CU Boulder's Mechanical Engineering Graduate Program (http://www.colorado.edu/mechanical/prospective-students/graduate) is one of the top ranked programs in the U.S. News & World Report Best Graduate Schools issue among public universities. Students receive a strong education and conduct groundbreaking tier-one research. We have 50+ faculty members conducting fundamental and applied research in air quality, biomedical, materials, mechanics of materials, micro/nanoscale, robotics and systems design, and thermo fluid sciences.

Boulder is also home to research and development operations for many large companies and four federal research labs: the National Center for Atmospheric Research, the National Institute for Standards and Technology, the National Oceanic and Atmospheric Administration, and the National Renewable Energy Laboratory.

Recent doctoral and master's graduates accepted employment at companies including, but not limited to: ConocoPhilips, Ford, Google, NASA Jet Propulsion Laboratory, Lockheed Martin, Nike, Sandia National Laboratories and Seagate. Many of our graduating PhD students also enter careers in academia.

**Master's Degrees**

- Mechanical Engineering - Master of Science (MS) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/mechanical-engineering/mechanical-engineering-master-science-ms)
- Mechanical Engineering - Professional Master of Science (MSME) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/mechanical-engineering/mechanical-engineering-professional-master-science-msme)

**Doctoral Degree**

- Mechanical Engineering - Doctor of Philosophy (PhD) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/mechanical-engineering/mechanical-engineering-doctor-philosophy-phd)

**Faculty**

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

- Affrunti, Andrew J. (https://experts.colorado.edu/display/fisid_149937) Instructor; MSE, University of Illinois at Urbana–Champaign
- Ahmed, Alaa A. (https://experts.colorado.edu/display/fisid_144736) Associate Professor; PhD, University of Michigan
- Borden, Mark A. (https://experts.colorado.edu/display/fisid_148514) Associate Professor; PhD, University of California, Davis
- Branch, Melvyn C. Professor Emeritus
- Brower, Timothy L. (https://experts.colorado.edu/display/fisid_147553) Senior Instructor; PhD, Colorado State University
- Bruns, Carson J. (https://experts.colorado.edu/display/fisid_159851) Assistant Professor; PhD, Northwestern University
- Carlson, Lawrence E. Professor Emeritus
- Castro, Francisco (https://experts.colorado.edu/display/fisid_147992) Instructor; PhD, University of Colorado Boulder
- Daily, John W. (https://experts.colorado.edu/display/fisid_100131) Professor; PhD, Stanford University
- Datta, Subhendu K. Professor Emeritus
- Ding, Xiaoyun (https://experts.colorado.edu/display/fisid_158563) Assistant Professor; PhD, Pennsylvania State University
- Ding, Yifu (https://experts.colorado.edu/display/fisid_146088) Associate Professor; PhD, University of Akron
- Ferguson, Virginia L. (https://experts.colorado.edu/display/fisid_110131) Associate Professor; PhD, University of Colorado Boulder
- Geers, Thomas L. Professor Emeritus
- Greenberg, Alan R. Professor Emeritus
- Hamlington, Peter Edward (https://experts.colorado.edu/display/fisid_149800) Assistant Professor, Associate Chair; PhD, University of Michigan Ann Arbor
- Hannigan, Michael P. (https://experts.colorado.edu/display/fisid_122655) Professor, Chair; PhD, California Institute of Technology
- Henze, Daven K. (https://experts.colorado.edu/display/fisid_144858) Associate Professor; PhD, California Institute of Technology
- Hertzig, Jean R. (https://experts.colorado.edu/display/fisid_105315) Associate Professor; PhD, University of California, Berkeley
- Humbert, J. Sean (https://experts.colorado.edu/display/fisid_156202) Professor; PhD, California Institute of Technology
- Kassoy, David R. Professor Emeritus
- Keplinger, Christoph M. (https://experts.colorado.edu/display/fisid_156421) Assistant Professor; PhD, Johannes Kepler Universität Linz (Austria)
- Knappe, Svenja A. (https://experts.colorado.edu/display/fisid_139588) Associate Research Professor; PhD, Rheinische Friedrich-Wilhelms-Universität (Germany)
- Knutsen, Jeffrey S. (https://experts.colorado.edu/display/fisid_145534) Senior Instructor; PhD, University of Colorado Boulder
- Kotys-Schwartz, Daria (https://experts.colorado.edu/display/fisid_144738) Senior Instructor; PhD, University of Colorado Boulder
- Labbe, Nicole J. (https://experts.colorado.edu/display/fisid_157742) Assistant Professor; PhD, University of Massachusetts, Amherst
Lee, Sehee (https://experts.colorado.edu/display/fisid_144739)  
Professor; PhD, Seoul National University (South Korea)

