Department of Mechanical, Materials, and Aerospace Engineering

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Chair:
Keith Bowman

The Department of Mechanical, Materials, and Aerospace Engineering offers several flexible programs in mechanical and aerospace engineering, with five major areas of study: computer-aided design and manufacturing, dynamics and control, fluid dynamics, solids and structures, and thermal sciences. The department also offers programs in materials science and engineering and manufacturing engineering.

Degrees Offered

Master of Science in Mechanical and Aerospace Engineering
Master of Science in Materials Science and Engineering
Master of Science in Manufacturing Engineering
Master of Engineering in Mechanical and Aerospace Engineering
Master of Engineering in Materials Science and Engineering
Master of Engineering in Manufacturing Engineering
Doctor of Philosophy in Mechanical and Aerospace Engineering
Doctor of Philosophy in Materials Science and Engineering

Interdisciplinary Programs

Master of Science in Mechanical and Aerospace Engineering with specialization in Energy/Environment/Economics (E^3)
Master of Science in Materials Science and Enginering with specialization in Energy/Environment/Economics (E^3)
Master of Engineering in Mechanical and Aerospace Engineering with specialization in Energy/Environment/Economics (E^3)
Master of Engineering in Materials Science and Engineering with specialization in Energy/Environment/Economics (E^3)

Certificate Programs

Computer Integrated Design and Manufacturing
Product Quality and Reliability Assurance

Research Centers

Fluid Dynamics Research Center (http://fdrc.iit.edu/)
Thermal Processing Technology Center (http://tptc.iit.edu/)

Research Facilities

Mechanical and aerospace engineering laboratories include the Fejer Unsteady Wind Tunnel; the Morkovin Low-Turbulence Wind Tunnel; the National Diagnostic Facility, a computer-controlled, high-speed, subsonic flow wind tunnel; a high-speed jet facility for aeroacoustic research; a hydrodynamics laboratory; flow visualization systems; laser-based measuring equipment and manufacturing; several computer-based data acquisition, processing and display systems of the Fluid Dynamics Research Center; laboratories in experimental mechanics; laboratories for research in robotics, guidance and navigation, computer integrated manufacturing, Footlik CAD lab, biomechanics and its instrumentation, combustion, and internal combustion engines.

Materials science and engineering laboratories include facilities for research in metallography, heat treatment, and mechanical testing; optical, scanning, and transmission electron microscopes; powder metallurgy, and laser machining facilities. The department has numerous computers and workstations available for computational research activities.

Research Areas

The faculty conducts research activities in fluid dynamics, including aeroacoustics, flow control, turbulent flows, unsteady and separated flows, instabilities and transition, turbulence modeling, flow visualization techniques, computational fluid dynamics; metallurgical and materials engineering, including microstructural characterization, physical metallurgy of ferrous and nonferrous alloys, powder materials, laser processing and machining, high temperature structural materials, mechanical behavior, fatigue and fracture, environmental fatigue and fracture, computational x-ray diffraction analysis, texture, recrystallization and computational methods in materials processing; solids and structures, including experimental mechanics of composites and cellular solids, high strain rate constitutive modeling and thermomechanical coupling, fracture mechanics, design and testing of prosthetic devices; computational mechanics, cable dynamics and analysis of inelastic solids; theoretical mechanics, including wave propagation, fracture, elasticity and models for scoliosis; computer added design and manufacturing, concentrated in the areas of computer- aided design, computer-based machine tool control, computer graphics in design, manufacturing processes, wear and fracture behavior of cutting tols, tribology, frictional wear characteristics of ceramics, dynamic systems, and mechanical vibrations; thermal sciences, alternative fuels, mobile and stationary source combustion emissions, and dynamics and control, including guidance, navigation, and control of aircraft and spacecraft, intelligent control for aircraft models, flow fields, robotics devices for laser machining; and dynamic analysis and control of complex systems.

Faculty

Arastoopour, Hamid, Professor of Chemical Engineering and Mechanical Engineering, Henry R. Linden Professor of Engineering, and Director of the Wanger Institute for Sustainability and Energy Research (WISER). B.S., Abadan Institute of Technology (Iran); M.S., Ph.D., G.E., Illinois Institute of Technology. Computational fluid dynamics (CFD) and transport phenomena of multiphase flow, fluidization, flow in porous media, particle technology and material processing, and environmental engineering problems, hydrogen storage, tire recycling, particle technology in applications to coal gasification, production of gas from unconventional gas reserves and hydrates, and energy sustainability issues.

Bowman, Keith J., Duchossois Leadership Professor of Materials Engineering and Chair. B.S., M.S., Case Western Reserve University; Ph.D., University of Michigan. Mechanical behavior of materials, electromechanical behavior, preferred orientation and property anisotropy, processing of ceramic materials.

Cammino, Roberto, Senior Lecturer of Mechanical and Aerospace Engineering. B.S., M.S., Ph.D., Illinois Institute of Technology. Fracture mechanics, finite element method.

Cassel, Kevin W., Associate Professor of Mechanical and Aerospace Engineering and Associate Chair. B.S., Messiah College; M.S., Ph.D., Lehigh University. Computational fluid dynamics, unsteady boundary-layer flows, buoyancy-driven flows, supersonic and hypersonic boundary-layer flows, and computational hemodynamics.

Cesarone, John C., Senior Lecturer of Mechanical Engineering. B.S., M.S., University of Illinois; Ph.D., Northwestern University. Robotics, reliability engineering and manufacturing.

Clack, Herek L., Associate Professor of Mechanical and Aerospace Engineering. B.S., Massachusetts Institute of Technology; Ph.D., University of California-Berkeley. Thermofluid systems: atomization, combustion, hazardous waste incineration, combustion emissions, heat/mass transfer and phase change, ultrasound and sonochemical materials processing.

Cramb, Alan W., Charles and Lee Finkl Professor of Metallurgical and Materials Engineering, Provost, and Senior Vice President for Academic Affairs. B.Sc., University of Strathclyde (Scotland); Ph.D., University of Pennsylvania. Initial solidification behavior of steels, solidification behavior of liquid oxides, effect of inclusion chemistry on solidification behavior, clean steel production, initial solidification phenomenain a continuous casting mold.

Datta-Barua, Seebany, Assistant Professor of Mechanical and Aerospace Engineering. B.S., M.S., Ph.D. Stanford University. Satellite-based atmospheric remote sensing, global navigation satellite systems, geospace environment imaging, estimation and monitoring.

Gosz, Michael R., Associate Professor Mechanical and Materials Engineering and Vice Provost for Admissions and Financial Aid. B.S., Marquette University; M.S., Ph.D., Northwestern University. Computational solid mechanics, fracture mechanics, interface effects in composite materials, modeling of composite structures subjected to thermal cycling, and nonlinear dynamic finite element analysis of submerged flexible structures.

Hall, Carrie M., Assistant Professor of Mechanical, Materials and Aerospace Engineering. B.S., Bob Jones University; Ph.D., Purdue University. Modeling and control of advanced internal combustion engines; development of clean and efficient utilization of alternative fuels.

Joerger, Mathieu, Research Assistant Professor of Mechanical, Materials and Aerospace Engineering. M.S, Ph.D., Illinois Institute of Technology.

Kallend, John S., Professor of Materials Engineering and Physics and Associate Dean for Accreditation, Armour College of Engineering. B.A., M.A., Ph.D., Cambridge University (England). Computational methods of crystallographic texture analysis and properties of polycrystalline aggregates.

Khanafseh, Samer, Research Assistant Professor of Mechanical and Aerospace Engineering. B.S., Jordan University of Science and Technology (Jordan); M.S., Ph.D., Illinois Institute of Technology.

Meade, Kevin P., Professor of Mechanical Engineering. B.S., M.S., Illinois Institute of Technology; Ph.D., Northwestern University. Solid mechanics, biomechanics, elasticity, fracture mechanics and computational mechanics.

Monnier, Bruno, Lecturer of Mechanical Engineering. Diploma d' Ingenieur, ENSEE/HT (France); M.S., Chalmers University of Technology (Sweden); Ph.D., Illinois Institute of Technology.

Nagib, Hassan M., John T. Rettaliata Professor of Mechanical and Aerospace Engineering. B.S., M.S., Ph.D., Illinois Institute of Technology. Fluid dynamics, heat transfer, applied turbulence, wind engineering, and aeroacoustics.

Nair, Sudhakar E., Professor of Mechanical and Aerospace Engineering and Applied Mathematics. B.Sc., Regional Engineering College (India); M.E., Indian Institute of Science (India); Ph.D., University of California-San Diego. Solid mechanics, stress analysis of composite and inelastic material, dynamics of cable, fracture mechanics and wave propagation theory.

Nash, Philip G., Professor of Materials Engineering and Director of the Thermal Processing Technology Center. B.S., City of London Polytechnic (England); Ph.D., Queen Mary College of London University (England). Physical metallurgy, intermetallics, powder metallurgy, composites, phase equilibria and transformations.

