…

- Make original research contributions to science, engineering and technology management fields.
- Demonstrate command over basic knowledge in the field and effective scholarly communication skills.
- Establish a career plan.
- Enact ethical research methodologies and practices.

Mechanical Engineering: PhD

Learning objective(s)/Students should be able to…

- Make original research contributions to science, engineering and technology management fields.
- Demonstrate command over basic knowledge in the field and effective scholarly communication skills.
- Design a classroom activity and gain teaching experience.
- Establish a career plan.
- Enact ethical research methodologies and practices.

Mechanical Engineering Courses

MECH_ENG 302-0 Artifical Life (1 Unit)
This course introduces students to the growing field of Artificial Life: the study of “life as it could be” rather than as it happened to unfold on Earth. We will address fundamental questions about what distinguishes life from matter; the conditions in which complex adaptive systems may arise and how they may be shaped to suit our needs; as well as whether or not there can even be a science of the artificial. Answers to these questions are of interest as a basic intellectual pursuit, but they may also lead to useful computational, mechanical, chemical and biological technologies.
Prerequisites: Comp_sci 349 or MS CS or PhDs CS.

MECH_ENG 314-0 Machine Dynamics (1 Unit)
This class covers the foundations of rigid multi-body mechanics. Topics include geometry of rigid bodies, rotating bodies, Lagrangian mechanics and variational principles, conservation of energy and momentum, symmetries, impact dynamics, and numerical methods that may be used to simulate mechanical systems. Students numerically simulate rigid body systems and use rigid body geometry to visualize simulations.
Prerequisite: GEN_ENG 205-4.

MECH_ENG 316-0 Mechanical Systems Design (1 Unit)
Design of mechanical systems such as cams, multi-bar linkages, and precision machines. Design principles and best practices. Case studies and team-based projects.
Prerequisite: MECH_ENG 315-0.

MECH_ENG 320-0 Micro- and Nanomechanical Properties of Surfaces (1 Unit)
Micro and nanomechanical interactions between surfaces, fractal nature of surfaces, interfacial forces, principles of micromechanics, characterization of surfaces using atomic force microscopy, optical interferometry, and nanoindentation.

MECH_ENG 322-0 Thermodynamics and Statistical Mechanics II (1 Unit)
Classical and statistical thermodynamics.
Prerequisite: MECH_ENG 222-0.

MECH_ENG 327-0 Finite Elements for Stress Analysis (1 Unit)
Development of finite elements from variational principles and application to static stress analysis. Introduction to techniques for transient and generalized field problems. Computer implementation of finite element techniques. Taught with CIV_ENV 327-0; may not receive credit for both courses.

MECH_ENG 328-0 Computational Failure Analysis (1 Unit)
The course will cover the use of the scientific method for accident investigation, hypothesis development, and the use of the finite element method to analyze the root cause of a failure. Practical application problems for both civil and mechanical structures will be analyzed using commercial finite element codes (Abaqus, Hypermesh, LS-Dyna).
Prerequisite: CIV_ENV 327-0 or MECH_ENG 327-0.

MECH_ENG 329-0 Mechanistic Data Science for Engineering (1 Unit)
Introduce mechanistic data science for engineering through the integration of mathematical scientific principles using six basic#data science concepts: multimodal data generation and collection, extraction of mechanistic features, knowledge-driven dimension reduction, reduced order surrogate models, regression and classification models, and system and design. These concepts will be implemented using Python and MATLAB for engineering applications.

MECH_ENG 333-0 Introduction to Mechatronics (1 Unit)
Introduction to microprocessor-controlled electromechanical systems. Interfacing sensors and actuators to computers, electrical and

mechanical prototyping, dissection of a commercial product. Final team project.
Prerequisite: MECH_ENG 233-0 or ELEC_ENG 221-0 or BMD_ENG 308-0, or consent of instructor.

MECH_ENG 340-1 Computer Integrated Manufacturing: Manufacturing Processes (1 Unit)
Use of computers to improve productivity and reduce costs in the manufacture of discrete parts and assemblies. Manufacturing processes: Analysis and evaluation of process usage in the contemporary manufacturing environment.
Prerequisite: MECH_ENG 240-0 or consent of instructor.