Lee, Yung-Cheng (https://experts.colorado.edu/display/fisid_103170)  
Professor; PhD, University of Minnesota Twin Cities

Li, Baowen (https://experts.colorado.edu/display/fisid_156203)  
Professor; PhD, Carl von Ossietzky Universität Oldenburg (Germany)

Long, Rong (https://experts.colorado.edu/display/fisid_151301)  
Assistant Professor; PhD, Cornell University

Lynch, Maureen Ellen (https://experts.colorado.edu/display/fisid_163404)  
Assistant Professor; PhD, Cornell University

MacCurdy, Robert B. (https://experts.colorado.edu/display/fisid_163307)  
Assistant Professor; PhD, Cornell University

Marshall, David B. (https://experts.colorado.edu/display/fisid_158629)  
Research Professor; PhD, Monash University (Australia)

Maute, Kurt (https://experts.colorado.edu/display/fisid_113875)  
Professor; PhD, University of Stuttgart (Germany)

McNeill, Nathan John (https://experts.colorado.edu/display/fisid_151518)  
Instructor; PhD, Purdue University

Milford, Jana B. (https://experts.colorado.edu/display/fisid_103268)  
Professor; PhD, Carnegie Mellon University

Miller, Shelly L. (https://experts.colorado.edu/display/fisid_110394)  
Professor; PhD, University of California, Berkeley

Mitra, Peter P. (https://experts.colorado.edu/display/fisid_155075)  
Instructor; PhD, University of Colorado, Boulder

Murray, Todd W. (https://experts.colorado.edu/display/fisid_146549)  
Professor; PhD, Johns Hopkins University

Neu, Corey P. (https://experts.colorado.edu/display/fisid_156210)  
Associate Professor; PhD, University of California, Davis

Pellegrino, John (https://experts.colorado.edu/display/fisid_130902)  
Research Professor; PhD, University of Colorado Boulder

Raj, Rishi (https://experts.colorado.edu/display/fisid_108413)  
Professor; PhD, Harvard University

Reamon, Derek T. (https://experts.colorado.edu/display/fisid_120538)  
Senior Instructor; PhD, Stanford University

Regner, Keith T. (https://experts.colorado.edu/display/fisid_158065)  
Instructor; PhD, Carnegie Mellon University

Rentschler, Mark E. (https://experts.colorado.edu/display/fisid_146091)  
Associate Professor; PhD, University of Nebraska-Lincoln

Riek, Gregory Brian (https://experts.colorado.edu/display/fisid_151727)  
Assistant Professor; PhD, Stanford University

Riffell, Daniel J. (https://experts.colorado.edu/display/fisid_154141)  
Scholar in Residence; MS, University of Colorado Boulder

Ruben, Shalom D. (https://experts.colorado.edu/display/fisid_149492)  
Senior Instructor; PhD, University of California, Los Angeles

Steinbrenner, Julie E. (https://experts.colorado.edu/display/fisid_152041)  
Instructor; PhD, Stanford University

Stoldt, Conrad R. (https://experts.colorado.edu/display/fisid_126290)  
Professor, Associate Chair; PhD, Iowa State University

Stowell, Michael (https://experts.colorado.edu/display/fisid_124136)  
Associate Professor; PhD, California Institute of Technology

Tan, Wei (https://experts.colorado.edu/display/fisid_141464)  
Associate Professor; PhD, University of Illinois at Chicago

Tsai, Janet Yi-Jen (https://experts.colorado.edu/display/fisid_156447)  
Instructor; PhD, University of Colorado Boulder

Vance, Marina E. (https://experts.colorado.edu/display/fisid_158217)  
Assistant Professor; PhD, Virginia Polytechnic Institute and State University

Vernerey, Franck J. (https://experts.colorado.edu/display/fisid_144760)  
Associate Professor; PhD, Northwestern University

Weidman, Patrick D.  
Professor Emeritus

Whiting, Gregory L. (https://experts.colorado.edu/display/fisid_159727)  
Associate Professor; PhD, University of Cambridge (England)