Ostrogorsky, Aleksandar, Professor of Mechanical and Materials Engineering. Dipl.Ing., University of Belgrade (Serbia); M.S., Rensselaer Polytechnic Institute; Sc.D., Massachusetts Institute of Technology. Heat and mass transfer phenomena occurring in materials processing; Directional solidification/single crystal growth focusing on semiconductor alloys; Wide band gap materials for gamma ray detectors (semiconductors and scintillators); Diffusion, growth of carbon nanotubes.

Pervan, Boris, Professor of Mechanical and Aerospace Engineering. B.S., University of Notre Dame; M.S., California Institute of Technology; Ph.D., Stanford University. Dynamics, control, guidance, and navigation.

Raman, Ganesh, Professor of Mechanical and Aerospace Engineering and Deputy Vice Provost for Research. B.Tech., Indian Institute of Technology (India); M.S., Cleveland State University; Ph.D., Case Western Reserve University. Experimental fluid mechanics, aeroacoustics, active flow control, jet screech, and fluidics.

Rempfer, Dietmar, Professor of Mechanical and Aerospace Engineering and Applied Mathematics and Associate Dean, Armour College of Engineering. M.S., Ph.D., Universitat Stuttgart (Germany). Fluid mechanics, especially theoretical studies of transitional and turbulent shear flows in open systems, numerical fluid mechanics, modeling for environmental and urban fluid mechanics, coherent structures in turbulent flows, control of transitional and turbulent wall layers, nonlinear dynamical systems.

Ruiz, Francisco, Associate Professor of Mechanical and Aerospace Engineering. B.S.M.E., Universidad Politecnica de Madrid (Spain); M.E., Ph.D., Carnegie-Mellon University. Combustion, atomization, pollution control of engines, fuel economy, alternative fuel, electronic cooling and special cooling.

Shaw, Leon L., Rowe Family Professor of Materials Science and Engineering. B.S., M.Eng., Fuzhou University (China); M.S., Ph.D., University of Florida. Materials synthesis and processing, energy storage and conversion, solid freeform fabrication.

Spenko, Matthew, Associate Professor of Mechanical Engineering. B.S. Northwestern University; M.S., Ph.D., Massachusetts Institute of Technology. Robotics, design, dynamics, and control.

Srivastava, Ankit, Assistant Professor of Mechanical, Materials and Aerospace Engineering. B.Tech., Indian Institute of Technology (India); M.S., Ph.D., University of California, San Diego. Wave propagation, phononics, metamaterials, NDE-SHM through wave techniques, Micromechanics and homogenization.

Tin, Sammy, Professor of Materials Engineering. B.S., California Polytechnic State University-San Luis Obispo; M.S., Carnegie Mellon University; Ph.D., University of Michigan. Processing and deformation characteristics of high-temperature structural materials, modeling the microstructure of Ni-base superalloy turbine disks during thermomechanical processing, understanding the mechanisms of creep and fatigue deformation in advanced high-refractory content single crystal turbine blades.

Vural, Murat, Associate Professor of Mechanical and Aerospace Engineering. B.Sc., M.Sc., Ph.D., Istanbul Technical University (Turkey). Experimental solid mechanics with emphasis on high-strain-rate mechanical response, thermomechanical coupling, failure characterization and constitutive modeling of homogeneous and heterogeneous materials.

Wark, Candace E., Professor of Mechanical and Aerospace Engineering. B.S., M.S., Michigan State University; Ph.D., Illinois Institute of Technology. Fluid dynamics, turbulence, digital data acquisition and processing.

Williams, David R., Professor of Mechanical and Aerospace Engineering and Director of the Fluid Dynamics Research Center. B.S.E., Stevens Institute of Technology; M.S.E., Ph.D., Princeton University. Experimental fluid mechanics with emphasis on flow measurement and flow control techniques.

Wu, Benxin, Associate Professor of Mechanical Engineering. B.S., Tsinghua University; M.S., University of Missouri-Rolla; Ph.D., Purdue University. Laser-matter interactions, laser applications in manufacturing, materials processing, and other areas.

Admission Requirements

Cumulative minimum undergraduate GPA: 3.0/4.0
GRE score minimum:
1000 (quantitative + verbal) 3.0 (analytical writing)
Typical admitted quantitative score is 650 minimum.
TOEFL minimum: 550/213/80*

Meeting the minimum GPA and test score requirements does not guarantee admission. Test scores and GPA are only two of several important factors considered. Admission as a regular graduate student normally requires a bachelor's degree from an accredited institution in mechanical engineering, aerospace engineering, metallurgical engineering, materials engineering, or engineering mechanics. A candidate with a bachelor's degree in another field, and with proficiency in other engineering disciplines, mathematics and physics, may also be eligible for admission. However, students must remove any deficiencies in essential undergraduate courses that are prerequisites for the chosen degree program, in addition to meeting the other requirements of the graduate program.

The chair for graduate programs serves as a temporary advisor to new full-time and part-time graduate students admitted to the department as matriculated students until an appropriate faculty member is selected as the advisor. Students are responsible for following the departmental procedures for graduate study. A guide to graduate study in the department is available on the departmental Web site (http://www.iit.edu/engineering/mmae) and in the MMAE main office (243 Engineering 1) to all registered MMAE graduate students, and should be consulted regularly for information on procedures, deadlines, forms, and examinations. Departmental seminars and colloquia are conducted on a regular basis. All full-time graduate students must register for the MMAE 593 seminar course each semester and attend them regularly.

The department reserves the right to review and approve or deny the application for admission of any prospective degree-seeking student. Non-degree graduate students who intend to seek a graduate degree from the department must maintain a GPA of 3.0 and must apply for admission as a degree-seeking student prior to the completion of nine credit hours of study. Maintaining the minimum GPA requirement does not guarantee admission to MMAE graduate degree programs. A maximum of nine credit hours of approved coursework taken as a non-degree student and passed with a grade of "B" or better may be applied to the degree.

* Paper-based test score/computer-based test score/internet-based test score.

Master of Engineering in Mechanical and Aerospace Engineering
Master of Engineering in Materials Science and Engineering
Master of Engineering in Manufacturing Engineering

30 credit hours

These programs are aimed at broadening student potential beyond the B.S., enhancing technical versatility and, in some instances, providing the opportunity for changes in career path. The Master of Engineering programs are course-only degree programs and require a minimum of 30 credit hours. There is no thesis or comprehensive examination requirement. The student, in consultation with his or her advisor, prepares a program of study that reflects individual needs and interests. The advisor, as well as the department's Graduate Studies Committee, the Department Chair, and the Graduate College must approve this program. Students working toward this degree are not eligible for departmental financial support.

Course Requirements for the Master of Engineering in Mechanical and Aerospace Engineering

Required Courses:

MMAE 501 Engineering Analysis I

AND one core course in major area of study

AND one of the following:

MMAE 451 Finite Element Methods in Engineering
MMAE 502 Engineering Analysis II
MMAE 517 Computational Fluid Dynamics
MMAE 532 AdvancedFinite Element Methods
MMAE 544 Design Optimization
OR
MMAE 570 Computational Methods in Materials Processing

AND elective courses as needed.

Core courses as determined by major area of study

Fluid Dynamics

MMAE 510 Fundamentals of Fluid Mechanics

Thermal Sciences

MMAE 520 Advanced Thermodynamics

Solids and Structures

MMAE 530 Advanced Mechanics of Solids

Dynamics and Controls

MMAE 541 Advanced Dynamics

Computer Aided Design and Manufacturing:

MMAE 545 Advanced CAD/CAM

Students may choose from a list of courses specific to their area of interest to complete degree requirements. Up to nine credit hours at the 400-level are allowed, assuming the courses were not required for an undergraduate degree. Up to six credit hours of accelerated (700-level) courses are allowed.

Course Requirements for the Master of Engineering in Materials Science and Engineering

Required Courses (choose seven)

MMAE 468 Introduction to Ceramic Materials
MMAE 470 Introduction to Polymer Science
MMAE 472 Advanced Aerospace Materials
MMAE 478 Service Failure Analysis
MMAE 480 Forging & Forming
MMAE 501 Engineering Analysis I
MMAE 520 Advanced Thermodynamics
MMAE 533 Fatigue & Fracture Mechanics
MMAE 554 Electrical, Magnetic, & Optical Properties of Materials
MMAE 561 Solidification & Crystal Growth
MMAE 562 Design of Modern Alloys
MMAE 563 Advanced Mechanical Metallurgy
MMAE 564 Dislocations & Strengthening Mechanisms
MMAE 565 Materials Laboratory
MMAE 566 Problems in High-Temperature Materials
MMAE 567 Fracture Mechanisms
MMAE 568 Diffusion
MMAE 569 Advanced Physical Metallurgy
MMAE 570 Computational Methods in Materials Processing
MMAE 571 Microstructural Characterizations of Materials
MMAE 573 Transmission Electron Microscopy
MMAE 574 Ferrous Transformations
MMAE 576 Materials & Process Selection
MMAE 578 Fiber Composites
MMAE 579 Advanced Materials Processing

To complete the degree requirements, students may choose from a list of courses and may apply up to twelve credit hours of 400-level courses, as long as they were not used to satisfy requirements for an undergraduate degree. Up to six credit hours of accelerated (700-level) courses are allowed

Course Requirements for Master of Engineering in Manufacturing Engineering

Mechanical and Aerospace Engineering Emphasis
Required Courses

MMAE 545 Advanced CAD/CAM
MMAE 546 Advanced Manufacturing Engineering
MMAE 547 Computer-Integrated Manufacturing Technologies
OR
MMAE 557 Computer-Integrated Manufacturing Systems
MMAE 560 Statistical Quality and Process Control

AND one course in materials science and engineering

AND one course emphasizing numerical methods:

MMAE 451 Finite Element Methods in Engineering
MMAE 517 Computational Fluid Dynamics
MMAE 532 Advanced Finite Element Methods
MMAE 544 Design Optimization
OR
MMAE 570 Computational Methods in Materials Processing

AND elective courses as needed.