MECH_ENG 340-2 Computer Integrated Manufacturing: CAD/CAM (1 Unit)
Use of computers to improve productivity and reduce costs in the manufacture of discrete parts and assemblies. CAD/ CAM: Geometric modeling, dimensioning systems, tolerances, design for manufacture, programming of machine tools.
Prerequisite: MECH_ENG 340-1 or consent of instructor.

MECH_ENG 340-3 Computer Integrated Manufacturing: Automation (1 Unit)
Use of computers to improve productivity and reduce costs in the manufacture of discrete parts and assemblies. Manufacturing automation: sensors, actuators, and computers for automation; principles of computer control; programmable logic controllers; robotic devices; assembly automation.
Prerequisite: MECH_ENG 340-2 or consent of instructor.

MECH_ENG 341-0 Computational Methods for Engineering Design (1 Unit)
Introduction to a wide range of computational techniques for engineering design. Modeling, simulation, optimization, design software, examples, and projects with emphasis on computational techniques for design and manufacturing related applications.
Prerequisite: senior standing or consent of instructor.

MECH_ENG 346-0 Introduction to Tribology (1 Unit)
Fundamentals of surface contact: surface topography, asperity contact, interfacial phenomena. Friction theories and wear mechanisms. Temperatures in sliding contacts. Hydrodynamic, hydrostatic, elastohydrodynamic, and boundary lubrication.

MECH_ENG 359-0 Reliability Engineering (1 Unit)
Probability concepts and random variables. Failure rates and reliability testing. Wearin, wear-out, random failures. Probabilistic treatment of loads, capacity, safety factors. Reliability of redundant and maintained systems. Fault tree analysis.
Prerequisite: GEN_ENG 205-4.

MECH_ENG 362-0 Stress Analysis (1 Unit)
Theory of elasticity: elastic stability, principle of minimum potential energy, Rayleigh-Ritz methods. Introduction to finite element methods of stress analysis: computer implementation and use of commercial codes. Structural analysis of rods, beams, columns, and plates.
Prerequisite: CIV_ENV 216-0.

MECH_ENG 363-0 Mechanical Vibrations (1 Unit)
Analysis of vibrations in single and multi-degree of freedom systems. Free and forced vibrations with various types of damping. Response to steady-state and transient excitations.
Prerequisite: MECH_ENG 314-0.

MECH_ENG 364-0 Introduction to Aerospace Engineering (1 Unit)
The purpose of the course is to learn the language of aerospace engineering and to explore emerging concepts in this field. This course will cover essential topics in areas relevant to aerospace engineering including Aerodynamics, Flight Dynamics, Propulsion, and Orbital Mechanics. Computational tools for structural analysis, fluid flow calculations, and flight dynamics modeling will be introduced.
Prerequisites: CIV_ENV 216-0, MECH_ENG 241-0 or equivalent.

MECH_ENG 366-0 Finite Elements for Design & Optimizatn (1 Unit)
Numerical methods for interaction and optimal CAD. Fully stressed design; design sensitivity analysis and descent methods; optimality criteria to automated design.
Prerequisites: senior standing; MECH_ENG 327-0 or consent of instructor.

MECH_ENG 367-0 Quantitative Methods in Life Cycle Analysis (1 Unit)
Lifecycle analysis (LCA) framework for environmental assessment of technology systems, focusing on modeling methods for systems mass and energy flows, process and input-output-based systems inventories, environmental impact analysis, and methods for robust engineering decisions. MECH_ENG 367-0 is taught with CHEM_ENG 367-0; may not receive credit for both courses.

MECH_ENG 371-0 Combustion Engines (1 Unit)
Theoretical and actual cycles, combustion, detonation, carburetion, fuels, performance characteristics, and fuel-cell power.

MECH_ENG 373-0 Engineering Fluid Mechanics (1 Unit)
Laminar and turbulent duct flows. Boundary layers and potential flows. Lift and drag forces. Thermodynamics and mechanics of compressible flow. Nozzle flows and choking. Wave motion and shock waves. Applications to fluid machinery.
Prerequisite: MECH_ENG 241-0.