Xiao, Jianliang (https://experts.colorado.edu/display/fisid_149777)  
Assistant Professor; PhD, Northwestern University

Yang, Ronggui (https://experts.colorado.edu/display/fisid_142640)  
Professor; PhD, Massachusetts Institute of Technology

Yin, Xiaobo (https://experts.colorado.edu/display/fisid_153484)  
Associate Professor; PhD, Stanford University

Zable, Jack L.  
Professor Emeritus

**Courses**

**MCEN 5010 (3) Microsystems Integration**  
A microsystem consists of microelectronic, optoelectronic, microwave, microelectromechanical and energy components interconnected. Thermal, electrical, fabrication and assembly issues for microsystems represented by iPhone series will be studied. The packaging and interconnection technologies used to establish the design and manufacturing infrastructure of microsystems will be reviewed. Other optoelectronic, MEMS and batter components for microsystems will also be studied.  

*Equivalent - Duplicate Degree Credit Not Granted: MCEN 4010*  
*Requisites:* Restricted to students with 87-180 credits (Senior, Fifth Year Senior) Mechanical (MCEN) majors or College of Engineering graduate students only.

*Grading Basis:* Letter Grade

**MCEN 5020 (3) Methods of Engineering Analysis 1**  
Studies selected topics from linear algebra, ordinary differential equations, and Fourier series. Assigns computer exercises. Correlates with analysis topics in other mechanical engineering graduate courses, and emphasizes applications.  

*Requisites:* Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

*Additional Information:* Departmental Category: Math
MCEN 5021 (3) Introduction to Fluid Dynamics
Focuses on physical properties of gases and liquids, and kinematics of flow fields. Analyzes stress; viscous, heat-conducting Newtonian fluids; and capillary effects and surface-tension-driven flow. Other topics include vorticity and circulation, ideal fluid flow theory in two and three dimensions, Schwartz-Christoffel transformations, free streamline theory, and internal and free-surface waves.

**Requisites:** Requires corequisite course of MCEN 5020. Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Fluids

MCEN 5022 (3) Classical Thermodynamics

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Thermal

MCEN 5023 (3) Solid Mechanics 1
Introduces stress, strain and motion of a continuous system. Discusses material derivative; fundamental laws of mass, momentum, energy and entropy; constitutive equations and applications to elasticians plastic materials.

**Equivalent - Duplicate Degree Credit Not Granted:** ASEN 5012

**Requisites:** Requires coreq course of MCEN 5020. Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering (MCEN) majors only.

**Additional Information:** Departmental Category: Solids

MCEN 5024 (3) Materials Chemistry and Structures
Provides graduate level students with a comprehensive overview of the chemistry and structure of material systems, with a focus on chemical bonding, the resulting material structures and their properties. This course is intended to become one of the four core courses offered in the new Materials Science curriculum. Course topics include: bonding in solids, crystalline and amorphous states, basic group theory, diffraction, metals and alloys, ceramics, and an intro to mat. characterization.

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Materials

MCEN 5027 (1) Graduate Seminar
Offers weekly presentations by visiting speakers, faculty, and students.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Grading Basis:** Pass/Fail

**Additional Information:** Departmental Category: Miscellaneous

MCEN 5032 (3) Sustainable Energy
Examines sustainability of our current energy systems, including transportation, using environmental and economic indicators. Uses systems analysis that addresses energy supply and demand. Explores the science and technology as well as environmental and economic feasibility of efficiency measures and renewable energy technologies. Additional emphasis is given to the global nature of the challenges and the potential for locally optimal solutions.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4032

**Grading Basis:** Letter Grade

**Additional Information:** Departmental Category: Thermal

MCEN 5034 (3) Thermodynamics of Materials
Provides a unified presentation of fundamental concepts applicable to the thermodynamics of engineering materials. Develops quantitative tools for understanding the physical principles that govern phase equilibrium and transformation. Generates binary and ternary phase diagrams and determine the resulting materials structures and corresponding physical and mechanical properties.

**Recommended:** Prerequisites MCEN 2024 and MCEN 3012.

**Additional Information:** Departmental Category: Materials

MCEN 5040 (3) Methods of Engineering Analysis 2
Studies selected topics from the theory of complex variables, integral transform methods, partial differential equations, and variational methods. Assigns computer exercises. Correlates with analysis topics in other mechanical engineering graduate courses, and emphasizes applications.