Materials Science and Engineering Emphasis
Required Courses

MMAE 547 Computer-Integrated Manufacturing Technologies
MMAE 560 Statistical Quality and Process Control

AND one of the following:

MMAE 445 Computer-Aided Design
MMAE 545 Advanced CAD/CAM
MMAE 546 Advanced Manufacturing Engineering
OR
MMAE 576 Materials and Process Selection

AND one of the following:

MMAE 574 Ferrous Transformations
MMAE 585 Engineering Optics and Laser-Based Manufacturing

AND one course emphasizing numerical methods:

MMAE 451 Finite Element Methods in Engineering
MMAE 517 Computational Fluid Dynamics
MMAE 532 Advanced Finite Element Methods
MMAE 544 Design Optimization
OR
MMAE 570 Computational Methods in Materials Processing

AND elective courses as needed.

Master of Engineering in Manufacturing Engineering via Internet

30 credit hours

The Master of Engineering in Manufacturing Engineering via Internet is a course-only, professionally oriented degree program that requires a minimum of 30 credit hours. There is no thesis or comprehensive examination requirement. The student, in consultation with the academic advisor, prepares a program reflecting individual needs and interests. All courses are administered online.

Required Courses

MMAE 545 Advanced CAD/CAM
MMAE 546 Advanced Manufacturing Engineering
MMAE 560 Statistical Quality and Process Control
AND
MMAE 547 Computer-Integrated Manufacturing Technologies
OR
MMAE 557 Computer-Integrated Manufacturing Systems

AND one materials course

MMAE 563 Advanced Mechanical Metallurgy

AND one course with emphasis on numerical methods

MMAE 704 Introduction to Finite Element Analysis (2 credit hours)

AND at least 13 credit hours from:

MMAE 433 Design of Thermal Systems
MMAE 445 Computer-Aided Design
MMAE 540 Robotics
MMAE 557 Computer Integrated Manufacturing-Systems
MMAE 589 Applications in Reliability Engineering I
MMAE 590 Applications in Reliability Engineering II
MMAE 715 Project Management (2 credit hours)

Master of Science in Mechanical and Aerospace Engineering
Master of Science in Materials Science and Engineering
Master of Science in Manufacturing Engineering

32 credit hours
Thesis
Oral comprehensive exam

The Master of Science degree program advances knowledge through post-baccalaureate coursework and state-of-the-art research in preparation for careers in industrial research and development. The M.S. degree is also generally acceptable as a prerequisite for study toward the doctorate. In line with the department's approach to its graduate programs, a student has considerable flexibility, in consultation with his or her program advisor, in formulating an M.S. program.

The M.S. in Mechanical and Aerospace Engineering or the M.S. in Materials Science and Engineering requires completion of a minimum of 32 credit hours of approved work, which includes six to eight credit hours of thesis research. Before completion of the first semester of graduate study, full-time students should select an area of specialization and a permanent advisor. Graduate students pursuing the M.S. degree on a part-time basis should select a permanent advisor before registering for their twelfth credit hour. The student, in consultation with the advisor, prepares a program of study that reflects individual needs and interests. The advisor must approve this program, as well as the department's Graduate Studies Committee, the Department Chair, and the Graduate College.

After completion of the thesis, the student is required to pass an oral comprehensive examination on his or her thesis and related topics. The examination committee consists of at least three appropriate faculty members who are nominated by the thesis advisor and appointed by the department's Graduate Studies Committee.

Course Requirements for the Master of Science in Mechanical and Aerospace Engineering

Required Courses

MMAE 501 Engineering Analysis I
MMAE 502 Engineering Analysis II

AND one core course in major area of study
AND 6 or more credit hours of non-core courses in major area
AND elective courses as needed.

Core courses as determined by major area of study
Fluid Dynamics

MMAE 510 Fundamentals of Fluid Mechanics

Thermal Sciences

MMAE 520 Advanced Thermodynamics

Solids and Structures

MMAE 530 Advanced Mechanics of Solids

Dynamics and Controls

MMAE 541 Advanced Dynamics

Computer Aided Design and Manufacturing

MMAE 545 Advanced CAD/CAM

No more than nine credit hours of 400-level courses that were not required for the completion of an undergraduate degree will be accepted as satisfying part of the program. Students with interdisciplinary programs will be given special consideration. Up to six credit hours of accelerated (700-level) courses are allowed.

Course Requirements for the Master of Science in Materials Science and Engineering

Required Courses (choose six)

MMAE 468 Introduction to Ceramic Materials
MMAE 470 Introduction to Polymer Science
MMAE 472 Advanced Aerospace Materials
MMAE 478 Service Failure Analysis
MMAE 480 Forging & Forming
MMAE 501 Engineering Analysis I
MMAE 520 Advanced Thermodynamics
MMAE 533 Fatigue & Fracture Mechanics
MMAE 554 Electrical, Magnetic, & Optical Properties of Materials
MMAE 561 Solidification & Crystal Growth
MMAE 562 Design of Modern Alloys
MMAE 563 Advanced Mechanical Metallurgy
MMAE 564 Dislocations & Strengthening Mechanisms
MMAE 565 Materials Laboratory
MMAE 566 Problems in High-Temperature Materials
MMAE 567 Fracture Mechanisms
MMAE 568 Diffusion
MMAE 569 Advanced Physical Metallurgy
MMAE 570 Computational Methods in Materials Processing
MMAE 571 Microstructural Characterizations of Materials
MMAE 573 Transmission Electron Microscopy
MMAE 574 Ferrous Transformations
MMAE 576 Materials & Process Selection
MMAE 578 Fiber Composites
MMAE 579 Advanced Materials Processing

AND 12-14 hours of non-core courses. Up to 12 credit hours of 400-level, non-core courses that were not required for the completion of an undergraduate degree and approved by the Graduate Studies Committee may count toward satisfying this requirement. Up to six credit hours of accelerated (700-level) courses are allowed.

Course Requirements for Master of Science in Manufacturing Engineering

Mechanical and Aerospace Engineering Emphasis Required Courses

MMAE 545 Advanced CAD/CAM
MMAE 546 Advanced Manufacturing Engineering
MMAE 547 Computer-Integrated Manufacturing Technologies
MMAE 560 Statistical Quality and Process Control

AND one course in materials science and engineering

AND one course emphasizing numerical methods:

MMAE 451 Finite Element Methods in Engineering
MMAE 517 Computational Fluid Dynamics
MMAE 532 Advanced Finite Element Methods
MMAE 544 Design Optimization
OR
MMAE 570 Computational Methods in Materials Processing

AND elective courses as needed.

Materials Science and Engineering Emphasis Required Courses

MMAE 547 Computer Integrated Manufacturing Technologies
MMAE 560 Statistical Quality and Process Control

AND one of the following:

MMAE 445 Computer-Aided Design
MMAE 545 Advanced CAD/CAM
MMAE 546 Advanced Manufacturing Engineering
OR
MMAE 576 Materials and Process Selection

AND one of the following:

MMAE 574 Ferrous Transformations
MMAE 575 Ferrous Products: Metallurgy and Manufacture
OR
MMAE 585 Engineering Optics and Laser-Based Manufacturing

AND one course emphasizing numerical methods:

MMAE 451 Finite Element Methods in Engineering
MMAE 517 Computational Fluid Dynamics
MMAE 532 Advanced Finite Element Methods
MMAE 538 Computational Techniques in FEM
MMAE 544 Design Optimization
OR
MMAE 570 Computational Methods in Materials Processing

AND elective courses as needed.

Doctor of Philosophy in Materials Science and Engineering
Doctor of Philosophy in Mechanical and Aerospace Engineering

84 credit hours beyond the Bachelor of Science
Qualifying examination
16 credit hours minimum beyond the M.S.
One full year (minimum) of thesis research
Comprehensive examination
Dissertation and oral defense

This program provides advanced, research-based education and knowledge through advanced coursework, state-of-the-art and original research, and publication of novel results in preparation for careers in academia and industrial research and development.

The department offers programs leading to the Ph.D. in Mechanical and Aerospace Engineering and the Ph.D. in Materials Science and Engineering. The doctoral degree is awarded in recognition of a high level of mastery in one of the several fields of the department including a significant original research contribution. A student working toward the Ph.D. degree has great flexibility in formulating an overall program to meet individual needs under the guidance of an advisor and the department.