MECH_ENG 377-0 Heat Transfer (1 Unit)
Fundamentals of heat transfer by conduction, convection, and radiation. Steady and transient heat conduction in solids. Forced and free convection in fluids. Properties of thermal radiation. Radiation heat transfer between solids. Solar radiation.
Prerequisite: MECH_ENG 241-0.

MECH_ENG 378-0 Applied Computational Fluid Dynamics and Heat Transfer (1 Unit)
This course provides an understanding of the theory and process of computational flow analysis by giving students the opportunity to use commercial simulation software (ANSYS/Fluent) to solve fluid flow problems. Topics covered include conservation of mass, momentum and energy; boundary conditions; turbulence modeling; mesh generation; solution procedures; and verification/validation. Topics will be presented through lectures, hands-on computer lab sessions, and team-based projects.

MECH_ENG 380-0 Thermal Energy Systems Design (1 Unit)
Applications of the principles of energy engineering analysis to the design of thermal systems. Consideration of such systems as air conditioning, oil piping, refrigeration, fluid distribution, and pneumatic control. Projects will be tailored to the class. Solution of open-ended design problems including introduction to EES (Engineering Equation Solver) software that has built-in thermophysical properties.
Prerequisite: Basic Thermodynamics or equivalent.

MECH_ENG 381-0 Introduction to Micro-electro-mechanical Systems (1 Unit)
Introduction to MEMS devices, with an emphasis on their manufacturing and mechanical behavior. Materials properties, microfabrication technology, mechanical behavior of microstructures, design, and packaging. Case studies on sensors, wireless communications, fluidic systems, microengines, and biological devices.
Prerequisite: CIV_ENV 216-0 or consent of instructor.

MECH_ENG 382-0 Experiments in Micro- and Nano Science and Engineering (1 Unit)
Interdisciplinary topics spanning the physical and biological sciences and engineering. Seven integrated labs in which students acquire hands-on experience in various aspects of micro-and nanoscience and engineering: cleanroom microfabrication, flow visualization in micro-channels, nanomechanics, AFM and dippen nanolithography, multiphysics computational tools, and experimental techniques to evaluate micro-and nanoscale devices.
Prerequisite: MECH_ENG 381-0 or consent of instructor.

MECH_ENG 390-0 Intro to Dynamic Systems (1 Unit)
Modeling the dynamic behavior of physical systems. Concepts of causality, dependent and independent storages, and state. Introduction to bond graphs. Generation of state equations; analytical and computer simulation of system behavior. Application to problems of engineering interest.
Prerequisites: MECH_ENG 241-0; CIV_ENV 216-0; GEN_ENG 205-4.

MECH_ENG 395-0 Special Topics in Mechanical Engineering (1 Unit)
Topics suggested by students or faculty members and approved by the department.

MECH_ENG 409-0 Swarms and Multi-Robot Systems (1 Unit)
This class surveys the state of the art research in robotic swarms, looking at both algorithms for controlling them and current hardware implementations. It also addresses the deficiencies keeping them from every-day use. Coursework includes reading research papers, student presentations and discussion of select papers, and projects implementing studied topics in a real or simulated robot swarm.
Prerequisite: Permission of Instructor. Cross-listed with COMP_SCI 409-0.

MECH_ENG 410-0 Quadrotor Design and Control (1 Unit)
Centered around a project where teams create and program an autonomous quadrotor robot, this class focuses on advanced embedded control of an electromechanical system. Topics include: programming interfaces between an embedded computer and external sensors/actuators, programming a timing-critical control loop for stable flight, and creating a software stack that interacts with low-level code to create a desired high-level behavior.
Prerequisite: Permission of Instructor. Cross-listed with COMP_SCI 410-0.

MECH_ENG 412-0 Fracture Mechanics (1 Unit)
This course introduces fracture mechanics from an engineering perspective with an emphasis on the underlying mechanics of linear and nonlinear crack front fields, the application of numerical analysis methods and the evaluation-interpretation of experimentally measured fracture properties of materials. It also covers several advanced topics such as dynamic fracture and interfacial fracture.