**Requisites:** Requires prerequisite course of MCEN 5020 (minimum grade D). Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Math

MCEN 5041 (3) Advanced Fluid Mechanics 1
Highlights exact solution of Navier-Stokes equations and fundamentals of rotating fluids. Considers Low Reynolds number flow; similarity solutions; viscous boundary layers, jets, and wakes; and unsteady viscous flow.

**Requisites:** Requires corequisite course of MCEN 5020. Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Fluids

MCEN 5042 (3) Heat Transfer
Studies development of equations governing transport of heat by conduction, convection, and radiation, and their solution. Includes analytical and numerical solution of initial and boundary value problems representative of heat conduction in solids. Describes heat transfer in free and forced convection, including laminar and turbulent flow. Also involves radiation properties of solids, liquids, and gases and transport of heat by radiation.

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Thermal
MCEN 5044 (3) Mechanical Behavior of Materials
This introductory-level graduate course incorporates relevant aspects of materials science, solid mechanics, thermodynamics and mathematics, and applies them to achieve a fundamental understanding of the mechanical behavior of crystalline and non-crystalline engineering materials.
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering (MCEN) majors only.
Additional Information: Departmental Category: Materials

MCEN 5045 (3) Design for Manufacturability
Topics include general design guidelines for manufacturability; aspects of manufacturing processes that affect design decisions; design rules to maximize manufacturability; economic considerations; value engineering and design for assembly. Presents case studies of successful products exhibiting DFMA principles. Priority enrollment for students admitted to the MS or BS/MS design track. Prerequisite of MCEN 4026 required for undergraduate students.
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering (MCEN) majors only.
Additional Information: Departmental Category: Materials

MCEN 5055 (3) Advanced Product Design
Introduces engineering design and development of consumer products. Includes learning sketching, brainstorming, idea generation, design thinking, user-centered design, product requirements and specifications, product constraints, human factors, aesthetics, industrial design, intellectual property, concept prototyping, idea selection, tolerancing, cost estimating, design for assembly, and materials selection. Entails a semester-long team re-design of a consumer product.
Additional Information: Departmental Category: Design

MCEN 5057 (3) Environmental Modeling
Enables students to develop and evaluate pollutant transport, fate, exposure, and risk models for air, water, and multi-media systems, with a special emphasis on air. Emphasizes the fundamental physics and chemistry that govern contaminant fate and transport and the basic mathematical equations and numerical approaches for describing these processes.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4057
Grading Basis: Letter Grade
Additional Information: Departmental Category: Miscellaneous

MCEN 5056 (3) Soft Machines
Introduces soft machines as a new paradigm of engineering that starts to impact healthcare, consumer electronics, renewable energy and collaborative robotics. Prepares students to participate in research on soft machines by starting with fundamentals of soft materials and by covering soft robotics, stretchable electronics, energy harvesting and functional polymers. Includes guest lectures, a literature review and a hands-on lab project.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4064 and MSEN 5046
Requisites: Restricted to students with 87-180 credits (Senior, Fifth Year Senior) Mechanical (MCEN) majors or College of Engineering graduate students only.
Grading Basis: Letter Grade

MCEN 5065 (3) Graduate Design I
First part of a two-course graduate product design experience in mechanical engineering. Covers problem definition and specifications, determining design requirements, user feedback, alternative design concepts, engineering analysis, concept prototypes and CAD drawings. Students make several oral design reviews, a final design presentation and prepare a written report. Entails a team product design, fabrication and testing cycle of sponsored project.
Requisites: Requires prerequisite course of MCEN 5055 (minimum grade C).
Grading Basis: Letter Grade
Additional Information: Departmental Category: Design

MCEN 5075 (3) Graduate Design II
Second part of two-course graduate product design experience in mechanical engineering. Includes refinement of prototype, design optimization, fabrication, testing, and evaluation. Students orally present the final design and prepare a written report and operation manual for the product. Entails a team product design, fabrication, and testing cycle of a sponsored project, leading to a fully-functional product.
Requisites: Requires prerequisite course of MCEN 5065 (minimum grade C).
Grading Basis: Letter Grade
Additional Information: Departmental Category: Design

MCEN 5115 (3) Mechatronics and Robotics I
Focuses on design and construction of microprocessor-controlled electro-mechanical systems. Lectures review critical circuit topics, introduce microprocessor architecture and programming, discuss sensor and actuator component selection, robotic systems and design strategies for complex, multi-system devices. Lab work reinforces lectures and allows hands-on experience with robotic design. Students must design and build an autonomous robotic device. Project expenses may be incurred ($50 maximum).
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4115
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Design