Further, the student must be accepted by a thesis advisor and pass a qualifying examination given by the department in order to be admitted to candidacy for the Ph.D. degree. The examination evaluates the student's background in order to determine the student's potential for achieving a doctorate.

The student, in consultation with the advisor, prepares a program of study to meet individual needs and interests, which must then be approved by the advisor, the department's Graduate Studies Committee, the Department Chair, and the Graduate College. The program of study usually consists of at least one full year of advanced coursework beyond the master's degree, or equivalent, and a minimum of one full year of thesis research.

After the student essentially completes all coursework, he or she must pass the Ph.D. comprehensive examination. Conducted by the student's Thesis Advisory Committee, this examination must be completed at least one year prior to graduation.

Concentrated research to satisfy the requirements of a doctoral dissertation is ordinarily conducted after the comprehensive examination has been passed. The dissertation must be approved by the student's Thesis Advisory Committee. Thesis research should be equivalent to at least one full years work, corresponding to up to 36 thesis credit hours. This work is performed on campus; the department's Graduate Studies Committee and the Dean of the Graduate College must approve off-campus research. The doctoral dissertation is expected to contain a distinct and substantial original contribution to the student's field of study. After the research has been completed and a preliminary draft of the dissertation is approved, the candidate defends his or her thesis at a final oral examination, which is open to the public.

Course Requirements for Materials Science and Engineering

Required Courses (choose six)

MMAE 468 Introduction to Ceramic Materials
MMAE 470 Introduction to Polymer Science
MMAE 472 Advanced Aerospace Materials
MMAE 478 Service Failure Analysis
MMAE 480 Forging & Forming
MMAE 501 Engineering Analysis I
MMAE 520 Advanced Thermodynamics
MMAE 533 Fatigue & Fracture Mechanics
MMAE 554 Electrical, Magnetic, & Optical Properties of Materials
MMAE 561 Solidification & Crystal Growth
MMAE 562 Design of Modern Alloys
MMAE 563 Advanced Mechanical Metallurgy
MMAE 564 Dislocations & Strengthening Mechanisms
MMAE 565 Materials Laboratory
MMAE 566 Problems in High-Temperature Materials
MMAE 567 Fracture Mechanisms
MMAE 568 Diffusion
MMAE 569 Advanced Physical Metallurgy
MMAE 570 Computational Methods in Materials Processing
MMAE 571 Microstructural Characterizations of Materials
MMAE 573 Transmission Electron Microscopy
MMAE 574 Ferrous Transformations
MMAE 576 Materials & Process Selection
MMAE 578 Fiber Composites
MMAE 579 Advanced Materials Processing

AND elective courses as needed.

Course Requirements for Mechanical and Aerospace Engineering

Required Courses:

MMAE 501 Engineering Analysis I
MMAE 502 Engineering Analysis II

AND two courses from group EA (fluid dynamics, thermals sciences and solids and structures students must take MMAE 507 Continuum Mechanics)
AND one core course in major area of study
AND one core course in second area
AND 9 or more credit hours of non-core courses in major area
AND elective courses as needed.

Core courses as determined by major area of study
Fluid Dynamics

MMAE 510 Fundamentals of Fluid Mechanics

Thermal Sciences

MMAE 520 Advanced Thermodynamics

Solids and Structures

MMAE 530 Advanced Mechanics of Solids

Dynamics and Controls

MMAE 541 Advanced Dynamics

Computer Aided Design and Manufacturing

MMAE 545 Advanced CAD/CAM

Group EA:

MMAE 503 Advanced Engineering Analysis
MMAE 508 Perturbation Methods
MMAE 509 Introduction to Continuum Mechanics
MATH 512 Partial Differential Equations
MATH 515 Ordinary Differential Equations and Dynamical Systems
MATH 522 Mathematical Modeling
MATH 535 Optimization I
MATH 544 Stochastic Dynamics
MATH 545 Stochastic Partial Differential Equations
MATH 553 Discrete Applied Mathematics I
ECE 511 Analysis of Random Signals
ECE 531 Linear System Theory
ECE 567 Statistical Signal Processing

Master of Science in Mechanical and Aerospace Engineering with (E^3) Specialization
Master of Science in Materials Science and Engineering with (E^3) Specialization
Master of Engineering in Mechanical and Aerospace Engineering with (E^3) Specialization
Master of Engineering in Materials Science and Engineering with (E^3) Specialization

The Energy/Environment/Economics (E^3) program was developed to respond to the rapidly changing needs of the energy industry by providing the interdisciplinary research and training required to produce a new breed of engineer - one who specializes in energy technologies and who understands the associated environmental issues and economic forces that drive technology choice.

E^3specialization requires an interdisciplinary thesis in an E^3area of research for M.S. and Ph.D. degrees, and an interdisciplinary graduate project for professional master's degrees. Graduate students in E^3should also be enrolled in fundamental courses related to the topics of energy, environment, and economics. $E^3$is designed primarily for students majoring in mechanical and aerospace, materials, chemical, environmental, or electrical engineering who are planning careers in energy-related fields. This interdisciplinary training prepares students to be not only creative and expert in a specialized area of energy extraction, conversion, or utilization, but also to possess a broad knowledge base of different energy sources, environmental issues related to energy extraction, conversion, and utilization, and of the impact of industrial ecology principles on the design and operation of energy systems. Furthermore, students will gain sufficient knowledge of economic and regulatory issues to enable them to make more viable technology choices.

General Degree Requirements

Students pursuing a master's degree are required to take 30-32 credit hours beyond the requirements of a B.S. degree program. The Ph.D. program requires 84 credit hours beyond the Bachelor of Science. The curriculum consists of two components: department core courses that provide a strong background in basic principles of the chosen engineering field and E^3specialization courses. Selected E^3undergraduate courses may be substituted for graduate courses with the approval of the designated advisor, if the total undergraduate credit hours for the M.E. or M.S. degree do not exceed departmental constraints.

Students are also required to attend interdisciplinary seminars during their first and/or second semesters, which are offered as part of the regular graduate seminars by the departments. A student completing a M.S. or Ph.D. thesis or professional master's project will be a member of an interdisciplinary research team consisting of professors and students from chemical, environmental, electrical, materials, and mechanical engineering backgrounds, working in a cross-disciplinary group project. Each interdisciplinary team must include professors from different departments.

Policies and procedures regarding admission, advising, financial aid, and comprehensive examinations are established by the individual departments offering this program.

Course Requirements for Master of Science in Mechanical and Aerospace Engineering with (E^3) Specialization

Engineering Analysis Courses

MMAE 501 Engineering Analysis I
MMAE 502 Engineering Analysis II

Core Courses

CHE 543 Energy, Environment, & Economics

AND one of the following:

MMAE 520 Advanced Thermodynamics
CHE 503 Thermodynamics
CHE 553 Advanced Thermodyanmics

AND one of the following:

MMAE 522 Nuclear, Fossil-Fuel, & Sustainable Energy Systems
MMAE 523 Fundamentals of Power Generation
MMAE 524 Fundamentals of Combustion
CHE 541 Renewable Energy Technologies

Non Core Courses
Two of the following:

MMAE 510 Fundamentals of Fluid Mechanics
MMAE 517 Computational Fluid Mechanics
MMAE 524 Fundamentals of Combustion
MMAE 525 Fundamentals of Heat Transfer
MMAE 526 Heat Transfer: Conduction
MMAE 527 Heat Transfer: Convection & Radiation

AND one of the following:

CHE 541 Renewable Energy Technologies
CHE 560/ MMAE 560 Statistical Quality & Process Control
EMS 500 Fundamentals of Environmental Science
EMS 503 Environmental Pollution Prevention & Control Strategies
EMS 504 Industrial Ecology & Systems
ENVE 501 Environmental Chemistry
ENVE 506 Chemodynamics
ENVE 542 Physiochemical Processes in Environmental Engineering
ENVE 551 Industrial Waste Treatment
ENVE 561 Design of Environmental Engineering Processes
ENVE 570 Air Pollution Meteorology
ENVE 577 Design of Air Pollution Control Devices
ENVE 578 Physical & Chemical Processes for Industrial Gas Cleaning
ENVE 580 Hazardous Waste Engineering

Thesis research

MMAE 591 Research and Thesis

AND elective courses as needed

Course Requirements for Master of Science in Materials Science and Engineering with (E^3) Specialization

Core Courses

CHE 543 Energy, Environment & Economics
MMAE 468 Introduction to Ceramic Materials
MMAE 569 Advanced Physical Metallurgy

AND one of the following:

MMAE 520 Advanced Thermodynamics
CHE 503 Thermodynamics
CHE 553 Advanced Thermodyanmics

AND one of the following:

MMAE 522 Nuclear, Fossil-Fuel, & Sustainable Energy Systems
MMAE 523 Fundamentals of Power Generation
CHE 541 Renewable Energy Technologies
CHE 566 Electrochemical Engineering

