Department of Mechanical and Aerospace Engineering

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The Department of Mechanical and Aerospace Engineering offers two undergraduate B.S. programs: one in Mechanical Engineering and the other in Aerospace Engineering. The Department also offers M.S. and Ph.D. programs in Mechanical and Aerospace Engineering.

Mechanical Engineers and Aerospace Engineers design, manufacture, and control machines ranging from robots to aircraft and spacecraft, design engines and power plants that drive these machines, analyze the environmental impact associated with power generation, and strive to promote environmental quality. These disciplines require the creative use of mathematics, physics, and chemistry together with engineering science and technology in areas such as fluid and solid mechanics, thermodynamics and heat transfer, dynamics, controls, and atmospheric science to achieve these goals. Mechanical Engineering and Aerospace Engineering students at UCI learn the problem-solving, design, modeling, and testing skills required to contribute to be leaders in advancing modern technology and to be on the forefront of scientific discoveries.

The Mechanical Engineering undergraduate program includes required courses that provide engineering fundamentals and technical electives that allow students to study particular areas of interest. Elective courses can be organized into specializations in Aerospace Engineering, Energy Systems and Environmental Engineering, Flow Physics and Propulsion Systems, and Design of Mechanical Systems. Independent research opportunities allow students to pursue other avenues for focusing their studies.

Aerospace Engineering deals with all aspects of aircraft and spacecraft design and operation, thus requiring the creative use of many different disciplines. The undergraduate curriculum in Aerospace Engineering includes courses in subsonic and supersonic aerodynamics, propulsion, controls and performance, light-weight structures, spacecraft dynamics, and advanced materials. In the senior capstone course, students work in teams on the preliminary design of a commercial jet transport.

Career opportunities for Mechanical and Aerospace Engineering graduates are in a broad range of industries, including manufacturers of vehicles of all types, as well as aircraft and spacecraft, micro-mechanical systems, rehabilitation engineering, and research laboratories in universities and government.

• Aerospace Engineering, B.S.
• Mechanical and Aerospace Engineering, M.S.
• Mechanical and Aerospace Engineering, Ph.D.
• Mechanical Engineering, B.S.

Faculty

Satya N. Atluri, ScD Massachusetts Institute of Technology, Professor Emeritus of Mechanical and Aerospace Engineering

James E. Bobrow, Ph.D. University of California, Los Angeles, Professor Emeritus of Mechanical and Aerospace Engineering (robotics, mechatronics, and design optimization)

Ramin Bostanabad, Ph.D. Northwestern University, Assistant Professor of Mechanical and Aerospace Engineering (design under uncertainty, probabilistic machine learning, materials informatics, computational microstructure characterization, topology optimization)

Jacob Brouwer, Ph.D. Massachusetts Institute of Technology, Professor of Mechanical and Aerospace Engineering; Civil and Environmental Engineering (fuel cells, energy systems dynamics, electrochemical systems design and analysis, chemical kinetics, reacting flows)

Natascha Buswell, Ph.D. Purdue University, Assistant Professor of Teaching of Mechanical and Aerospace Engineering (graduate engineering education, faculty development, engineering teaching, engineering education research methods)

Penghui Cao, Ph.D. Boston University, Assistant Professor of Mechanical and Aerospace Engineering; Materials Science and Engineering (fundamental understanding of the mechanisms by which materials plastically deform and fail, particularly in extreme environments)

David Copp, Ph.D. University of California, Santa Barbara, Assistant Professor of Teaching of Mechanical and Aerospace Engineering (optimal control and estimation, hybrid dynamical systems, energy storage, pedagogy)

Donald Dabdub, Ph.D. California Institute of Technology, Associate Dean, Undergraduate Education and Professor of Mechanical and Aerospace Engineering; Civil and Environmental Engineering (mathematical modeling of urban and global air pollution, dynamics of atmospheric aerosols, secondary organic aerosols, impact of energy generation on air quality, chemical reactions at gas-liquid interfaces)
Derek Dunn-Rankin, Ph.D. University of California, Berkeley, Professor Emeritus of Mechanical and Aerospace Engineering; Civil and Environmental Engineering; Environmental Health Sciences (combustion, optical particle sizing, particle aerodynamics, laser diagnostics and spectroscopy)

Said E. Elghobashi, Ph.D. University of London, Distinguished Professor Emeritus of Mechanical and Aerospace Engineering (direct numerical simulation of turbulent, chemically reacting and dispersed two-phase flows)

Manuel Gamera-Castaño, Ph.D. Yale University, Associate Professor of Mechanical and Aerospace Engineering (electric propulsion, with emphasis on colloid thruster technology for precision formation flying missions and Hall thrusters. Electrohydrodynamic atomization of liquids and related problems like electrospray ionization and technological applications of electrosprays, aerosol diagnostics)

Tryphon Georgiou, Ph.D. University of Florida, Distinguished Professor of Mechanical and Aerospace Engineering (dynamical systems and control, mathematical physics, applied mathematics. Current interests focus on stochastic control, geometry of optimal mass transport, inverse problems in physics and signal analysis, and topics related to the control of fluids, networks and thermodynamic systems)

Faryar Jabbari, Ph.D. University of California, Los Angeles, Associate Dean for Academic Affairs and Professor of Mechanical and Aerospace Engineering (optimal control theory, distributed parameter systems, parameter identification)

Zak Kassas, Ph.D. University of Texas at Austin, Assistant Professor of Mechanical and Aerospace Engineering; Electrical Engineering and Computer Science (cyber-physical systems (CPS), autonomous vehicles (aerial, ground, indoor, underwater), satellite-based navigation, intelligent transportation systems (ITS), cognitive and software-defined radio (SDR), sensor fusion)

Solmaz S. Kia, Ph.D. University of California, Irvine, Assistant Professor of Mechanical and Aerospace Engineering; Computer Science (systems and control, decentralized/distributed algorithm design for multi-agent systems, cooperative robotics)

John C. LaRue, Ph.D. University of California, San Diego, Professor Emeritus of Mechanical and Aerospace Engineering (fluid mechanics, heat transfer, turbulence)

Jaeho Lee, Ph.D. Stanford University, Assistant Professor of Mechanical and Aerospace Engineering (heat transfer, thermal management, thermoelectrics, phononics, nanomaterials)

Robert Liebeck, Ph.D. University of Illinois at Urbana-Champaign, Adjunct Professor of Mechanical and Aerospace Engineering (aerodynamics, hydrodynamics, aircraft design)

Feng Liu, Ph.D. Princeton University, Professor of Mechanical and Aerospace Engineering (computational fluid dynamics, turbomachinery, propulsion)

Marc J. Madou, Ph.D. Ghent University, UCI Chancellor’s Professor of Mechanical and Aerospace Engineering; Biomedical Engineering; Chemical and Biomolecular Engineering (miniaturization science (MEMS and NEMS) with emphasis on chemical and biological applications)

J. Michael McCarthy, Ph.D. Stanford University, Director of the Performance Engineering Program and Professor of Mechanical and Aerospace Engineering (design of mechanical systems, computer aided design, kinematic theory of spatial motion)

Vincent G. McDonell, Ph.D. University of California, Irvine, Adjunct Professor of Mechanical and Aerospace Engineering (combustion, alternative fuels, gas turbines, sprays, diagnostics, combined heat and power, emissions, autoignition/flashback)

Kenneth D. Mease, Ph.D. University of Southern California, Professor Emeritus of Mechanical and Aerospace Engineering (nonlinear dynamics and control; flight guidance and control)