MCEN 5117 (3) Anatomy and Physiology for Engineers
Explores human physiological function from an engineering, specifically mechanical engineering, viewpoint. Provides an introduction to human anatomy and physiology with a focus on learning fundamental concepts and applying engineering (mass transfer, fluid dynamics, mechanics, modeling) analysis.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4117
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Miscellaneous

MCEN 5121 (3) Compressible Flow
Applies energy, continuity, and momentum principles to compressible flow. Topics include normal and oblique shocks; Prandtl-Meyer expansion; methods of characteristics; and one-, two-, and three-dimensional subsonic, supersonic, and hypersonic flows.
Requisites: Requires prerequisite course of MCEN 5021 (minimum grade D). Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Fluids
MCEN 5122 (3) Statistical Thermodynamics

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Thermal

MCEN 5125 (3) Optimal Design
This course focuses on linear optimization and will introduce non-linear optimization. Formulating engineering applications as optimization problems that can be solved using industry known solvers will be learned. Some of these applications will include minimum cost mechanical design, wind farm power maximization, minimum energy control, production control, and more. Previous programming experience required.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4125

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Design

MCEN 5127 (3) Biomedical Ultrasound
Covers the design of ultrasound systems for medical imaging and therapy, including the physics of wave propagation, transducers, acoustic lenses, pulse-echo imaging and caviation dynamics, with an emphasis on current topics in biomedical ultrasound. Includes lectures on theory, practice and special topics; a laboratory on wave propagation; oral presentations on current literature; and a design project.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4127

**Requisites:** Restricted to graduate students only.

**Grading Basis:** Letter Grade

**Additional Information:** Departmental Category: Miscellaneous

MCEN 5131 (3) Air Pollution Control Engineering
Introduces air quality regulations, meteorology and modeling. Examines methods for controlling major classes of air pollutants, including particulate matter and oxides of sulfur and nitrogen, as well as control technology for industrial sources and motor vehicles. Requires interdisciplinary design projects.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4131

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Fluids

MCEN 5133 (3) Intro to Tissue Biomechanics
Focuses on developing an understanding of the fundamental mechanical principles that govern the response of hard and soft biological tissue to mechanical loading. Specifically, covers mechanical behavior of biological materials/tissues, classical biomechanics problems in various tissues, the relationship between molecular, cellular and physiological processes and tissue biomechanics and critical analysis of related journal articles.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4133

**Additional Information:** Departmental Category: Materials

MCEN 5135 (3) Wind Energy and Wind Turbine Design
Focuses on understanding and applying principles related to current wind energy technology. Students will apply technical coursework from throughout the ME curriculum (fluids, dynamics, circuits, economics) to the process of designing a wind turning and determining whether their proposal is feasible from an economic standpoint.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4135

**Requisites:** Restricted to Mechanical (MCEN), Civil (CVEN) or Aerospace (ASEN) Engineering graduate students only.

**Additional Information:** Departmental Category: Design

MCEN 5137 (3) Anatomy and Physiology 2
Provides in-depth understandings of anatomy and physiology as well as introductions to transport phenomena, flow mechanics and solid mechanics in several organ systems: the cardiovascular, pulmonary, kidney, endocrine and digestive systems. Introduces artificial physiological systems to replace or assist physiological functions and introduce the concepts of physiological barriers that prevent diagnosis or effective therapeutics.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4137

**Grading Basis:** Letter Grade

**Additional Information:** Departmental Category: Miscellaneous

MCEN 5141 (3) Indoor Air Pollution
Describes the impact of indoor air pollutants on human health, including an introduction to key pollutants and their sources. Students will estimate emission factors, calculate generation/ventilation rates, quantify the impact of deposition and chemical reactions and explore relevant control technology. Current issues will also be addressed, including climate change, green building design, economic concerns and relevance to the developing world.

**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4141

**Requisites:** Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.

**Additional Information:** Departmental Category: Miscellaneous

MCEN 5147 (3) Mechanobiology
Studies how mechanical forces modulate the morphological and structural fitness of biological tissues. Current molecular mechanisms by which cells convert mechanical stimulus into chemical activity and the literature supporting them will be discussed. Students will acquire an understanding and expertise from the analysis of primary literature and completion of a synthesis project.