AND elective courses as needed

Non Core Courses
Two of the following:

MMAE 525 Fundamentals of Heat Transfer
MMAE 561 Solidification & Crystal Growth
MMAE 563 Advanced Mechanical Metallurgy
MMAE 566 Problems in High-Temperature Materials
MMAE 571 Miscrostructural Characterization of Materials
MMAE 573 Transmission Electron Microscopy
MMAE 579 Advanced Materials Processing
MMAE 470 Introduction to Polymer Science

AND one of the following:

CHE 567 Fuel Cell Fundamentals
EMS 500 Fundamentals of Environmental Science
EMS 503 Environmental Pollution Prevention & Control Strategies
EMS 504 Industrial Ecology & Systems
ENVE 501 Environmental Chemistry
ENVE 506 Chemodynamics
ENVE 542 Physiochemical Processes in Environmental Engineering
ENVE 551 Industrial Waste Treatment
ENVE 561 Design of Environmental Engineering Processes
ENVE 570 Air Pollution Meteorology
ENVE 577 Design of Air Pollution Control Devices
ENVE 578 Physical and Chemical Processes for Industrial Gas Cleaning
ENVE 580 Hazardous Waste Engineering

Thesis research

MMAE 591 Thesis

AND elective courses as needed

Course Requirements for Master of Engineering in Mechanical and Aerospace Engineering with (E^3) Specialization

Engineering Analysis Courses

MMAE 501 Engineering Analysis I
MMAE 502 Engineering Analysis II

Core Courses

CHE 543 Energy, Environment & Economics

AND one of the following:

MMAE 520 Advanced Thermodynamics
CHE 503 Thermodynamics
CHE 553 Advanced Thermodyanmics

AND one of the following:

MMAE 522 Nuclear, Fossil-Fuel, & Sustainable Energy Systems
MMAE 523 Fundamentals of Power Generation
MMAE 524 Fundamentals of Combustion
CHE 541 Renewable Energy Technologies

Non Core Courses
Two of the following:

MMAE 510 Fundamentals of Fluid Mechanics
MMAE 517 Computational Fluid Mechanics
MMAE 524 Fundamentals of Combustion
MMAE 525 Fundamentals of Heat Transfer
MMAE 526 Heat Transfer: Conduction
MMAE 527 Heat Transfer: Convection & Radiation

AND one of the following:

CHE 541 Renewable Energy Technologies
CHE 560/ MMAE 560 Statistical Quality & Process Control
EMS 500 Fundamentals of Environmental Science
EMS 503 Environmental Pollution Prevention & Control Strategies
EMS 504 Industrial Ecology & Systems
ENVE 501 Environmental Chemistry
ENVE 506 Chemodynamics
ENVE 542 Physiochemical Processes in Environmental Engineering
ENVE 551 Industrial Waste Treatment
ENVE 561 Design of Environmental Engineering Processes
ENVE 570 Air Pollution Meteorology
ENVE 577 Design of Air Pollution Control Devices
ENVE 578 Physical & Chemical Processes for Industrial Gas Cleaning
ENVE 580 Hazardous Waste Engineering

AND elective courses as needed

Course Requirements for Master of Engineering in Materials Science and Engineering with (E^3) Specialization

Core Courses

CHE 543	Energy, Environment & Economics
MMAE 468	Introduction to Ceramic Materials
MMAE 569	Advanced Physical Metallurgy

AND one of the following:

MMAE 520	Advanced Thermodynamics
CHE 503	Thermodynamics
CHE 553	Advanced Thermodyanmics

AND one of the following:

MMAE 522	Nuclear, Fossil-Fuel, & Sustainable Energy Systems
MMAE 523	Fundamentals of Power Generation
CHE 541	Renewable Energy Technologies
CHE 566	Electrochemical Engineering

Non Core Courses
Two of the following:

MMAE 525	Fundamentals of Heat Transfer
MMAE 561	Solidification & Crystal Growth
MMAE 563	Advanced Mechanical Metallurgy
MMAE 566	Problems in High-Temperature Materials
MMAE 571	Miscrostructural Characterization of Materials
MMAE 573	Transmission Electron Microscopy
MMAE 579	Advanced Materials Processing
MMAE 470	Introduction to Polymer Science

AND one of the following:

CHE 567	Fuel Cell Fundamentals
EMS 500	Fundamentals of Environmental Science
EMS 503	Environmental Pollution Prevention & Control Strategies
EMS 504	Industrial Ecology & Systems
ENVE 501	Environmental Chemistry
ENVE 506	Chemodynamics
ENVE 542	Physiochemical Processes in Environmental Engineering
ENVE 551	Industrial Waste Treatment
ENVE 561	Design of Environmental Engineering Processes
ENVE 570	Air Pollution Meteorology
ENVE 577	Design of Air Pollution Control Devices
ENVE 578	Physical and Chemical Processes for Industrial Gas Cleaning
ENVE 580	Hazardous Waste Engineering

AND elective courses as needed

Certificate Programs

Computer Integrated Design and Manufacturing

Required Courses (choose four)

MMAE 445	Computer-Aided Design
MMAE 540	Robotics
MMAE 545	Advanced CAD/CAM
MMAE 547	Computer Integrated Manufacturing-Technologies
MMAE 557	Computer Integrated Manufacturing-Systems

Product Quality and Reliability Assurance

Required Courses

MMAE 560	Statistical Quality and Process Control
MMAE 589	Applications in Reliability Engineering I
MMAE 590	Applications in Reliability Engineering II
MMAE 720	Introduction to Design Assurance

Course Descriptions

Numbers in parentheses represent class hours, lab hours, and total credit hours, respectively.

MMAE 501
Engineering Analysis I
Vectors and matrices, systems of linear equations, linear transformations, eigenvalues and eigenvectors, systems of ordinary differential equations, decomposition of matrices, and functions of matrices. Eigenfunction expansions of differential equations, self-adjoint differential operators, Sturm-Liouville equations. Complex variables, analytic functions and Cauchy-Riemann equations, harmonic functions, conformal mapping, and boundary-value problems. Calculus of variations, Euler's equation, constrained functionals, Rayleigh-Ritz method, Hamilton's principle, optimization and control. Prerequisite: An undergraduate course in differential equations.
(3-0-3)

MMAE 502
Engineering Analysis II
Generalized functions and Green's functions. Complex integration: series expansions of complex functions, singularities, Cauchy's residue theorem, and evaluation of real definite integrals. Integral transforms: Fourier and Laplace transforms, applications to partial differential equations and integral equations.
Prerequisite(s): [(MMAE 501)]
(3-0-3)

MMAE 503
Advanced Engineering Analysis
Selected topics in advanced engineering analysis, such as ordinary differential equations in the complex domain, partial differential equations, integral equations, and/or nonlinear dynamics and bifurcation theory, chosen according to student and instructor interest.
Prerequisite(s): [(MMAE 502)]
(3-0-3)

MMAE 508
Perturbation Methods
Asymptotic series, regular and singular perturbations, matched asymptotic expansions, and WKB theory. Methods of strained coordinates and multiple scales. Application of asymptotic methods in science and engineering.
Prerequisite(s): [(MMAE 501)]
(3-0-3)

MMAE 509
Introduction to Continuum Mechanics
A unified treatment of topics common to solid and fluid mechanics. Cartesian tensors. Deformation, strain, rotation and compatibility equations. Motion, velocity gradient, vorticity. Momentum, moment of momentum, energy, and stress tensors. Equations of motion, frame indifference. Constitutive relations for elastic, viscoelastic, and fluids and plastic solids.
Prerequisite(s): [(MMAE 501)]
(3-0-3)

MMAE 510
Fundamentals of Fluid Mechanics
Kinematics of fluid motion. Constitutive equations of isotropic viscous compressible fluids. Derivation of Navier-Stokes equations. Lessons from special exact solutions, self-similarity. Admissibility of idealizations and their applications; inviscid, adiabatic, irrotational, incompressible, boundary-layer, quasi one-dimensional, linearized and creeping flows. Vorticity theorems. Unsteady Bernoulli equation. Basic flow solutions. Basic features of turbulent flows.
Prerequisite(s): [(MMAE 501*)] An asterisk (*) designates a course which may be taken concurrently.
(4-0-4)

MMAE 511
Dynamics of Compressible Fluids
Low-speed compressible flow past bodies. Linearized, subsonic, and supersonic flow past slender bodies. Similarity laws. Transonic flow. Hypersonic flow, mathematical theory of characteristics. Applications including shock and nonlinear wave interaction in unsteady one-dimensional flow and two-dimensional, planar and axisymmetric supersonic flow.
Prerequisite(s): [(MMAE 510)]
(3-0-3)

MMAE 512
Dynamics of Viscous Fluids
Navier-Stokes equations and some simple exact solutions. Oseen-Stokes flows. Boundary-layer equations and their physical interpretations. Flows along walls, and in channels. Jets and wakes. Separation and transition to turbulence. Boundary layers in unsteady flows. Thermal and compressible boundary layers. Mathematical techniques of similarity transformation, regular and singular perturbation, and finite differences.
Prerequisite(s): [(MMAE 510)]
(4-0-4)