MECH_ENG 413-0 Experimental Solid Mechanics (1 Unit)
Experimental techniques in measuring stress and strain. Strain gauge, photoelastic, brittle coating, and Moire techniques studies and applied with selected laboratory experiments. CIV_ENV 413-0 and MECH_ENG 413-0 are co-listed.

MECH_ENG 414-1 Mechanics of Composite Materials 1 (1 Unit)
Introduction to basic concepts: fabrication of composite materials, micromechanics, macro-mechanics of unidirectional lamina, failure theories, mechanics of multidirectional laminate, lamination theory, hydrothermal effects, inter-laminar stresses, stress concentrations, structural design and optimization, and nondestructive evaluation. CIV_ENV 414-1 and MECH_ENG 414-1 are co-listed.

MECH_ENG 415-0 Mechanics of Manufacturing Processes (1 Unit)
Understanding the fundamental mechanics of manufacturing processes is essential for process design, control, monitoring, innovation and planning. This course starts with the mechanics in sheet metal forming as a demonstration, and gradually explores the dominant mechanisms in a variety of manufacturing processes, including subtractive processes, volume-constant processes, and additive manufacturing. The course invites students to work with the instructor together to explore the possibility of unifying the description of manufacturing processes based on fundamental physics involved in the processes.
Prerequisite: Preferably CIV_ENV 417-1, CIV_ENV 417-2, or equivalent.

MECH_ENG 416-0 Computational Nanodynamics (1 Unit)
The objective of this course is to learn how to use theoretical and computational modeling tools to simulate dynamic solid mechanics phenomena at small scales.

MECH_ENG 417-0 Multi-scale Modeling and Simulation in Solid Mechanics (1 Unit)
Introduction to modern computational methods such as molecular dynamics and continuum mechanics. Applications will be nanostructure and polymer composites.

MECH_ENG 417-1 Mechanics of Continua 1 (1 Unit)
Introduction to mechanics of continuous media. Cartesian tensors; kinematics of deformable media; stress; balance laws; constitutive relations for selected solids and fluids.

MECH_ENG 418-0 Multi-Scale Modeling and Simulation in Fluid Mechanics (1 Unit)
Introduction to modern computational methods such as molecular dynamics and continuum mechanics. Applications will be Biological and bioinspired materials: Biopolymer, Protein, DNA, Lipids.

MECH_ENG 419-0 Wave Propagation In Elastic Solids (1 Unit)
Introduction of elastodynamic wave equations in anisotropic solids, plane longitudinal transverse, and surface waves, harmonic waves and pulses, energy considerations, reflection, transmission, and mode conversion, scattering and diffraction problems, reciprocity relations, piezoelectric materials, and band engineering using periodic solids and metamaterials.
Prerequisites: CIV_ENV 415-0, MECH_ENG 363-0 or MECH_ENG 390-0, or equivalent.

MECH_ENG 420-0 Micro-and Nanoscale Fluid Dynamics (1 Unit)
The molecular basis of fluid mechanics, the Knudsen number and non-slip boundary conditions, Stokes flow, electrokinetic flows: Debye layers, zeta-potentials, Helmholtz-Smoluchowski slip boundary conditions.

MECH_ENG 422-0 Statistical Mechanics for Applications (1 Unit)
Modeling of systems with emergent behavior. The course has two components: (1) basic and intermediate statistical mechanics, and (2) application of the course methods to a case study, chosen from topics to include: dynamics of polymers, including proteins and nucleic acids; molecular machines; pattern formation, including turbulence and phyllotaxis; geomorphology; conflict, including warfare, terrorism and revolution; and economics.

MECH_ENG 423-0 Intro to Computational Fluid Dynamics (1 Unit)
Discretization methods, solution of Navier-Stokes equations, algorithms for fluid flow problems (pressure-based algorithms, fractional time-stepping schemes, etc.), three-dimensional, steady, unsteady flows.

MECH_ENG 424-0 Advanced Topics in Computational Fluid Dynamics (1 Unit)
Moving mesh techniques, immersed boundary techniques, numerical methods for sub-micron/nanoscale fluid dynamics-stochastic equations, molecular dynamics for liquids, Monte Carlo simulations, hybrid simulations.