**Requisites:** Restricted to students with 87-180 credits (Senior, Fifth Year Senior) Mechanical (MCEN) majors or College of Engineering graduate students only.

**Grading Basis:** Letter Grade

MCEN 5151 (3) Flow Visualization
Explores techniques for the visualization of the physics of fluid flows including seeding with dyes, particles and bubbles, and shadowgraphy and schlieren. Reviews optics and fluid physics, especially atmospheric clouds. Assignments are student-driven, to individuals and mixed teams of graduates, undergraduates, engineering majors and photography/video majors.

**Equivalent - Duplicate Degree Credit Not Granted:** CINE 4200, MCEN 4151, ARTF 5200, ATLS 4151 and ATLS 5151

**Additional Information:** Departmental Category: Fluids
MCEN 5152 (3) Introduction to Combustion
Focuses on the mechanisms by which fuel and oxidizers are converted into combustion products. Application to practical combustion devices such as Otto, Diesel, gas turbine and power plant combustion systems. Consideration of combustion-generated air pollution, fire safety and combustion efficiency.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4152
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Thermal

MCEN 5154 (3) Biocolloids and Biomembranes
Covers the thermodynamics and mechanics of biological membranes and biomedical colloids. Considers intermolecular and surface forces, self-assembly and colloidal stability. Addresses structure-property relationships and design principles for biomedical applications. Focuses on monolayers, bilayers, micelles, filmicelles, liposomes, polymersomes, emulsions, microbubbles, polypeptides and polyelectrolyte multilayer capsules.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4154
Recommended: Prerequisites APPM 2360 and PHYS 1120.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Materials

MCEN 5161 (3) Aerosols
Introduces atmospheric aerosols and properties of their distributions, followed by fundamental descriptions of single particle dynamics, thermodynamics, nucleation, coagulation, mass transfer and populations dynamics. During the second half of the course, the focus will shift to sources and sinks of atmospheric aerosols, their impacts on atmospheric chemistry and radiation, and the impacts of these processes on air quality and climate.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Fluids

MCEN 5173 (3) Finite Element Analysis
Introduces the theory behind and applications of the finite element method as a general and powerful tool to model a variety of phenomena in mechanical engineering. Applications include structural mechanics, mechanics of elastic continua and heat conduction.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4173
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Solids

MCEN 5174 (3) Failure of Engineering Materials
Examines the fundamental concepts regarding the failure of engineering materials. Case studies are used to integrate a basic understanding of material failure mechanisms with analysis techniques and tools. Topics include the elastic properties (isotropic and anisotropic materials) and the origin of elastic behavior, viscoelasticity, plasticity (dislocation mechanisms, yielding criteria, strengthening mechanisms), creep, fracture and fatigue.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4174
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Materials

MCEN 5183 (3) Mechanics of Composite Materials
Introduces various kinds of composite materials, composite fabrication techniques, the physical and mechanical behavior of composites, and analytical and experimental methodologies.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4183
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Solids

MCEN 5194 (3) Electrochemical Energy Conversion and Storage
Presents the fundamentals, principles and experimental techniques of electrochemistry, the background of ionic or electronic conduction of metal, semiconductor, inorganic and polymer materials and applications in the areas of batteries, fuel cells, electrochemical double layer capacitors, electrochemical photonics, sensors and semiconductor electrochemistry.
Equivalent - Duplicate Degree Credit Not Granted: MCEN 4194
Recommended: Prerequisites MCEN 2024 and MCEN 3032.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Materials

MCEN 5208 (1-4) Special Topics
Credit hours and subject matter to be arranged.
Repeatable: Repeatable for up to 6.00 total credit hours.
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Miscellaneous

MCEN 5218 (1-4) Special Topics in Mechanical Engineering
Subject matter to be selected from topics of current interest.
Repeatable: Repeatable for up to 15.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students in College of Engineering and Applied Science or to students with 57-180 credits (Junior or Senior) or Mechanical Engineering Concurrent Degree students.
Additional Information: Departmental Category: Miscellaneous

MCEN 5255 (3) Design for Mfg
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Design

MCEN 5258 (1-3) Sp Tpcs-Combustion Seminar
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Special Topics