MMAE 513
Turbulent Flows
Stationary random functions. Correlation tensors. Wave number space. Mechanics of turbulence. Energy spectrum. Dissipation and energy cascade. Turbulence measurements. Isotropic turbulence. Turbulent transport processes. Mixing and free turbulence. Wall-constrained turbulence. Compressibility effects. Sound and pseudo-sound generated by turbulence. Familiarity with basic concepts of probability and statistics and with Cartesian tensors is assumed.
Prerequisite(s): [(MMAE 510)]
(4-0-4)

MMAE 514
Stability of Viscous Flows
Concept of hydrodynamic stability. Governing equations. Analytical and numerical treatment of eigenvalue problems and variational methods. Inviscid stability of parallel flows and spiral flows. Thermal instability and its consequences. Stability of channel flows, layered fluid flows, jets and flows around cylinders. Other effects and its consequences; moving frames, compressibility, stratification, hydromagnetics. Nonlinear theory and energy methods. Transition to turbulence.
Prerequisite(s): [(MMAE 502 and MMAE 510)]
(4-0-4)

MMAE 515
Engineering Acoustics
Characteristics of sound waves in two and three dimensions. External and internal sound wave propagation. Transmission and reflection of sound waves through media. Sources of sound from fixed and moving bodies. Flow-induced vibrations. Sound-level measurement techniques.
(3-0-3)

MMAE 516
Advanced Experimental Methods in Fluid Mechanics
Design and use of multiple sensor probes to measure multiple velocity components, reverse-flow velocities, Reynolds stress, vorticity components and intermittency. Simultaneous measurement of velocity and temperature. Theory and use of optical transducers, including laser velocimetry and particle tracking. Special measurement techniques applied to multiphase and reacting flows. Laboratory measurements in transitional and turbulent wakes, free-shear flows, jets, grid turbulence and boundary layers. Digital signal acquisitions and processing.
Instructor's consent required.
(2-3-3)

MMAE 517
Computational Fluid Dynamics
Classification of partial differential equations. Finite-difference methods. Numerical solution techniques including direct, iterative, and multigrid methods for general elliptic and parabolic differential equations. Numerical algorithms for solution of the Navier-Stokes equations in the primitive-variables and vorticity-stream function formulations. Grids and grid generation. Numerical modeling of turbulent flows. Additional Prerequisite: An undergraduate course in numerical methods.
Prerequisite(s): [(MMAE 510)]
(3-0-3)

MMAE 518
Spectral Methods in Computational Fluid Dynamics
Application of advanced numerical methods and techniques to the solution of important classes of problems in fluid mechanics. Emphasis is in methods derived from weighted-residuals approaches, like Galerkin and Galerkin-Tau methods, spectral and pseudospectral methods, and dynamical systems modeling via projections on arbitrary orthogonal function bases. Finite element and spectral element methods will be introduced briefly in the context of Galerkin methods. A subsection of the course will be devoted to numerical turbulence modeling, and to the problem of grid generation for complex geometries.
Prerequisite(s): [(MMAE 501 and MMAE 510)]
(3-0-3)

MMAE 519
Cardiovascular Fluid Mechanics
Anatomy of the cardiovascular system. Scaling principles. Lumped parameter, one-dimensional linear and nonlinear wave propagation, and three-dimensional modeling techniques applied to simulate blood flow in the cardiovascular system. Steady and pulsatile flow in rigid and elastic tubes. Form and function of blood, blood vessels, and the heart from an engineering perspective. Sensing, feedback, and control of the circulation. Includes a student project.
(3-0-3)

MMAE 520
Advanced Thermodynamics
Macroscopic thermodynamics: first and second laws applied to equilibrium in multicomponent systems with chemical reaction and phase change, availability analysis, evaluations of thermodynamic properties of solids, liquids, and gases for single and multicomponent systems. Applications to contemporary engineering systems. Prerequisite: An undergraduate course in applied thermodynamics.
(3-0-3)

MMAE 522
Nuclear, Fossil-Fuel, & Sustainable Energy Systems
Principles, technology, and hardware used for conversion of nuclear, fossil-fuel, and sustainable energy into electric power will be discussed. Thermodynamic analysis – Rankine cycle. Design and key components of fossil-fuel power plants. Nuclear fuel, reactions, materials. Pressurized water reactors (PWR). Boiling water reactors (BWR). Canadian heavy water (CANDU) power plants. Heat transfer from the nuclear fuel elements. Introduction to two phase flow: flow regimes; models. Critical heat flux. Environmental effects of coal and nuclear power. Design of solar collectors. Direct conversion of solar energy into electricity. Wind power. Geothermal energy. Energy conservation and sustainable buildings. Enrichment of nuclear fuel. Nuclear weapons and effects of the explosions.
(3-0-3)

MMAE 523
Fundamentals of Power Generation
Thermodynamic, combustion, and heat transfer analyses relating to steam-turbine and gas-turbine power generation. Environmental impacts of combustion power cycles. Consideration of alternative and sustainable power generation processes such as wind and tidal, geothermal, hydroelectric, solar, fuel cells, nuclear power, and microbial. Prerequisite: An undergraduate course in applied thermodynamics.
(3-0-3)

MMAE 524
Fundamentals of Combustion
Combustion stoichiometry. Chemical equilibrium. Adiabatic flame temperature. Reaction kinetics. Transport processes. Gas flames classification. Premixed flames. Laminar and turbulent regimes. Flame propagation. Deflagrations and detonations. Diffusion flames. Spray combustion. The fractal geometry of flames. Ignition theory. Pollutant formation. Engine combustion. Solid phase combustion. Combustion diagnostics. Prerequisite: An undergraduate course in thermodynamics and heat transfer or instructor consent.
(3-0-3)

MMAE 525
Fundamentals of Heat Transfer
Modes and fundamental laws of heat transfer. The heat equations and their initial and boundary conditions. Conduction problems solved by separation of variables. Numerical methods in conduction. Forced and natural convection in channels and over exterior surfaces. Similarity and dimensionless parameters. Heat and mass analogy. Effects of turbulence. Boiling and condensation. Radiation processes and properties. Blackbody and gray surfaces radiation. Shape factors. Radiation shields. Prerequisite: An undergraduate course in heat transfer.
(3-0-3)

MMAE 526
Heat Transfer: Conduction
Fundamental laws of heat conduction. Heat equations and their initial and boundary conditions. Steady, unsteady and periodic states in one or multidimensional problems. Composite materials. Methods of Green's functions, eigenfunction expansions, finite differences, finite element methods.
Prerequisite(s): [(MMAE 502 and MMAE 525)]
(3-0-3)

MMAE 527
Heat Transfer: Convection & Radiation
Convective heat transfer analyses of external and internal flows. Forced and free convection. Dimensional analysis. Phase change. Heat and mass analogy. Reynolds analogy. Turbulence effects. Heat exchangers, regenerators. Basic laws of Radiation Heat Transfer. Thermal radiation and quantum mechanics pyrometry. Infrared measuring techniques.
Prerequisite(s): [(MMAE 525)]
(3-0-3)

MMAE 529
Theory of Plasticity
Phenomenological nature of metals, yield criteria for 3-D states of stress, geometric representation of the yield surface. Levy-Mises and Prandtl-Reuss equations, associated and non-associated flow rules, Drucker's stability postulate and its consequences, consistency condition for nonhardening materials, strain hardening postulates. Elastic plastic boundary value problems. Computational techniques for treatment of small and finite plastic deformations.
Prerequisite(s): [(MMAE 530)]
(3-0-3)

MMAE 530
Advanced Mechanics of Solids
Mathematical foundations: tensor algebra, notation and properties, eigenvalues and eigenvectors. Kinematics: deformation gradient, finite and small strain tensors. Force and equilibrium: concepts of traction/stress, Cauchy relation, equilibrium equations, properties of stress tensor, principal stresses. Constitutive laws: generalized Hooke's law, anisotropy and thermoelasticity. Boundary value problems in linear elasticity: plane stress, plane strain, axisymmetric problems, Airy stress function. Energy methods for elastic solids. Torsion. Elastic and inelastic stability of columns.
Prerequisite(s): [(MMAE 501*)] An asterisk (*) designates a course which may be taken concurrently.
(3-0-3)

MMAE 531
Theory of Elasticity
Notion of stress and strain, field equations of linearized elasticity. Plane problems in rectangular and polar coordinates. Problems without a characteristic length. Plane problems in linear elastic fracture mechanics. Complex variable techniques, energy theorems, approximate numerical techniques.
Prerequisite(s): [(MMAE 530)]
(3-0-3)

MMAE 532
Advanced Finite Element Methods
Continuation of MMAE 451/CAE 442. Covers the theory and practice of advanced finite element procedures. Topics include implicit and explicit time integration, stability of integration algorithms, unsteady heat conduction, treatment of plates and shells, small-strain plasticity, and treatment of geometric nonlinearity. Practical engineering problems in solid mechanics and heat transfer are solved using MATLAB and commercial finite element software. Special emphasis is placed on proper time step and convergence tolerance selection, mesh design, and results interpretation.
Prerequisite(s): [(CAE 442) OR (MMAE 451)]
(3-0-3)