MECH_ENG 425-0 Fundamentals of Fluid Dynamics (1 Unit)

Basis for advanced courses in fluid dynamics. Stress, flow kinematics, rate of strain, material derivatives, and general balance equations. Navier-Stokes equations and exact solutions.

MECH_ENG 426-1 Advanced Finite Element Methods I (1 Unit)
Discretization methods, weak and strong forms, Newton methods for constrained and unconstrained problems, explicit methods, continuation methods.
Prerequisite: MECH_ENG 327-0 or equivalent.

MECH_ENG 426-2 Advanced Finite Element Methods II (1 Unit)
Alternative mesh descriptions, Langrangian, Eulerian, and arbitrary Langrangian Eulerian, meshless methods and particle methods, continuum based shell formations, contract-impact.
Prerequisite: MECH_ENG 426-1.

MECH_ENG 427-0 Viscous Fluid Dynamics (1 Unit)
D'Alembert's paradox and the role of viscosity, vorticity diffusion, boundary layers, separation, viscous dissipation of energy, introduction to turbulence, Stokes flow.

MECH_ENG 430-0 Turbulence & Combustion (1 Unit)
Introductory course in theory and modeling of turbulent/reacting flows.
Level: graduate/advanced undergraduate.
Prerequisite: at least one graduate/advanced undergraduate level course in fluid mechanics. Familiarity with vector/multivariate calculus and ordinary differential equations.

MECH_ENG 432-0 The Calculus of Variations and Its Applications (1 Unit)
Extremizing multivariate functions, the functional and its variation, Euler-Lagrange equations, isoperimetric problems, applications to optics, mechanics, potential theory, fluid mechanics, wave theory and elasticity.

MECH_ENG 433-0 Advanced Mechatronics (1 Unit)
Hands-on laboratory class on design and control of electromechanical systems. Real time operating systems, analog and digital electronics, sensors and actuators. Lectures, labs, and projects.

MECH_ENG 434-0 Bioinspired Surface Engineering (1 Unit)
Introduction into bioinspired engineering and surface engineering associated with multiscale (i.e., nano/micro/milli) surface textures and materials for developing functional surfaces. Interdisciplinary topics ranging from fluid mechanics to physical chemistry (related to general chemistry and thermodynamics), heat transfer, optics, and solid mechanics will be covered.

MECH_ENG 439-0 Computer Control in Manufacturing (1 Unit)
Digital control theory, design methodology, and techniques for controller implementation of digital computers. Discrete system modeling, system identification, and adaptive control methods. Single and multiaxis motion-generation algorithms. Multiple objective control systems for machinery guidance, manufacturing process, and precision control.
Prerequisites: MECH_ENG 340-1, MECH_ENG 340-2, or permission of instructor.

MECH_ENG 440-1 Tech In Mfg Env (1 Unit)
An introduction to quantitative principles in modern manufacturing technology. Techniques for understanding limitations on precision, repeatability, and rate imposed by physics; enhancement of quality and productivity by automatic control; process monitoring; information management; and the effects of these factors on success in the marketplace.
Prerequisite: Enrollment in MMM program or by petition to the department.

MECH_ENG 441-0 Engineering Optimization for Product Design and Manufacturing (1 Unit)
Introduction to optimization theory and numerical techniques. Formulations, algorithms, computer implementation, examples/projects with emphasis in numerical and emerging techniques for design and manufacturing related applications.
Prerequisite: Graduate standing, senior undergraduate, or permission of instructor.

MECH_ENG 442-0 Metal Forming (1 Unit)
Metal forming processes: drawing, extrusion, rolling, forging, and sheet metal forming. Process analysis and design: force estimation, friction and redundant work effects, temperatures generated, defects, and process and equipment limitations.

MECH_ENG 443-0 Metal Cutting (1 Unit)
Theory and applications of metal cutting. Basic principles and significant features of current research. Chip formation mechanics in orthogonal and oblique cutting, tool wear, and fracture. Cutting process and machine tool dynamics and methods for their in-process identification. Stability analysis of the machining process, chatter vibrations, and chatter suppression. Surface generation and characterization.
Prerequisites: MECH_ENG 340-1, MECH_ENG 340-2, or permission of instructor.