MCEN 5636 (3) Micro-Electro-Mechanical Systems 1
Addresses issues of micro-electro-mechanical systems (MEMS) modeling, design, and fabrication. Emphasizes the design and fabrication of sensors and actuators due to significance of these devices in optics, medical instruments, navigation components, communications, and robotics. Department consent required.
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Manufacturing and Systems

MCEN 5832 (3) Special Topics
Additional Information: Departmental Category: Special Topics
MCEN 5848 (1-6) Independent Study
Available only through approval of graduate advisor. Subjects arranged to fit the needs of the particular student. May be repeated for up to 6 total credits.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to College of Engineering graduate students only.
Additional Information: Departmental Category: Miscellaneous

MCEN 5858 (1-6) Independent Study
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Miscellaneous

MCEN 5868 (1-3) Independent Study
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Miscellaneous

MCEN 5901 (3) Reacting Flows
Provides an introduction to reacting flows and combustion. Covers chemical kinetics, including global and detailed mechanisms and the variable density flow equations are derived. Relevant non-dimensional parameters and limiting behaviors are discussed. The Rankine-Hugoniot relations are presented and various aspects of diffusion, kinetically dominated and balanced combustion are outlined. Flame structures are discussed, including laminar and turbulent flames, and the Burke-Schumann solution is outlined. The turbulent forms of the motion equations are derived, and the reactive scalar transport equation and mixture fraction variable are presented. The flamelet progress variable approach is outlined, including a comparison of steady and unsteady flamelet models. Specific topics in spray combustion, triple flames, solid-gas reactors and detonations are discussed.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 6001
Requisites: Requires prerequisite course of MCEN 5021 (minimum grade C). Restricted to College of Engineering and Applied Science graduate students or BS/MS Concurrent Degree Students only.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Fluids

MCEN 6184 (3) Structure and Properties of Polymers
Emphasizes the relationship between molecular structure and macroscopic properties. Structural aspects include chain conformation, configuration, and the crystalline and amorphous states. Discusses physical and mechanical properties with a focus on solution and phase behavior, transitions of bulk polymers, and rubber and viscoelastic behavior. Requires background in basic material science and polymer related concepts.
Requisites: Restricted to College of Engineering graduate students only.
Additional Information: Departmental Category: Materials

MCEN 6228 (3) Special Topics
Subject matter to be selected from topics of current interest.
Repeatable: Repeatable for up to 15.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Special Topics

MCEN 6848 (1-6) Independent Study
Available only through approval of graduate advisor. Subjects arranged to fit the needs of the particular student.
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Miscellaneous

MCEN 6858 (1-6) Independent Study
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Miscellaneous

MCEN 6888 (1-3) Independent Study
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Miscellaneous

MCEN 6901 (3) Reacting Flows
Provides an introduction to reacting flows and combustion. Covers chemical kinetics, including global and detailed mechanisms and the variable density flow equations are derived. Relevant non-dimensional parameters and limiting behaviors are discussed. The Rankine-Hugoniot relations are presented and various aspects of diffusion, kinetically dominated and balanced combustion are outlined. Flame structures are discussed, including laminar and turbulent flames, and the Burke-Schumann solution is outlined. The turbulent forms of the motion equations are derived, and the reactive scalar transport equation and mixture fraction variable are presented. The flamelet progress variable approach is outlined, including a comparison of steady and unsteady flamelet models. Specific topics in spray combustion, triple flames, solid-gas reactors and detonations are discussed.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 6001
Requisites: Requires prerequisite course of MCEN 5021 (minimum grade C). Restricted to College of Engineering and Applied Science graduate students or BS/MS Concurrent Degree Students only.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Fluids

MCEN 6949 (1) Master's Candidate for Degree
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Thesis

MCEN 6959 (1-6) Master's Thesis
Additional Information: Departmental Category: Thesis

MCEN 7221 (3) Turbulence
Hydrodynamic stability theory, equations for turbulent flows, free shear flows and boundary layers, homogeneous and isotropic turbulence, overview of turbulent combustion, reaction kinetics, energy equation, Favre averaging, Pdfs, premixed and nonpremixed flame modeling, and recent developments.
Requisites: Restricted to any College of Engineering and Applied Science graduate students or to Mechanical Engineering undergraduate majors only.
Additional Information: Departmental Category: Fluids

MCEN 7228 (3) Special Topics
Additional Information: Departmental Category: Special Topics

MCEN 8999 (1-10) Doctoral Thesis
Additional Information: Departmental Category: Thesis