MECHANICAL ENGINEERING

https://www.mccormick.northwestern.edu/mechanical/

Degree Types: PhD, MS


We combine innovative teaching and pioneering research in a highly collaborative environment that transcends traditional academic boundaries. Graduate students are not required to follow a rigid curriculum. Each student may tailor a course of study that accommodates individual needs, talents, and interests.

Degrees Offered

- 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 Courses

MECH_ENG 314-0 Machine Dynamics (1 Unit)
Three-dimensional kinematics: rotation axes and mechanism analysis, rotation matrices and Euler’s angles for rigid bodies. Three-dimensional kinetics: dynamics of particles, central force problems, dynamics of rigid bodies, rotational inertia matrices and principal axes, dynamics of mechanisms, the gyroscope and other torque-free problems. Prerequisite: MECH_ENG 202-0.

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 317-0 Molecular Modeling and the Interface to Micromechanics (1 Unit)
Introduction to modern computational methods for calculating thermodynamic, transport, and structural properties of materials. Computational chemistry, molecular simulation, and mesoscopic methods, with emphasis on tribology applications.

MECH_ENG 318-0 Multiscale Simulations (1 Unit)
Introduction to multiscale modeling and simulation methods for studying material interactions in micro and nanomechanical systems, as well as in electronic packaging. Hands-on exercises using equipment to characterize nanoscale properties and parallel computer codes.

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 & 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 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, ELEC_ENG 221-0, or consent of instructor.

MECH_ENG 340-1 Comp Integ 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 Integ 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 Integ Manuf: 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)

MECH_ENG 359-0 Reliability Engineering (1 Unit)

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 202-0

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)
Prerequisite: MECH_ENG 241-0.

MECH_ENG 377-0 Heat Transfer I (1 Unit)
Prerequisite: MECH_ENG 241-0.

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 385-0 Nanotechnology (1 Unit)
Manipulation of matter at the nanometer-length scale to produce useful devices and materials. Scientific and engineering properties of nanoscale systems. Emphasis on development of new techniques.

MECH_ENG 389-0 Molecular Machines in Biology (1 Unit)
Introduction to engineering principles that govern cellular activities at the molecular level. Emphasis on the dynamics and kinematics of proteins, especially those that are locomotory or force generating. Lectures, team projects, and presentations.
Prerequisite: MATH 228-1 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 202-0, 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 413-0 Experimental Solid Mechanics (1 Unit)
Brief review of applied elasticity and fracture mechanics. Review of experimental methods for measuring mechanical behavior of solids, including deformation and fracture, fracture toughness and dynamic response at high strain rates. Methods discussed include strain gages, photoelasticity, birefringent coatings, moiré, digital image correlation, and fiber optic methods. 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 414-2 Mechanics of Composite Materials II (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 414-2 and MECH_ENG 414-2 are co-listed.

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 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 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 421-0 Design and Analysis of Microfluidic Systems (1 Unit)**
Introduction to Lab-on-chip, mTAS, microreactors & microarrays, fluid mechanics of microfluidic devices, multi-physics phenomena e.g. electrohydrodynamics, magnetohydrodynamics, developing reduced order models, design and analysis.

**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 424-1 Computational Fluid Dynamics I (1 Unit)**

**MECH_ENG 424-2 Computational Fluid Dynamics II (1 Unit)**

**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 425-2 Fundamentals of Fluid Dynamics II (1 Unit)**

**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 428-0 Compressible and Inviscid Fluid Dynamics (1 Unit)**
Fuler equations and the evolution of vorticity, 2D incompressible flows, potential flows, shock waves, acoustics.

**MECH_ENG 429-0 Turbulent Flows (1 Unit)**
Kinematics of turbulent flow fields: dynamical processes. Application of models to isotropic and shear flow turbulence; turbulent diffusion. Effects of compressibility and buoyancy on turbulent flows.

**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.
redundant work effects, temperatures generated, defects, and process and equipment limitations.

**MECH_ENG 443-0 Metal Cutting (1 Unit)**
Prerequisites: MECH_ENG 340-1, MECH_ENG 340-2, or permission of instructor.

**MECH_ENG 445-0 Micromanufacturing (1 Unit)**
Mechanics of robotic manipulation, computer representations and algorithms for manipulation planning, applications to industrial automation, parts feeding, grasping, fixtureing, assembly.

**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 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)**
Topics selected from work of current interest in mechanical engineering.

**MECH_ENG 450-0 Geometry in Robotics (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 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 453-0 Micro Systems Design (1 Unit)**
Theory and tools for analyzing and designing microsystems used in MEMS/Nanotechnology. Includes device physics and analysis, design techniques, and computer-aided design tools for micro systems technology.

**MECH_ENG 454-0 Numerical Methods in Optimal Control of Nonlinear Systems (1 Unit)**
Application of tools from differential geometry and Lie groups to problems in dynamics, controllability, and motion planning for mechanical systems, particularly with non-Euclidean configuration spaces.

**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 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 317-0, CIV_ENV 415-0, MECH_ENG 362-0 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 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. Some programming experience (MatLab is okay). Undergraduate student enrollment by permission of instructor only.

**MECH_ENG 470-0 High Performance Computing for Multiphysics Applications (1 Unit)**
Equations of motion for reacting flows, theory of laminar flames, flame structure and stability, combustion of liquid and solid fuels, ignition, extinction, and flammability limits.

**MECH_ENG 478-1 Combustion (1 Unit)**
Current topics dealing with intracellular and extracellular transport, including ion channels, molecular motors, the mechanics of DNA, microtubules, flagella dynamics, locomotion, collective behavior, infection, signaling.
Prerequisite: Permission of instructor.

**MECH_ENG 492-0 Robust Control Theory (1 Unit)**

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

**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.