Lawrence Muzio, Ph.D. University of California, Berkeley, Adjunct Professor of Mechanical and Aerospace Engineering (thermodynamics, combustion and combustion in practical systems, air pollution formation and control, advanced diagnostics applied to practical combustion systems)

Bihter Padak, Ph.D. Stanford University, Assistant Professor of Mechanical and Aerospace Engineering; Chemical and Biomolecular Engineering

Dimitri Papamoschou, Ph.D. California Institute of Technology, Professor of Mechanical and Aerospace Engineering (compressible turbulence, jet and fan aeroacoustics, jet noise reduction, mixing enhancement, microphone phased array methods)

Edwin Peraza Hernandez, Ph.D. Texas A&M University, Assistant Professor of Mechanical and Aerospace Engineering (morphing structures, deployable structures, origami, tensegrity, active materials, structural optimization)

Roger H. Rangel, Ph.D. University of California, Berkeley, Department Chair and Professor of Mechanical and Aerospace Engineering (heat transfer, fluid mechanics, two-phase flows, fluid instability and atomization)

David J. Reinkensmeyer, Ph.D. University of California, Berkeley, Professor of Anatomy and Neurobiology; Biomedical Engineering; Mechanical and Aerospace Engineering; Physical Medicine and Rehabilitation

G. Scott Samuelsen, Ph.D. University of California, Berkeley, Director of Advanced Power and Energy Program, Research Professor and Professor Emeritus of Mechanical and Aerospace Engineering; Civil and Environmental Engineering (combustion, sprays, laser diagnostics, air quality, turbulent transport, alternative fuels, modeling reacting flows, practical systems, energy and environmental conflict)
Andrei M. Shkel, Ph.D. University of Wisconsin-Madison, *Professor of Mechanical and Aerospace Engineering; Biomedical Engineering; Electrical Engineering and Computer Science* (design and advanced control of micro-electro-mechanical systems (MEMS); high precision micro-machined gyroscopes; MEMS-enhanced optical systems, tools and prosthetic appliances; electromechanical and machine-information systems integration)

Athanasios Sideris, Ph.D. University of Southern California, *Professor of Mechanical and Aerospace Engineering* (control systems, neural networks)

William A. Sirignano, Ph.D. Princeton University, *Henry Samueli Endowed Chair in Engineering and Distinguished Professor of Mechanical and Aerospace Engineering* (combustion theory, multiphase flows, turbulent reacting flows, computational methods, rocket and jet propulsion, gas turbine and internal combustion engines)

Hai-Tinh Taha, Ph.D. Virginia Polytechnic Institute and State University, *Assistant Professor of Mechanical and Aerospace Engineering* (geometric nonlinear control theory; unsteady aerodynamics and aeroelasticity; optimization, calculus of variations and optimal control; flight dynamics and autopilot design; airplane performance and configuration aerodynamics)

Mark Walter, Ph.D. California Institute of Technology, *Professor of Teaching of Mechanical and Aerospace Engineering* (mechanics of multifunctional materials, building energy efficiency)

Yun Wang, Ph.D. Pennsylvania State University, *Professor of Mechanical and Aerospace Engineering* (fuel cells, computational modeling, thermo-fluidics, two-phase flows, electrochemistry, Computational Fluid Dynamics (CFD), turbulent combustion)

Gregory N. Washington, Ph.D. North Carolina State University at Raleigh, *Professor Emeritus of Mechanical and Aerospace Engineering* (dynamic systems with emphasis on modeling and control of smart material systems and devices)

Yoon Jin Won, Ph.D. Stanford University, *Assistant Professor of Mechanical and Aerospace Engineering; Chemical and Biomolecular Engineering* (multi-scale structures for thermal and energy applications, in particular fabrication, characterization, and integration of structured materials)

**Affiliate Faculty**

Mohammad A. Al Faruque, Ph.D. University of Kaiserslautern, *Chair of Emulex Career Development and Associate Professor of Electrical Engineering and Computer Science; Computer Science; Mechanical and Aerospace Engineering* (cyber-physical systems, internet of things, embedded systems, CPS security)

Aparna Chandramowlishwaran, Ph.D. Georgia Institute of Technology, *Assistant Professor of Electrical Engineering and Computer Science; Computer Science; Mechanical and Aerospace Engineering* (high-performance computing, domain-specific compilers, algorithm-architecture co-design, data analysis, and scientific computing)

Joyce H. Keyak, Ph.D. University of California, San Francisco, *Professor in Residence of Radiological Sciences; Biomedical Engineering; Mechanical and Aerospace Engineering*

Arash Kheradvar, Ph.D. California Institute of Technology, *Professor of Biomedical Engineering; Mechanical and Aerospace Engineering* (cardiac mechanics, cardiovascular devices, cardiac imaging)

Abraham P. Lee, Ph.D. University of California, Berkeley, *Professor of Biomedical Engineering; Mechanical and Aerospace Engineering* (integrated point-of-care diagnostics, engineered "theranostic" vesicles and particles, active cell sorting microdevices, microphysiological microsystems, and high throughput droplet bioassays)

Beth A. Lopour, Ph.D. University of California, Berkeley, *Assistant Professor of Biomedical Engineering; Mechanical and Aerospace Engineering* (computational neuroscience, signal processing, mathematical modeling, epilepsy, translational research)

Timothy Rupert, Ph.D. Massachusetts Institute of Technology, *Associate Professor of Materials Science and Engineering; Chemical and Biomolecular Engineering; Mechanical and Aerospace Engineering* (mechanical behavior, nanomaterials, structure property relationships, microstructural stability, grain boundaries and interfaces, materials characterization)

Lorenzo Valdevit, Ph.D. Princeton University, *Director of Institute for Design and Manufacturing Innovation (IDMI) and Associate Professor of Materials Science and Engineering; Mechanical and Aerospace Engineering* (architected materials, mechanical metamaterials, additive manufacturing, optimal design)

Vasan Venugopalan, Sc.D. Massachusetts Institute of Technology, *Department Chair and Professor of Chemical and Biomolecular Engineering; Biomedical Engineering; Materials Science and Engineering; Mechanical and Aerospace Engineering; Surgery* (laser-generated thermal, mechanical and radiative transport processes for application in medical diagnostics, imaging, therapeutics, biotechnology)

Iryna Zenyuk, Ph.D. Carnegie Mellon University, *Associate Director of National Fuel Cell Research Center and Assistant Professor of Chemical and Biomolecular Engineering; Materials Science and Engineering; Mechanical and Aerospace Engineering* (renewable energy, fuel cells, electrolyzers, batteries, X-ray imaging techniques, multi-scale modeling, transport phenomena)
Courses

ENGRMAE 10. Introduction to Engineering Computations. 4 Units.
Introduction to the solution of engineering problems through the use of the computer. Elementary programming, numerical analysis, and data visualization with a high-level programming language such as MATLAB.

(Design units: 1)
Corequisite: MATH 2A
Prerequisite: MATH 2A or MATH 5A
Overlaps with EECS 10, EECS 12, BME 60B.
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Chemical Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment.

ENGRMAE 30. Statics. 4 Units.
Addition and resolution of forces, distributed forces, equivalent system of forces centroids, first moments, moments and products on inertia, equilibrium of rigid bodies, trusses, beams, cables. Course may be offered online.

(Design units: 0)
Corequisite: MATH 2D
Prerequisite: MATH 2D and PHYSICS 7C
Same as ENGRCEE 30, ENGR 30.
Restriction: School of Engineering students have first consideration for enrollment.