MECH_ENG 445-0 Micromanufacturing (1 Unit)
The course focuses on the emerging global trend toward product miniaturization and the accompanying trend toward the miniaturization of manufacturing equipment and systems. Fundamental scientific and technological topics associated with miniaturization will be discussed.

MECH_ENG 446-0 Advanced Tribology (1 Unit)
Generalized Reynolds equation; thermal, turbulent, inertia, fluid compressibility, and surface roughness effects in sliding bearings; fatigue, scuffing, and wear in elastohydro-dynamic contact; plastohydrodynamic lubrication in metal rolling, extrusion, and forging.

MECH_ENG 447-0 AI in Manfuacturing (1 Unit)
Students will explore a broad spectrum of ML and AI tools, from traditional statistical learning to recent AI foundation models, to address manufacturing challenges with an emphasis on both practical application and an intuitive understanding of the underlying theoretical principles. By the end of the course, we will have developed the skills necessary to tackle complex manufacturing data analytics problems and contribute to AI for manufacturing research.
Prerequisites: ME340-1: Introduction to Manufacturing Processes, ME224: Scientific and embedded programing in Python, MATH 228: Multiple Integration and Vector Calculus.

MECH_ENG 448-0 Flexible Automation and Robotics (1 Unit)
Introduction to state-of-the-art research in robotics. Robot geometries and kinematics; robot programming languages; dynamics and control; motion planning; machine vision; parts-feeders and jigs; assembly planning; sensors and actuators; scheduling; mobile robots.

MECH_ENG 449-0 Robotic Manipulation (1 Unit)
Representations of the configuration and spatial motion of rigid bodies and robots based on modern screw theory. Forward, inverse, and differential kinematics. Robot dynamics, trajectory planning, and motion control. Wheeled mobile robots and mobile manipulation.

MECH_ENG 450-0 Embedded Systems in Robotics (1 Unit)
This project-based course provides experience with a variety of software tools and concepts useful for a robotics engineer working with practical embedded systems. The Robot Operating System (ROS 2) will be used as an example framework, and learning ROS 2 will be a primary goal of the course. By the end of the course, student teams will have completed a robotics project using a real robot. The primary programming language

used in this course is Python and all assignments require the use of a Linux laptop.

MECH_ENG 451-0 Micromachining (1 Unit)
Fundamental fabrication issues for microscale components used in MEMS/Nanotechnology. Understand and designing microfabrication processes based on photolithography and deposition/etching steps.

MECH_ENG 454-0 Numerical Methods in Optimal Control of Nonlinear Systems (1 Unit)
This course will cover methods in numerical optimization and optimal control with an emphasis on engineering applications and computation. Topics include differentiation, gradient descent, Newton's method, optimal control, and optimal switching control. Examples will be drawn largely from aerospace, robotics, and biomedical applications.

MECH_ENG 455-0 Active Learning in Robotics (1 Unit)
This class covers the fundamentals of automatically determining actions for obtaining information in robotic systems. Topics include methods in optimal control, probability and filtering theory, information theory and information measures, active sensing, infotaxis, nonparametric modeling techniques, and Markov Decision Processes. Case studies in papers are used to illustrate and test concepts.
Prerequisites: Programming experience and a graduate-level class in dynamics, control, or similar topic OR MECH_ENG 314 OR permission of instructor.

MECH_ENG 456-0 Mechanics of Advanced Materials (1 Unit)
Microscale mechanisms and their relation to macroscopic behavior and mathematical constitutive modeling for advanced material systems. Emphasis on polymer viscoelasticity, shape memory materials, other material systems.

MECH_ENG 464-0 Aerodynamics (1 Unit)
This course provides an introduction to aerodynamics and is relevant to students interested in the aerospace concentration. Topics will include: subsonic, supersonic and hypersonic flows including thin airfoil theory, Prandtl's lifting line theory, and boundary layer theory.

MECH_ENG 465-0 Wave Propagation in Elastic Solids (1 Unit)
Plane waves, longitudinal and transverse waves, harmonic waves and pulses, energy considerations, reflection, and transmission mode conversion. Fourier superposition, surface waves, basic singular solutions, integral representations, scattering and diffraction problems, and waves in layers and rods.
Prerequisites: MECH_ENG 363-0, or MECH_ENG 390-0 and ES_APPM 311-1, ES_APPM 311-2, or equivalents.