MMAE 533
Fatigue & Fracture Mechanics
Analysis of the general state of stress and strain in solids; dynamic fracture tests (FAD, CAT). Linear elastic fracture mechanics (LEFM), Griffith-Irwin analysis, ASTM, KIC, KIPCI, KIA, KID. Plane stress, plane strain; yielding fracture mechanics (COD, JIC). Fatigue crack initiation. Goodman diagrams and fatigue crack propagation. Notch sensitivity and stress concentrations. Low-cycle fatigue, corrosion and thermal fatigue. Prerequisite: An undergraduate course in mechanics of solids.
(3-0-3)

MMAE 535
Wave Propagation
This is an introductory course on wave propagation. Although the ideas are presented in the context of elastic waves in solids, they easily carry over to sound waves in water and electromagnetic waves. The topics include one dimensional motion of elastic continuum, traveling waves, standing waves, energy flux, and the use of Fourier integrals. Problem statement in dynamic elasticity, uniqueness of solution, basic solution of elastodynamics, integral representations, steady state time harmonic response. Elastic waves in unbounded medium, plane harmonic waves in elastic half-spaces, reflection and transmission at interfaces, Rayleigh waves, Stoneley waves, slowness diagrams, dispersive waves in waveguides and phononic composites, thermal effects and effects of viscoelasticity, anisotropy, and nonlinearity on wave propagation.
(3-0-3)

MMAE 536
Experimental Solid Mechanics
Review of applied elasticity. Stress, strain and stress-strain relations. Basic equations and boundary value problems in plane elasticity. Methods of strain measurement and related instrumentation. Electrical resistance strain gauges, strain gauge circuits and recording instruments. Analysis of strain gauge data. Brittle coatings. Photoelasticity; photoelastic coatings; moire methods; interferometric methods. Applications of these methods in the laboratory. Prerequisite: An undergraduate course in mechanics of solids.
(3-2-4)

MMAE 540
Robotics
Kinematics and inverse kinematics of manipulators. Newton-Euler dynamic formulation. Independent joint control. Trajectory and path planning using potential fields and probabilistic roadmaps. Adaptive control. Force control.
Prerequisite(s): [(MMAE 443 and MMAE 501*)] An asterisk (*) designates a course which may be taken concurrently.
(3-0-3)

MMAE 541
Advanced Dynamics
Kinematics of rigid bodies. Rotating reference frames and coordinate transformations; Inertia dyadic. Newton-Euler equations of motion. Gyroscopic motion. Conservative forces and potential functions. Generalized coordinates and generalized forces. Lagrange's equations. Holonomic and nonholonomic constraints. Lagrange multipliers. Kane's equations. Elements of orbital and spacecraft dynamics. Additional Prerequisite: An undergraduate course in dynamics.
Prerequisite(s): [(MMAE 501*)] An asterisk (*) designates a course which may be taken concurrently.
(3-0-3)

MMAE 542
Applied Dynamical Systems
This course will cover analytical and computational methods for studying nonlinear ordinary differential equations especially from a geometric perspective. Topics include stability analysis, perturbation theory, averaging methods, bifurcation theory, chaos, and Hamiltonian systems.
Prerequisite(s): [(MMAE 501)]
(3-0-3)

MMAE 543
Modern Control Systems
Review of classical control. Discrete-time systems. Linear difference equations. Z-transform. Design of digital controllers using transform methods. State-space representations of continuous and discrete-time systems. State feedback. Controllability and observability. Pole placement. Optimal control. Linear-Quadratic Regulator (LQR). Probability and stochastic processes. Optimal estimation. Kalman Filter. Additional Prerequisite: An undergraduate course in classical control.
Prerequisite(s): [(MMAE 501*)] An asterisk (*) designates a course which may be taken concurrently.
(3-0-3)

MMAE 544
Design Optimization
Optimization theory and practice with examples. Finite-dimensional unconstrained and constrained optimization, Kuhn-Tucker theory, linear and quadratic programming, penalty methods, direct methods, approximation techniques, duality. Formulation and computer solution of design optimization problems in structures, manufacturing and thermofluid systems. Prerequisite: An undergraduate course in numerical methods.
(3-0-3)

MMAE 545
Advanced CAD/CAM
Interactive computer graphics in mechanical engineering design and manufacturing. Mathematics of three-dimensional object and curved surface representations. Surface versus solid modeling methods. Numerical control of machine tools and factory automation. Applications using commercial CAD/CAM in design projects.
Prerequisite(s): [(MMAE 445)]
(3-0-3)

MMAE 546
Advanced Manufacturing Engineering
Introduction to advanced manufacturing processes, such as powder metallurgy, joining and assembly, grinding, water jet cutting, laser-based manufacturing, etc. Effects of variables on the quality of manufactured products. Process and parameter selection. Important physical mechanisms in manufacturing process. Prerequisite: An undergraduate course in manufacturing processes or instructor consent.
(3-0-3)

MMAE 547
Computer-Integrated Manufacturing Technologies
The use of computer systems in planning and controlling the manufacturing process including product design, production planning, production control, production processes, quality control, production equipment and plant facilities.
(3-0-3)

MMAE 551
Experimental Mechatronics
Team-based project. Microprocessor controlled electromechanical systems. Sensor and actuator integration. Basic analog and digital circuit design. Limited Enrollment.
Prerequisite(s): [(MMAE 443)]
(2-3-3)

MMAE 552
Introduction to the Space Environment
Overview of the space environment, particularly Earth's ionosphere, magnetosphere, and interplanetary space. Effects of solar activity on geospace variability. Basic plasma characteristics. Single particle motions. Waves in magnetized plasmas. Charged particle trapping in planetary magnetic fields and its importance in near-earth-space phenomena. Macroscopic equations for a conducting fluid. Ground and space-based remote sensing and in situ measurement techniques. Space weather effects on human-made systems. Students must have already taken undergraduate courses in electromagnetics and in fluid mechanics.
(3-0-3)

MMAE 554
Electrical, Magnetic & Optical Properties of Materials
Electronic structure of solids. Conductors, semiconductors, dielectrics, superconductors. Ferroelectric and piezoelectric materials. Magnetic properties, magnetocrystalline, anisotropy, magnetic materials and devices. Optical properties and their applications.
(3-0-3)

MMAE 555
Introduction to Navigation Systems
Fundamental concepts of positioning and dead reckoning. Principles of modern satellite-based navigation systems, including GPS, GLONASS, and Galileo. Differential GPS (DGPS) and augmentation systems. Carrier phase positioning and cycle ambiguity resolution algorithms. Autonomous integrity monitoring. Introduction to optimal estimation, Kalman filters, and covariance analysis. Inertial sensors and integrated navigation systems.
Prerequisite(s): [(MMAE 443 and MMAE 501*)] An asterisk (*) designates a course which may be taken concurrently.
(3-0-3)

MMAE 556
Nanoscale Imaging & Manipulation
Includes an overview of scanning probe microscopy and of AFM imaging: mathematical morphology; imaging simulation and surface recognition; and high-speed AFM imaging. Also covers nanoscale physics, including probing nanoscale forces, van der Waals force, electrostatic force, and capillary force. Nanomanipulation topics such as mechanical scratching and pushing electrophoresis, and augmented reality. Manipulation automation and manipulation planning. Applications of selected topics covered.
(3-0-3)

MMAE 557
Computer-Integrated Manufacturing Systems
Advanced topics in Computer-Integrated Manufacturing, including control systems, group technology, cellular manufacturing, flexible manufacturing systems, automated inspection, lean production, Just-In-Time production, and agile manufacturing systems.
(3-0-3)

MMAE 560
Statistical Quality & Process Control
Basic theory, methods and techniques of on-line, feedback quality control systems for variable and attribute characteristics. Methods for improving the parameters of the production, diagnosis, and adjustment processes so that quality loss is minimized. Same as CHE 560.
(3-0-3)

MMAE 561
Solidification & Crystal Growth
Properties of melts and solids. Thermodynamic and heat transfer concepts. Single and poly-phase alloys. Macro and micro segregation. Plane-front solidification. Solute boundary layers. Constitutional supercooling. Convection in freezing melts. Effective segregation coefficients. Zone freezing and purification. Single crystal growth technology. Czochralski, Kyropulous, Bridgman, and Floating Zone methods. Control of melt convection and crystal composition. Equipment. Process control and modeling. Laboratory demonstration. Prerequisite: A background in crystal structure and thermodynamics.
(3-0-3)

MMAE 562
Design of Modern Alloys
Phase rule, multicomponent equilibrium diagrams, determination of phase equilibria, parameters of alloy development, prediction of structure and properties. Prerequisite: A background in phase diagrams and thermodynamics.
(2-0-2)