ENGRMAE 52. Computer-Aided Design. 4 Units.
Develops skills for interpretation and presentation of mechanical design drawings and the use of CAD in engineering design. An integrated approach to drafting based on sketching, manual drawing, and three-dimensional CAD techniques is presented.

(Design units: 0.5)
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment.

ENGRMAE 57. Manufacturing Processes in Engineering. 2 Units.

(Design units: 0)
Grading Option: Pass/no pass only.
Restriction: School of Engineering students have first consideration for enrollment.

ENGRMAE 60. Electric Circuits. 4 Units.
Design and analysis of analog circuits based on lumped circuit elements with emphasis on the use of operational amplifiers. Sinusoidal and transient response. Constructional and laboratory testing of analog circuits, and introduction to data acquisition. Materials fee.

(Design units: 2)
Corequisite: MATH 3D
Prerequisite: PHYSICS 7D and PHYSICS 7LD
Overlaps with EECS 70A.
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.
ENGRMAE 80. Dynamics. 4 Units.
Introduction to the kinematics and dynamics of particles and rigid bodies. The Newton-Euler, Work/Energy, and Impulse/Momentum methods are explored for ascertaining the dynamics of particles and rigid bodies. An engineering design problem using these fundamental principles is also undertaken.

(Design units: 0.5)

Prerequisite: MATH 2D and PHYSICS 7C

Same as ENGRCEE 80, ENGR 80.

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Civil Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment. Environmental Engineering Majors have first consideration for enrollment.

ENGRMAE 91. Introduction to Thermodynamics. 4 Units.
Thermodynamic principles; open and closed systems representative of engineering problems. First and second law of thermodynamics with applications to engineering systems and design.

(Design units: 0.5)

Prerequisite: PHYSICS 7C and MATH 2D

Overlaps with CBE 40B.

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Civil Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment. Environmental Engineering Majors have first consideration for enrollment.

ENGRMAE 93. Topics in Design Project . 1-4 Units.
Early-stage design/hands-on experience for students, and allows them to participate alongside seniors in the design project.

(Design units: 1)

Repeatability: Unlimited as topics vary.

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.

ENGRMAE 106. Mechanical Systems Laboratory. 4 Units.
Experiments in linear systems, including op-amp circuits, vibrations, and control systems. Emphasis on demonstrating that mathematical models can be useful tools for the analysis and design of electro-mechanical systems. Materials fee.

(Design units: 2)

Prerequisite: ENGRMAE 60 or EECS 70A

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Civil Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment. Environmental Engineering Majors have first consideration for enrollment.

ENGRMAE 107. Fluid Thermal Science Laboratory. 4 Units.
Fluid and thermal engineering laboratory. Experimental analysis of fluid flow, heat transfer, and thermodynamic systems. Probability, statistics, and uncertainty analysis. Report writing is emphasized and a design project is required. Materials fee.

(Design units: 1)

Corequisite: ENGRMAE 120

Restriction: Mechanical Engineering Majors have first consideration for enrollment.
ENGRMAE 108. Aerospace Laboratory. 4 Units.
Analytical and experimental investigation in aerodynamics, fluid dynamics, and heat transfer. Emphasis on study of flow over objects and lift and drag on airfoils. Introduction to basic diagnostic techniques. Report writing is emphasized. Design project is required.

(Design units: 2)
Prerequisite: ENGRMAE 130B
Restriction: Aerospace Engineering Majors have first consideration for enrollment. Mechanical Engineering majors have second consideration for enrollment.

ENGRMAE 110. Combustion and Fuel Cell Systems. 4 Units.
Fundamentals of gaseous, liquid, and coal-fired combustion and fuel cell systems. Fuels, fuel-air mixing, aerodynamics, and combustion and fuel cell thermodynamics. Operating and design aspects of practical systems including engines, power generators, boilers, furnaces, and incinerators.

(Design units: 2)
Prerequisite: ENGRMAE 115
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Chemical Engineering Majors have first consideration for enrollment. Environmental Engineering Majors have first consideration for enrollment.

ENGRMAE 112. Propulsion. 4 Units.
Application of thermodynamics and fluid mechanics to basic flow processes and cycle performance in propulsion systems: gas turbines, ramjets, scramjets, and rockets.

(Design units: 1)
Prerequisite: ENGRMAE 135
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.

ENGRMAE 113. Electric Propulsion. 4 Units.
Space propulsion requirements and maneuvers, stressing those best suited to electric propulsion. An introduction to plasma physics. Electrothermal, electromagnetic, and electrostatic accelerators, with emphasis in technologies (ion engines, Hall thrusters, and colloidal thrusters) belonging to the latter family.

(Design units: 1)
Prerequisite: ENGRMAE 112
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.

Concurrent with ENGRMAE 213.

ENGRMAE 114. Fuel Cell Fundamentals and Technology. 4 Units.
Introduction to electrochemistry and electrocatalysis; nature of fuel-cell electrodes and electrolytes; charge transfer reactions at interfaces; charge transport and mass transport processes; fuel processing reactions; determination of fuel cell efficiency, fuel flexibility, emissions, and other characteristics.

(Design units: 0)
Prerequisite: ENGRMAE 115
Restriction: Seniors only. Mechanical Engineering Majors have first consideration for enrollment. Chemical Engineering majors have second consideration for enrollment.

Concurrent with ENGRMAE 214A.
ENGRMAE 115. Applied Engineering Thermodynamics. 4 Units.
Application of thermodynamic principles to compressible and incompressible processes representative of practical engineering problems; power cycles, refrigeration cycles, multicomponent mixtures, air conditioning systems, combustion, and compressible flow. Design of a thermodynamic process.

(Design units: 2)
Prerequisite: ENGRMAE 91 or CBE 40B or ENGRMSE 65A
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment.

ENGRMAE 117. Solar and Renewable Energy Systems. 4 Units.
Basic principles, design, and operation of solar and other renewable energy systems including solar photo-voltaic, solar thermal, wind, and PEM fuel cell. Includes power generation and storage, and renewable fuels for transportation and stationary power generation.

(Design units: 1)
Prerequisite: (ENGRMAE 91 or CBE 40B)
Restriction: Mechanical Engineering Majors have first consideration for enrollment.

ENGRMAE 118. Sustainable Energy Systems. 4 Units.
Basic principles, design, and operation of sustainable energy systems including wind, solar photo-voltaic and thermal, hydroelectric, geothermal, oceanic, biomass combustion, advanced coal, and next generation nuclear. Includes power generation, storage, and transmission for stationary power generation.

(Design units: 1)
Prerequisite: ENGRMAE 115
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.
Concurrent with ENGRMAE 218.

ENGRMAE 119. Climate Solutions. 4 Units.
Focuses on carbon neutrality and climate stability, addressing.
Same as EARTHSS 179, UPPP 111.
Restriction: Upper-division students only.

ENGRMAE 120. Heat and Mass Transfer. 4 Units.
Fundamentals of heat and mass transfer. Conduction, heat and mass transfer by convection in laminar and turbulent flows, radiation heat transfer, and combined modes of heat and mass transfer. Practical engineering applications.

(Design units: 0)
Prerequisite: ENGRMAE 130B
Overlaps with CBE 120B.
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment.
ENGRMAE 130A. Introduction to Fluid Mechanics. 4 Units.
Fundamental concepts; fluid statics; fluid dynamics; Bernoulli's equation; control-volume analysis; basic flow equations of conservation of mass, momentum, and energy; differential analysis; potential flow; viscous incompressible flow.