MECH_ENG 466-0 Inelastic Constitutive Relations for Solids (1 Unit)
Introduction to the formulation and implementation of inelastic constitutive relations for solids. Viscoelasticity, rate-independent plasticity, viscoplasticity. State variable descriptions and thermodynamic restrictions.
Prerequisites: CIV_ENV 417-1, CIV_ENV 415-0 or equivalent.

MECH_ENG 467-0 Industrial Energy Management and Utilization (1 Unit)
As time permits, in this course the students will learn about historical energy usage; energy conservation vs. energy management; elements of an energy audit; data normalization of energy consumption using product-mix data or degree days etc.; utility rate structures & deregulation; energy economics; energy conservation opportunities in thermal-fluid Systems; combustion systems; steam & condensate Systems; energy recovery systems; industrial insulation; and electrical energy conservation.
Prerequisite: Thermodynamics (MECH_ENG 222-0 or equivalent) or Consent of Instructor or Graduate Standing.

MECH_ENG 468-0 Computational Neuromechanics and Neuroethology (1 Unit)
Understanding the nervous system through an integrative (body+brain +environment) approach placing emphasis on computational and evolutionary methods of understanding.
Prerequisite: Ability to program in Matlab.

MECH_ENG 469-0 Machine Learning and Artificial Intelligence for Robotics (1 Unit)
A coverage of artificial intelligence, machine learning and statistical estimation topics that are especially relevant for robot operation and robotics research. The focus is on robotics-relevant aspects of ML and AI that are not covered in depth in COMP_SCI 348-0 or COMP_SCI 349-0. Course evaluation will be largely project-based.
Prerequisites: Graduate-level standing or permission of instructor. Some programming experience (Matlab is okay).

MECH_ENG 470-0 High Performance Computing for Multiphysics Applications (1 Unit)
Theory, numerical methods, code development, and practical considerations for large-scale simulation of complex engineering systems, particularly those that bring together multiple physical phenomena. Topics include parallel programming and performance, iterative solvers and preconditioning, solution algorithms, and applications.

MECH_ENG 472-1 Robot Design Studio (1 Unit)
This is a two-quarter hands-on sequence in which students work in a team in a professional environment to design and build a robust, elegant, and sophisticated electromechanical system. Students are required to take both quarters. Credit for the first quarter will be given upon completion of the second quarter.
Prerequisite: Consent of Instructor.

MECH_ENG 472-2 Robot Design Studio (1 Unit)
Teams of students will design and build robots. For instance, in 2020, teams build robots inspired by the Summer Olympics such as a robot that can perform on the uneven bars. The ultimate goal is to build a robust, elegant machine capable of performing exciting dynamic feats. Students will refine skills in mechatronics, electromechanical design, real-time programming, sensor selection and integration, motor/transmission design, and feedback control.
Prerequisite: MECH_ENG 472-1.

MECH_ENG 495-0 Selected Topics in Mechanical Engg (1 Unit)
Topics selected from work of current interest in mechanical engineering.

MECH_ENG 497-0 Special Topics in Mechanical Engineering (0.5 Unit)
In-depth review of how a number of new computer-aided engineering technologies are used to give the modern manufacturing enterprise strategic advantage.

MECH_ENG 499-0 Projects (1-3 Units)
Special projects carried out under staff direction. Permission of instructor and department required. May be repeated for credit.

MECH_ENG 512-0 Seminar (0 Unit)

MECH_ENG 513-0 Professional Essentials (0 Unit)
Seminar course covering techniques for teaching and technical presentation skills, organizational issues associated with teaching and presentations. Active teaching duties will be assigned during the course and performance feedback provided.

MECH_ENG 519-0 Responsible Conduct of Research Training (0 Unit)

MECH_ENG 590-0 Research (1-4 Units)

Independent investigation of selected problems pertaining to thesis or dissertation. May be repeated for credit. - SEE DEPT FOR SECTION AND PERMISSION NUMBERS.