(Design units: 0)

Corequisite: ENGRMAE 91
Prerequisite: PHYSICS 7C and MATH 2D and MATH 2E and MATH 3D and (ENGRMAE 30 or ENGRCEE 30 or ENGR 30) and (ENGRMAE 80 or ENGRCEE 80 or ENGR 80). PHYSICS 7C with a grade of C- or better. MATH 2D with a grade of C- or better. MATH 2E with a grade of C- or better. MATH 3D with a grade of C- or better. ENGRMAE 30 with a grade of C- or better. ENGRCEE 30 with a grade of C- or better. ENGR 30 with a grade of C- or better. ENGRMAE 80 with a grade of C- or better. ENGRCEE 80 with a grade of C- or better. ENGR 80 with a grade of C- or better

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.

ENGRMAE 130B. Introduction to Viscous and Compressible Flows. 4 Units.
Introduction to the analysis of viscous flows including fully developed laminar and turbulent flow in a pipe, viscous flow over immersed bodies, evaluation of boundary layer characteristics, lift and drag, compressible flow in a duct and normal shock waves.

(Design units: 1)

Prerequisite: ENGRMAE 130A

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.

ENGRMAE 132. Computational Fluid Dynamics. 4 Units.
Introduction to computational fluid dynamics in simple engineering devices. The numerical simulations will be performed via the widely-used software ANSYS-Fluent. While Fluent is the choice of software, all major CFD packages are based on a similar numerical method.

(Design units: 0)

Prerequisite: ENGRMAE 130B. ENGRMAE 130B with a grade of C- or better

Restriction: Aerospace Engineering Majors only. Mechanical Engineering Majors only.

ENGRMAE 135. Compressible Flow. 4 Units.
Compressibility effects in fluid mechanics. One-dimensional flow with area variation, friction, heat transfer, and shocks. Design of gas supply systems. Two-dimensional flow with oblique shocks and isentropic waves. Supersonic airfoil theory and design, wind tunnel design. Basic diagnostics.

(Design units: 1)

Prerequisite: ENGRMAE 130A

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.

ENGRMAE 136. Aerodynamics. 4 Units.
Analysis of flow over aircraft wings and airfoils, prediction of lift, moment, and drag. Topics: fluid dynamics equations; flow similitude; viscous effects; vorticity, circulation, Kelvin's theorem, potential flow; superposition principle, Kutta-Joukowski theorem; thin airfoil theory; finite wing theory; compressibility.

(Design units: 1)

Prerequisite: ENGRMAE 130B

Restriction: Aerospace Engineering Majors have first consideration for enrollment. Mechanical Engineering Majors have first consideration for enrollment.
ENGRMAE 145. Theory of Machines and Mechanisms. 4 Units.
Presents the basic mathematical theory of machines. Focuses on the principles of cam design, gearing and gear train analysis, and the kinematic and
dynamic analysis of linkages, together with an introduction to robotics.

(Design units: 2)
Prerequisite: ENGRMAE 52 and (ENGRMAE 80 or ENGRCEE 80 or ENGR 80) and (MATH 3A or I&C SCI 6N)
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Materials Science and Engineering majors have second
consideration for enrollment.

ENGRMAE 146. Astronautics. 4 Units.
Motion in gravitational force fields, orbit transfers, rocketry, interplanetary trajectories, attitude dynamics and stabilization, navigation, reentry, the space
environment.

(Design units: 1)
Prerequisite: ENGRMAE 80 or ENGRCEE 80 or ENGR 80
Restriction: Aerospace Engineering Majors have first consideration for enrollment.

ENGRMAE 147. Vibrations. 4 Units.
Analysis of structural vibrations of mechanical systems. Modeling for lumped and distributed parameter systems. Topics include single and multi-degree
of freedom systems, free and forced vibrations, Fourier series, convolution integral, mass/stiffness matrices, and normal modes with design project.

(Design units: 1)
Prerequisite: (ENGR 80 or ENGRCEE 80 or ENGRMAE 80) and MATH 2E and MATH 3D
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for
enrollment.

ENGRMAE 150. Mechanics of Structures. 4 Units.

(Design units: 2)
Prerequisite: (ENGRCEE 30 or ENGR 30 or ENGRMAE 30) and MATH 3A
Same as ENGR 150.
Overlaps with ENGRCEE 150.
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for
enrollment. Chemical Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for
enrollment.

ENGRMAE 150L. Mechanics of Structures Laboratory. 1 Unit.
Experimental techniques for the measurement of mechanical properties of materials and structures. Methods for load, displacement, and strain
measurements. Tension, bending, compression tests. Determination of strength, stiffness, toughness for metals, polymers, ceramics, and composites.
Deformation of structures. Materials fee.

(Design units: 0)
Corequisite: ENGRMAE 150
Prerequisite: ENGRMAE 30 or ENGR 30 or ENGRCEE 30
Overlaps with ENGRCEE 150L.
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for
enrollment. Materials Science and Engr Majors have first consideration for enrollment.
ENGRMAE 151. Mechanical Engineering Design. 4 Units.
A comprehensive group design project experience that involves identifying customer needs, idea generation, reverse engineering, preliminary design, standards, prototype development, testing, analysis, and redesign of a product involving fluid, thermal, and mechanical components. Introduces design for manufacturing and the environment. Materials fee.

(Design units: 3)

Corequisite: ENGRMAE 170
Prerequisite: ENGRMAE 120 and ENGRMAE 145

Restriction: Seniors only. Mechanical Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment.

ENGRMAE 152. Introduction to Computer-Aided Engineering. 4 Units.
Elements and principles of computer-aided engineering with modern hardware and software are presented with a design focus. Case studies are used to assist in finite-element method techniques. Not offered every year.

(Design units: 2)

Prerequisite: (ENGRMAE 150 or ENGR 150) and ENGRMAE 120

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment.

ENGRMAE 153. Advanced BIOMEMS Manufacturing Techniques. 4 Units.
Introduction to BIOMEMS. Advanced biotechnology/biomedicine equipment based on MEMS and NEMS. Fundamentals of MEMS/NEMS sensing techniques and the biological and physics principles involved and the preferred MEMS and NEMS manufacturing techniques.

(Design units: 0)

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Biomedical Engineering Majors have first consideration for enrollment.

Concurrent with ENGRMAE 253.

ENGRMAE 155. Composite Materials and Structures. 4 Units.
Motivation for composite materials. Different classifications according to the nature of the matrix (PMC, MMC, CMC) and the reinforcement topology (fibers, whiskers, particulates). Mechanical properties. Failure mechanisms. Designing with composite materials. Advantages and limitations of homogenization techniques for numerical modeling.

(Design units: 0)

Prerequisite: ENGR 54 and (ENGRMAE 150 or ENGRCEE 150 or ENGR 150)

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering majors have second consideration for enrollment. Chemical Engineering majors have second consideration for enrollment. Civil Engineering majors have second consideration for enrollment. Materials Science and Engineering majors have second consideration for enrollment.

Concurrent with ENGRMAE 255.

ENGRMAE 156. Mechanical Behavior and Design Principles. 4 Units.
Principles governing structure and mechanical behavior of materials, relationship relating microstructure and mechanical response with application to elasticity, plasticity, yielding, necking, creep, and fracture of materials. Introduction to experimental techniques to characterize the properties of materials. Design parameters.

(Design units: 2)

Prerequisite: ENGR 54

Same as ENGRMSE 155.

Restriction: Mechanical Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment. Aerospace Engineering majors have second consideration for enrollment.
ENGRMAE 157. Lightweight Structures. 4 Units.

(Design units: 2)
Prerequisite: ENGR 150 or ENGRCEE 150 or ENGRMAE 150
Restriction: Aerospace Engineering Majors have first consideration for enrollment. Mechanical Engineering majors have second consideration for enrollment. Civil Engineering majors have second consideration for enrollment. Materials Science and Engineering majors have second consideration for enrollment.

ENGRMAE 158. Aircraft Performance. 4 Units.
Flight theory applied to subsonic propeller and jet aircraft. Nature of aerodynamic forces, drag and lift of wing and fuselage, high-lift devices, level-flight performance, climb and glide performance, range, endurance, take-off and landing distances, static and dynamic stability and control.

(Design units: 2)
Prerequisite: ENGRMAE 130A
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.

ENGRMAE 159. Aircraft Design. 4 Units.
Preliminary design of subsonic general aviation and transport aircraft with emphasis on layout, aerodynamic design, propulsion, and performance. Estimation of total weight and weight distribution, design of wings, fuselage, and tail, selection and location of engines, prediction of overall performance.

(Design units: 4)
Prerequisite: ENGRMAE 112 and ENGRMAE 136 and ENGRMAE 158
Restriction: Aerospace Engineering Majors have first consideration for enrollment. Mechanical Engineering Majors have first consideration for enrollment.

ENGRMAE 164. Air Pollution and Control. 4 Units.
Sources, dispersion, and effects of air pollutants. Topics include emission factors, emission inventory, air pollution, meteorology, air chemistry, air quality modeling, impact assessment, source and ambient monitoring, regional control strategies.

(Design units: 2)
Prerequisite: (ENGRMAE 91 or CBE 40B) and ENGRMAE 130A
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Chemical Engineering Majors have first consideration for enrollment. Environmental Engineering Majors have first consideration for enrollment.

ENGRMAE 170. Introduction to Control Systems. 4 Units.

(Design units: 2)
Prerequisite: (ENGRMAE 80 or ENGRCEE 80 or ENGR 80) and ENGRMAE 106
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment. Civil Engineering Majors have first consideration for enrollment. Materials Science and Engr Majors have first consideration for enrollment.

ENGRMAE 171. Digital Control Systems. 4 Units.

(Design units: 2)
Prerequisite: ENGRMAE 170
Restriction: Civil Engineering Majors have first consideration for enrollment. Mechanical Engineering Majors have first consideration for enrollment.
ENGRMAE 172. Design of Computer-Controlled Robots. 4 Units.
Students design a small robotic device and program it to exhibit sentient behaviors. The basic aspects of mechatronic design are covered, including motor and sensor selection, control strategies, and microcomputer programming for the implementation of control paradigms. Materials fee.

(Design units: 3)
Corequisite: ENGRMAE 60
Prerequisite: ENGRMAE 170

Restriction: Mechanical Engineering Majors have first consideration for enrollment.
Concurrent with ENGRMAE 280.

ENGRMAE 175. Dynamics and Control of Aerospace Vehicles. 4 Units.

(Design units: 3)
Prerequisite: ENGRMAE 106

Restriction: Aerospace Engineering Majors have first consideration for enrollment. Mechanical Engineering Majors have first consideration for enrollment.

ENGRMAE 182. Introduction to Machine Learning. 4 Units.

ENGRMAE 183. Computer-Aided Mechanism Design. 4 Units.
Focuses on design of planar, spherical, and spatial mechanisms using computer algebra and graphics. Topics include exact and approximate analytical design techniques. Students are required to use existing software (or develop new algorithms) to design various mechanisms for new applications.

(Design units: 4)
Prerequisite: MATH 3A or I&C SCI 6N

Restriction: Mechanical Engineering Majors have first consideration for enrollment.

ENGRMAE 184. Fundamentals of Experimental Design. 4 Units.
Review of statistics as applied to experimental research. Fundamentals and principles of statistical experimental design and analysis with emphasis on understanding and use of designed experiments, response surfaces, linear regression modeling, and process optimization.

(Design units: 1)
Restriction: Mechanical Engineering Majors have first consideration for enrollment. Aerospace Engineering Majors have first consideration for enrollment.

Concurrent with ENGRMAE 284.

ENGRMAE 185. Numerical Analysis in Mechanical Engineering. 4 Units.

(Design units: 2)
Prerequisite: (ENGRMAE 10 or EECS 10 or EECS 12 or BME 60B) and MATH 3D and MATH 2E

Overlaps with MATH 105A.

ENGRMAE 188. Engineering Design in Industry. 4 Units.
Principles of engineering design in the context of an industrial application. Local manufacturing firms define an engineering design project to be completed in 10 weeks. Projects include initial brainstorming to final design, with a formal presentation.

(Design units: 4)
Repeatability: May be taken for credit 3 times.
Restriction: Mechanical Engineering Majors have first consideration for enrollment.
ENGRMAE 189. Senior Project - Special Topics. 1-4 Units.
Group or individual senior project of theoretical or applied nature involving design. Materials fee.

(Design units: 1-4)

Repeatability: May be taken for credit for 12 units as topics vary.
Restriction: Seniors only. Mechanical Engineering Majors only.

ENGRMAE 193. Topics in MAE Design. 1-4 Units.
Provides early-stage design/hands-on experience for upper-division students, and allows them to participate in senior design projects course ENGRMAE 189.

(Design units: 1)

Repeatability: May be taken for credit for 12 units as topics vary.
Restriction: Aerospace Engineering Majors have first consideration for enrollment. Mechanical Engineering Majors have first consideration for enrollment.

ENGRMAE 195. Seminars in Engineering. 1-4 Units.
Seminars by individual faculty in major fields of interest. Materials fee.

(Design units: 1-4)

Repeatability: Unlimited as topics vary.

ENGRMAE 198. Group Study. 1-4 Units.
Group study of selected topics in Aerospace and Mechanical Engineering.

(Design units: 1-4)

Repeatability: May be repeated for credit unlimited times.
Restriction: Upper-division students only.

ENGRMAE 199. Individual Study. 1-4 Units.
For undergraduate Engineering majors in supervised but independent reading, research, or design. Students taking individual study for design credit are to submit a written paper to the instructor and to the Undergraduate Student Affairs Office in the School of Engineering.

(Design units: 1-4)

Repeatability: May be taken for credit for 8 units.

ENGRMAE 199P. Individual Study. 1-4 Units.
For undergraduate Engineering majors in supervised but independent reading, research, or design. Students taking individual study for design are to submit a written paper to the instructor and to the Undergraduate Student Affairs Office in the School of Engineering.

(Design units: 1-4)

Grading Option: Pass/no pass only.
Repeatability: May be repeated for credit unlimited times.

ENGRMAE 200A. Engineering Analysis I. 4 Units.
Linear algebra, including vector spaces, matrices, linear systems of equations, least squares, and the eigenvalue problem. Ordinary differential equations, including analytical and numerical solution methods, stability, and phase portraits.

Restriction: Graduate students only.

ENGRMAE 200B. Engineering Analysis II. 4 Units.
Review of ordinary differential equations, including Bessel and Legendre functions. Partial differential equations, including the diffusion equation, Laplace's equation, and the wave equation. Fourier series, Fourier and Laplace transforms and their applications.

Restriction: Graduate students only.
**ENGRMAE 205. Perturbation Methods in Engineering. 4 Units.**

Prerequisite: ENGRMAE 200A and ENGRMAE 200B. Knowledge of linear differential equations.

Restriction: Graduate students only.

**ENGRMAE 206. Nonlinear Optimization Methods. 4 Units.**

Prerequisite: ENGRMAE 200A

Restriction: Graduate students only.

**ENGRMAE 207. Methods of Computer Modeling in Engineering and the Sciences. 4 Units.**
Unified introduction to finite volume, finite element, field-boundary element, meshless, primal, dual, and mixed methods. Nonlinear problems posed by ordinary as well as partial differential equations. Computer implementations and comparisons of accuracy and convergence.

Restriction: Graduate students only.

**ENGRMAE 209P. Energy Efficiency Technology. 4 Units.**
Principles, design, operation of energy efficient technology in the built environment, including solar energy, green building design, low waste/ emissions construction materials, energy harvesting, built environment energy conversion and storage, high efficiency lighting, daylighting, heat pumps, cooling systems, renewable power systems.

Restriction: Master of Engineering students only. Graduate students only.

**ENGRMAE 210. Advanced Fundamentals of Combustion. 4 Units.**
Premixed, nonpremixed, and heterogenous reactions, with emphasis on kinetics, thermal ignition, turbulent flame propagation, detonations, explosions, flammability limits, diffusion flame, quenching, flame stabilization, and particle and spray combustion. Not offered every year.

Prerequisite: ENGRMAE 224 or ENGRMAE 230B

Restriction: Graduate students only.

**ENGRMAE 211P. Energy Storage Systems and Technology. 4 Units.**
Basic principles, design, and operation of energy storage systems and technology including lithium ion battery systems for transportation and stationary applications, for flow batteries (e.g., vanadium redox, sodium sulfur), and for reversible fuel cell electrolyzer systems and hydrogen energy storage.

Prerequisite: Required: Undergraduate-level knowledge of applied engineering thermodynamics.

Restriction: Master of Engineering students only. Graduate students only.

**ENGRMAE 212. Engineering Electrochemistry: Fundamentals and Applications. 4 Units.**
Introduction to engineering electrochemistry fundamentals and applications. Examine thermodynamics and transport principles in typical electrochemical systems. Electrochemical sensors, batteries, fuel cells, and supercapacitors. Manufacturing aspects will also be covered.

Restriction: Graduate students only.

**ENGRMAE 212P. Engineering Electrochemistry: Fundamentals and Applications. 4 Units.**
Introduction to engineering electrochemistry fundamentals and applications. Examine thermodynamics and transport principles in typical electrochemical systems. Electrochemical sensors, batteries, fuel cells, and supercapacitors. Manufacturing aspects are also covered.

Restriction: Master of Engineering students only. Graduate students only.

**ENGRMAE 213. Electric Propulsion. 4 Units.**
Space propulsion requirements and maneuvers, stressing those best suited to electric propulsion. An introduction to plasma physics. Electrothermal, electromagnetic and electrostatic accelerators, with emphasis in technologies (ion engines, Hall thrusters and colloidal thrusters) belonging to the latter family.

Restriction: Graduate students only.

Concurrent with ENGRMAE 113.
ENGRMAE 214A. Fuel Cell Fundamentals and Technology. 4 Units.
Introduction to electrochemistry and electrocatalysis; nature of fuel-cell electrodes and electrolytes; charge transfer reactions at interfaces; charge transport and mass transport processes; fuel processing reactions; determination of fuel cell efficiency, fuel flexibility, emissions and other characteristics.

Restriction: Graduate students only.

Concurrent with ENGRMAE 114.

ENGRMAE 214AP. Fuel Cell Fundamentals and Technology. 4 Units.
Introduction to electrochemistry and electrocatalysis; nature of fuel-cell electrodes and electrolytes; charge transfer reactions at interfaces; charge transport and mass transport processes; fuel processing reactions; determination of fuel cell efficiency, fuel flexibility, emissions, and other characteristics.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 214B. Fuel Cell Systems and Degradation. 4 Units.
Fuel cell systems design; impacts of operating conditions; experimental and theoretical analysis methods for fuel cells systems; introduction to degradation mechanisms and mitigation techniques; provides broad insight into fuel-cell science, technology, system design and operation. Offered every other year.

Prerequisite: ENGRMAE 214A

Restriction: Graduate students only.

ENGRMAE 214C. PEM Fuel Cells. 4 Units.
An in-depth introduction to the fundamentals of PEM fuel cells, including thermodynamics, kinetics, and transport in electrochemical systems. Topics of specific interest to mechanical engineers will include water/heat management and dynamic responses.

Prerequisite: ENGRMAE 214A

Restriction: Graduate students only.

ENGRMAE 215. Advanced Combustion Technology. 4 Units.
Pollutant formation and experimental methods. Formation of gaseous pollutants and soot; transformation and emission of fuel contaminants in gas, liquid, and solid fuel combustion; methods employed to measure velocity, turbulence intensity, temperature, composition, particle size; methods to visualize reacting flows.

Prerequisite: ENGRMAE 200A and (ENGRMAE 230A or ENGRMAE 270A)

Restriction: Graduate students only.

ENGRMAE 216. Statistical Thermodynamics. 4 Units.
Statistics of independent particles, development of quantum mechanical description of atoms and molecules, application of quantum mechanics, evaluation of thermodynamics properties for solids, liquids, and gases, statistical mechanics of dependent particles (ensembles).

Restriction: Graduate students only.

ENGRMAE 217. Generalized Thermodynamics. 4 Units.
Generalized thermodynamics develops the laws of continuum thermodynamics from a set of plausible and intuitive postulates. The postulates are motivated qualitatively by a statistical description of matter and are justified by a posterior success for the resulting theory.

Restriction: Graduate students only.

ENGRMAE 217P. Generalized Thermodynamics. 4 Units.
Generalized thermodynamics develops the laws of continuum thermodynamics from a set of plausible and intuitive postulates. The postulates are motivated qualitatively by a statistical description of matter and are justified by a posterior success for the resulting theory.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 218. Sustainable Energy Systems. 4 Units.
Basic principles, design and operation of sustainable energy systems including wind, solar photo-voltaic and thermal, hydroelectric, geothermal, oceanic, biomass combustion, advanced coal and next generation nuclear. Includes power generation, storage, and transmission for stationary power generation.

Restriction: Graduate students only.

Concurrent with ENGRMAE 118.
ENGRMAE 218P. Sustainable Energy Systems. 4 Units.
Basic principles, design, and operation of sustainable energy systems including wind, solar photo-voltaic and thermal, hydroelectric, geothermal, oceanic, biomass combustion, advanced coal, and next generation nuclear. Includes power generation, storage, and transmission for stationary power generation.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 219P. Solar and Renewable Energy Systems. 4 Units.
Basic principles, design, and operation of solar and other renewable energy systems including solar photo-voltaic, solar thermal, wind, and PEM fuel cell. Includes power generation and storage, and renewable fuels for transportation and stationary power generation.

Prerequisite: Required: Knowledge of applied engineering thermodynamics.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 220. Conduction Heat Transfer. 4 Units.
Steady state and transient conduction heat transfer in one- and multi-dimensional geometries. Analytical methods, exact and approximate. Numerical techniques are also included.

Restriction: Graduate students only.

ENGRMAE 221. Convective Heat and Mass Transfer. 4 Units.

Prerequisite: ENGRMAE 230B

Restriction: Graduate students only.

ENGRMAE 222. Radiative Heat Transfer. 4 Units.

Restriction: Graduate students only.

ENGRMAE 223A. Numerical Methods in Heat, Mass, and Momentum Transport (Laminar Flows) I. 4 Units.
Introduction to the discretization of various types of partial differential equations (parabolic, elliptic, hyperbolic). Finite-volume discretization for one- and two-dimensional flows. Use of a two-dimensional elliptic procedure to predict sample laminar flows.

Prerequisite or corequisite: ENGRMAE 230A

Restriction: Graduate students only.

ENGRMAE 223B. Numerical Methods in Heat, Mass, and Momentum II. 4 Units.

Prerequisite: ENGRMAE 223A

Restriction: Graduate students only.

ENGRMAE 224. Advanced Transport Phenomena. 4 Units.

Restriction: Graduate students only.

ENGRMAE 226. Special Topics in Fluid and Thermal Sciences. 1-4 Units.
Special topics of current interest in fluid mechanics, heat and mass transfer, multiphase flows, or combustion. Emphasis could be placed on theory, computational methods, or experimental techniques.

Repeatability: Unlimited as topics vary.

Restriction: Graduate students only.
ENGRMAE 227. Thermal Resistance Analysis in Microdevices and Nanomaterials. 4 Units.
Heat transfer and thermal resistance analysis relevant for microdevices and nanomaterials. Overview of recent progress in nanotechnology and materials science. Thermal modeling strategies for novel electronic devices and energy conversion systems.

Restriction: Graduate students only.

ENGRMAE 228. Nanoscale Phase Change Transport Physics. 4 Units.
Discusses a wide range of phase change processes (i.e., evaporation, boiling, condensation, and freezing) through the use of novel thermal metamaterials with the aim of enhancing phase change performances.

Prerequisite: Undergraduate-level heat transfer is recommended.

Restriction: Graduate students only.

ENGRMAE 229P. Nanoscale Materials for Modern Electronics. 4 Units.
Introduction to design and synthesis of nanomaterials. Topics include thermal and liquid transport in materials systems, phase change heat transfer physics, and mechanical properties in materials systems.

Prerequisite: Required: Undergraduate-level knowledge of heat transfer.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 230A. Inviscid Incompressible Fluid Mechanics I. 4 Units.

Restriction: Graduate students only.

ENGRMAE 230B. Viscous Incompressible Fluid Mechanics II. 4 Units.

Restriction: Graduate students only.

ENGRMAE 230C. Compressible Fluid Dynamics. 4 Units.

Prerequisite: ENGRMAE 230A or ENGRMAE 230B

Restriction: Graduate students only.

ENGRMAE 230D. Theoretical Foundations of Fluid Mechanics. 4 Units.

Prerequisite: ENGRMAE 230A and ENGRMAE 230B

Restriction: Graduate students only.

ENGRMAE 231. Fundamentals of Turbulence. 4 Units.

Prerequisite: ENGRMAE 230A and ENGRMAE 230B

Restriction: Graduate students only.

ENGRMAE 232. Turbulent Free Shear Flows. 4 Units.

Prerequisite: ENGRMAE 200B and ENGRMAE 230A and ENGRMAE 230B

Restriction: Graduate students only.
ENGRMAE 236. Nonequilibrium Gas Dynamics. 4 Units.

Prerequisite: ENGRMAE 230C

Restriction: Graduate students only.

ENGRMAE 237. Computational Fluid Dynamics. 4 Units.
Mathematical, physical, and computational fundamentals of computational fluid dynamics, numerical methods for solving the Euler and Navier-Stokes equations. Topics include: finite-difference and finite-volume discretization, time marching methods, von Neumann analysis, upwinding, flux splitting, TVD, and other high-resolution shock-capturing schemes.

Prerequisite: ENGRMAE 230C

Restriction: Graduate students only.

ENGRMAE 238. Experimental Fluid Dynamics. 4 Units.

Prerequisite: ENGRMAE 230A and ENGRMAE 230B

Restriction: Graduate students only.

ENGRMAE 239. Dynamics of Unsteady Flows. 4 Units.

Prerequisite: ENGRMAE 230A is recommended.

Restriction: Graduate students only.

ENGRMAE 241. Dynamics. 4 Units.
Kinematics and dynamics of three-dimensional motions. Lagrange's equations, Newton-Euler equations. Applications include robot systems and spinning satellites.

Restriction: Graduate students only.

ENGRMAE 242. Robotics. 4 Units.

Restriction: Graduate students only.

ENGRMAE 244. Theoretical Kinematics. 4 Units.
Spatial rigid body kinematics is presented with applications to robotics. Orthogonal Matrices, Rodrigues' formula, Quaternions, Plucker coordinates, screw theory, and dual numbers are studied using modern projective geometry and multi-linear algebra. Applications include trajectory planning, inverse kinematics, and workspace analysis.

Restriction: Graduate students only.

ENGRMAE 245. Spatial Mechanism Design. 4 Units.
Fundamental kinematic theory required for planar, spherical, and spatial mechanism design. The focus is on algebraic methods for the exact solution of constraint equations. Not offered every year.

Restriction: Graduate students only.

ENGRMAE 247. Micro-System Design. 4 Units.
Covers the fundamentals of the many disciplines needed for design of Micro-Electro-Mechanical Systems (MEMS): microfabrication technology, structural mechanics on micro-scale, electrostatics, circuit interface, control, computer-aided design, and system integration.

Same as EECS 278.

Restriction: Graduate students only.
ENGRMAE 247P. Micro-System Design. 4 Units.
Covers the fundamentals of the many disciplines needed for design of Micro-Electro-Mechanical Systems (MEMS): microfabrication technology, structural mechanics on micro-scale, electrostatics, circuit interface, control, computer-aided design, and system integration.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 249. Micro-Sensors and Actuators. 4 Units.
Introduction to the technology of Micro-Electro-Mechanical Systems (MEMS). Fundamental principles and applications of important microsensors, actuation principles on microscale. Introduction to the elements of signal processing; processing of materials for micro sensor/actuator fabrication; smart sensors and microsensor/microactuator array devices.

Same as EECS 279.

Restriction: Graduate students only.

ENGRMAE 250. Biorobotics. 4 Units.
Sensors, actuators, and neural circuits for biological movement control from an engineering perspective. Current approaches to robotic and mechatronic devices that support and enhance human movement in health and following neurologic injuries like stroke and spinal cord injury.

Restriction: Graduate students only.

ENGRMAE 252. Fundamentals of Microfabrication. 4 Units.
Introduces Engineering and Science students to the science of miniaturization. Different options to make very small machines (micro and nano size) are reviewed, materials choices are discussed, scaling laws are analyzed, and many practical applications are listed.

Restriction: Graduate students only.

ENGRMAE 252P. Fundamentals of Microfabrication. 4 Units.
Introduces engineering and science students to the science of miniaturization. Different options to make very small machines (micro and nano size) are reviewed, materials choices are discussed, scaling laws are analyzed, and many practical applications are listed.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 253. Advanced BIOMEMS Manufacturing Techniques. 4 Units.
Introduction to BIOMEMS. Advanced biotechnology/biomedicine equipment based on MEMS and NEMS. Fundamentals of MEMS/NEMS sensing techniques and the biological and physics principles involved and the preferred MEMS and NEMS manufacturing techniques.

Restriction: Graduate students only.

Concurrent with ENGRMAE 153.

ENGRMAE 254. Mechanics of Solids and Structures. 4 Units.
Finite deformation kinematics; stress and strain measures; invariance in solid mechanics; objective rates; constitutive theory of elastic and inelastic solids; rate formulations; computational approaches; theories of plates and shells; applications to aerospace vehicles.

Restriction: Graduate students only.

ENGRMAE 254P. Mechanics of Solids and Structures. 4 Units.
Finite deformation kinematics; stress and strain measures; invariance in solid mechanics; objective rates; constitutive theory of elastic and inelastic solids; rate formulations; computational approaches; theories of plates and shells; applications to aerospace vehicles.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 255. Composite Materials and Structures. 4 Units.
Motivation for composite materials. Different classifications according to the nature of the matrix (PMC, MMC, CMC) and the reinforcement topology (fibers, whiskers, particulates). Mechanical properties. Failure mechanisms. Designing with composite materials. Advantages and limitations of homogenization techniques for numerical modeling.

Restriction: Graduate students only.

Concurrent with ENGRMAE 155.

ENGRMAE 256. Nanomechanics. 4 Units.
Nanoscale materials and the experimental and computational techniques used to measure their properties. Mechanical behavior is the main focus, but other material properties such as diffusion and electron transport are discussed.

Restriction: Graduate students only.
ENGRMAE 257P. Fabrication and Characterization of Nanomaterials. 4 Units.
Introduction to nanoscale materials and experimental and computational techniques. Topics include materials synthesis techniques, thin film deposition, nanoparticle and nanowire growth, characterization with electrons and X-rays, forces and surface interactions at the nanoscale, structure-property scaling laws, and atomistic/multiscale computer modeling.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 258. Mechanical Behavior of Solids - Continuum Theories. 4 Units.
Presents a continuum, macroscopic view of deformation and failure of solids. Covers elasticity, plasticity, visco-elasticity, visco-plasticity, fracture and fatigue. Topics include discussions of physical behavior, mathematical formalism and measurement techniques.

Prerequisite: ENGRMAE 254

Restriction: Graduate students only.

ENGRMAE 259. Mechanical Behavior of Solids - Atomistic Theories. 4 Units.
Presents atomistic mechanisms that control mechanical behavior of materials. Covers plasticity, dislocation theory, strengthening mechanisms, high-temperature diffusion and gain boundary sliding, shear localization, void formation, ductile rupture, brittle fracture and fatigue.

Restriction: Graduate students only.

ENGRMAE 259P. Mechanical Behavior of Solids - Atomistic Theories. 4 Units.
Presents atomistic mechanisms that control mechanical behavior of materials. Covers plasticity, dislocation theory, strengthening mechanisms, high-temperature diffusion and gain boundary sliding, shear localization, void formation, ductile rupture, brittle fracture, and fatigue.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 260. Current Issues Related to Air Quality, Climate, and Energy. 4 Units.
Current issues related to the atmosphere, climate, and air quality in the context of energy conversion and sustainability. Topics include transportation systems; building design; impacts on humans and ecosystems; modeling and meteorology; economics; and application to public policies.

Prerequisite: ENGRMAE 261 or CHEM 245 or EARTHSS 240

Same as CHEM 241.

Restriction: Graduate students only.

ENGRMAE 270A. Linear Systems I. 4 Units.
Input-output and state-space representations of continuous-time linear systems. State transition matrices, Controllability and observability. Irreducible realizations. State feedback and observer design.

Restriction: Graduate students only.

ENGRMAE 270B. Linear Systems II. 4 Units.

Prerequisite: ENGRMAE 270A

Restriction: Graduate students only.

ENGRMAE 272. Robust Control Theory. 4 Units.

Prerequisite: ENGRMAE 270A

Restriction: Graduate students only.
ENGRMAE 274. Optimal Control. 4 Units.
Principles and methods of optimal control. Topics include objectives and issues in controlling nonlinear systems; linear variational and adjoint equations; optimality conditions via variational calculus, maximum principle, and dynamic programming; solution methods; applications to control robots and aerospace vehicles.

Prerequisite: ENGRMAE 200A and ENGRMAE 270A
Restriction: Graduate students only.

ENGRMAE 275. Nonlinear Feedback Systems. 4 Units.
Advanced tools for feedback control system analysis and synthesis. Norms, operators, Lp spaces, contraction mapping theorem, Lyapunov techniques along with their extensions. Circle criterion positivity and passivity. Applications to nonlinear control methods, such as sliding mode or adaptive techniques.

Prerequisite: ENGRMAE 270B
Restriction: Graduate students only.

ENGRMAE 276. Geometric Nonlinear Control. 4 Units.
Using the mathematics of differential geometry, a number of the concepts and results of linear systems theory have been extended to nonlinear systems. Describes these extensions and illustrate their use in nonlinear system analysis and design. Not offered every year.

Prerequisite: ENGRMAE 200A and ENGRMAE 270A
Restriction: Graduate students only.

ENGRMAE 277. Learning Control Systems. 4 Units.

Restriction: Graduate students only.

ENGRMAE 278. Parameter and State Estimation. 4 Units.

Prerequisite: ENGRMAE 200A and ENGRMAE 270A
Restriction: Graduate students only.

ENGRMAE 279. Special Topics in Mechanical Systems. 4 Units.
Selected topics of current interest in mechanical systems. Topics include robotics, kinematics, control, dynamics, and geometric modeling.

Prerequisite: ENGRMAE 270A and ENGRMAE 241
Repeatability: Unlimited as topics vary.
Restriction: Graduate students only.

ENGRMAE 280. Design of Computer-Controlled Robots. 4 Units.
The basic aspects of mechatronic design are covered, including motor and sensor selection, control strategies, finite state machines, inertial measurement units, and implementation of advanced feedback control laws. Students work in groups to create their own mechatronic device. Materials fee.

Restriction: Graduate students only.
Concurrent with ENGRMAE 172.

ENGRMAE 284. Fundamentals of Experimental Design. 4 Units.
Fundamentals and principles of statistical experimental design and analysis. Emphasis addresses understanding and use of designed experiments, response surfaces, linear regression modeling, process optimization, and development of links between empirical and theoretical models.

Restriction: Graduate students only.
Concurrent with ENGRMAE 184.
ENGRMAE 294. Master of Science Thesis Project. 4 Units.
Tutorial in which masters-level students taking the comprehensive examination option undertake a masters-level research project.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

ENGRMAE 295. Special Topics in Mechanical and Aerospace Engineering. 1-4 Units.
Special topics by individual faculty in major fields of interest.

Repeatability: Unlimited as topics vary.

ENGRMAE 295P. Special Topics in Mechanical and Aerospace Engineering. 4 Units.
Studies in selected areas of Mechanical and Aerospace Engineering. Topics addressed vary each quarter.

Repeatability: Unlimited as topics vary.

Restriction: Master of Engineering students only. Graduate students only.

ENGRMAE 296. Master of Science Thesis Research. 1-16 Units.
Individual research or investigation conducted in the pursuit of preparing and completing the thesis required for the M.S. in Engineering.

Repeatability: May be repeated for credit unlimited times.

ENGRMAE 297. Doctor of Philosophy Dissertation Research. 1-16 Units.
Individual research or investigation conducted in the pursuit of preparing and completing the dissertation required for the Ph.D. in Engineering.

Repeatability: May be repeated for credit unlimited times.

ENGRMAE 298. Seminars in Mechanical and Aerospace Engineering. 1 Unit.
Presentation of advanced topics and reports of current research efforts in mechanical engineering. Required of all graduate students in mechanical engineering.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

ENGRMAE 299. Individual Research. 1-16 Units.
Individual research or investigation under the direction of an individual faculty member.

Repeatability: May be repeated for credit unlimited times.

Restriction: Consent of instructor to enroll