MMAE 563
Advanced Mechanical Metallurgy
Analysis of the general state of stress and strain in solids. Analysis of elasticity and fracture, with a major emphasis on the relationship between properties and structure. Isotropic and anisotropic yield criteria. Testing and forming techniques related to creep and superplasticity. Deformation mechanism maps. Fracture mechanics topics related to testing and prediction of service performance. Static loading to onset of rapid fracture, environmentally assisted cracking fatigue, and corrosion fatigue. Prerequisite: A background in mechanical properties.
(3-0-3)

MMAE 564
Dislocations & Strengthening Mechanisms
Basic characteristics of dislocations in crystalline materials. Dislocations and slip phenomena. Application of dislocation theory to strengthening mechanisms. Strain hardening. Solid solution and particle strengthening. Dislocations and grain boundaries. Grain size strengthening. Creep. Fatigue. Prerequisite: Background in materials analysis.
(3-0-3)

MMAE 565
Materials Laboratory
Advanced synthesis projects studying microstructure and properties of a series of binary and ternary alloys. Gain hands-on knowledge of materials processing and advanced materials characterization through an integrated series of experiments to develop understanding of the processing-microstructure-properties relationship. Students arc melt a series of alloys, examine the cast microstructures as a function of composition using optical and electron microscopy, DTA, EDS, and XRD. The alloys are treated in different thermal and mechanical processes. The microstructural and mechanical properties modification and changes during these processes are characterized. Groups of students will be assigned different alloy systems, and each group will present their results orally to the class and the final presentation to the whole materials science and engineering group.
(1-6-3)

MMAE 566
Problems in High-Temperature Materials
Temperature-dependent mechanical properties. Creep mechanisms. Basic concepts in designing in high-temperature materials. Metallurgy of basic alloy systems. Surface stability. High-temperature oxidation. Hot corrosion. Coatings and protection. Elements of process metallurgy.Prerequisite: Background in mechanical properties, crystal defects, and thermodynamics.
Prerequisite(s): [(MMAE 564)]
(3-0-3)

MMAE 567
Fracture Mechanisms
Basic mechanisms of fracture and embrittlement of metals. Crack initiation and propagation by cleavage, microvoid coalescence, and fatigue mechanisms. Hydrogen embrittlement, stress corrosion cracking and liquid metal embrittlement. Temper brittleness and related topics.Prerequisite: Background in crystal structure, defects, and mechanical properties.
(3-0-3)

MMAE 568
Diffusion
Theory, techniques and interpretation of diffusion studies in metals. Prerequisite: Background in crystal structures, defects, and thermodynamics.
(2-0-2)

MMAE 569
Advanced Physical Metallurgy
Thermodynamics and kinetics of phase transformations, theory of nucleation and growth, metastability, phase diagrams.Prerequisite: Background in phase diagrams and thermodynamics.
(3-0-3)

MMAE 570
Computational Methods in Materials Processing
Advanced theories and computational methods used in understanding and modeling of various materials processing that involve deformation, solidification, microstructural changes etc. This course will discuss the fundamental theories and mathematical models that describe the relevant physical phenomena in the computational framework of finite element method. If will consist of three parts: (1) Lectures on fundamental theories and models; (2) computational and numerical methods; (3) computer laboratories.Prerequisite: Background in finite element methods and materials processing.
(3-0-3)

MMAE 571
Miscrostructural Characterization of Materials
Advanced optical microscopy. Scanning and transmission electron microscopes. X-ray microanalysis. Surface characterization. Quantitative microscopy. Elements of applied statistics.
(2-3-3)

MMAE 573
Transmission Electron Microscopy
Design, construction and operation of transmission electron microscope, including image formation and principles of defect analysis in materials science applications. Theory and use of state-of-the-art micro characterization techniques for morphological, crystallographic, and elemental analysis at high spatial resolutions at 10 nanometers in metallurgical and ceramic studies will also be covered.
(2-3-3)

MMAE 574
Ferrous Transformations
Allotropic modifications in iron and solid solution effects of the important alloying elements on iron. Physical metallurgy of pearlite, bainite and martensite reactions. Physical and mechanical property changes during eutectoid decomposition and tempering.Prerequisite: Background in phase diagrams and thermodynamics.
(3-0-3)

MMAE 576
Materials & Process Selection
Context of selection; decision analysis; demand, materials and processing profiles; design criteria; selection schemes; value and performance oriented selection; case studies.
(3-0-3)

MMAE 578
Fiber Composites
Basic concepts and definitions. Current and potential applications of composite materials. Fibers, Matrices, and overview of manufacturing processes for composites. Review of elasticity of anisotropic solids and transformation of stiffness/compliance matrices. Micromechanics: methods for determining mechanical properties of heterogeneous materials. Macromechanics: ply analysis, off-axis stiffness, description of laminates, laminated plate theories, special types of laminates. Applications of concepts to the design of simple composite structural components. Failure theories, hydrothermal effects.Prerequisite: Background in polymer synthesis and properties.
(3-0-3)

MMAE 579
Advanced Materials Processing
Processing science and fundamentals in making advanced materials, particularly nanomaterials and composites. Applications of the processing science to various processing technologies including severe plastic deformation, melt infiltration, sintering, co-precipitation, sol-gel process, aerosol synthesis, plasma spraying, vapor-liquid-solid growth, chemical vapor deposition, physical vapor deposition, atomic layer deposition, and lithography.
Prerequisite(s): [(MMAE 467)]
(3-0-3)

MMAE 585
Engineering Optics & Laser-Based Manufacturing
Fundamentals of geometrical and physical optics as related to problems in engineering design and research; fundamentals of laser-material interactions and laser-based manufacturing processes. This is a lecture-dominated class with around three experiments organized to improve students' understanding of the lectures. The topics covered include: geometrical optics (law of reflection and refraction, matrix method, etc.); physical optics (wave equations, interference, polarization, Fresnel equations, etc.); optical properties of materials and Drude theory; laser fundamentals; laser-matter interactions and laser-induced thermal and mechanical effects, laser applications in manufacturing (such as laser hardening, machining, sintering, shock peening, and welding). Knowledge of Heat & Mass Transfer required.
(3-0-3)

MMAE 589
Applications in Reliability Engineering I
This first part of a two-course sequence focuses on the primary building blocks that enable an engineer to effectively communicate and contribute as a part of a reliability engineering effort. Students develop an understanding of the long term and intermediate goals of a reliability program and acquire the necessary knowledge and tools to meet these goals. The concepts of both probabilistic and deterministic design are presented, along with the necessary supporting understanding that enables engineers to make design trade-offs that achieve a positive impact on the design process. Strengthening their ability to contribute in a cross functional environment, students gain insight that helps them understand the reliability engineering implications associated with a given design objective, and the customer's expectations associated with the individual product or product platforms that integrate the design. These expectations are transformed into metrics against which the design can be measured. A group project focuses on selecting a system, developing a flexible reliability model, and applying assessment techniques that suggest options for improving the design of the system.
(3-0-3)

MMAE 590
Applications in Reliability Engineering II
This is the second part of a two-course sequence emphasizing the importance of positively impacting reliability during the design phase and the implications of not making reliability an integrated engineering function. Much of the subject matter is designed to allow the students to understand the risks associated with a design and provide the insight to reduce these risks to an acceptable level. The student gains an understanding of the methods available to measure reliability metrics and develops an appreciation for the impact manufacturing can have on product performance if careful attention is not paid to the influencing factors early in the development process. The discipline of software reliability is introduced, as well as the influence that maintainability has on performance reliability. The sequence culminates in an exhaustive review of the lesson plans in a way that empowers practicing or future engineers to implement their acquired knowledge in a variety of functional environments, organizations and industries. The group project for this class is a continuation of the previous course, with an emphasis on applying the tools and techniques introduced during this second of two courses.
Prerequisite(s): [(MMAE 589)]
(3-0-3)

MMAE 591
Research & Thesis M.S.

(Credit: Variable)

MMAE 593
MMAE Seminar
Reports on current research. Full-time graduate students in the department are expected to register and attend.
(1-0-0)

MMAE 594
Project for Master of Engineering Students
Design projects for the master of mechanical and aerospace engineering, master of materials engineering, and master of manufacturing engineering degrees.
(Credit: Variable)

MMAE 597
Special Topics
Advanced topic in the fields of mechanics, mechanical and aerospace, metallurgical and materials, and manufacturing engineering in which there is special student and staff interest. (Variable credit)
(Credit: Variable)

MMAE 600
Continuance of Residence

(0-0-1)

MMAE 691
Research & Thesis Ph.D.

(Credit: Variable)

MMAE 704
Introduction to Finite Element Analysis
This course provides a comprehensive overview of the theory and practice of the finite element method by combining lectures with selected laboratory experiences . Lectures cover the fundamentals of linear finite element analysis, with special emphasis on problems in solid mechanics and heat transfer. Topics include the direct stiffness method, the Galerkin method, isoperimetric finite elements, equation solvers, bandwidth of linear algebraic equations and other computational issues. Lab sessions provide experience in solving practical engineering problems using commercial finite element software. Special emphasis is given to mesh design and results interpretation using commercially available pre- and post-processing software.
(2-0-2)

MMAE 705
Computer Aided Design with Pro Engineer
This course provides an introduction to Computer-Aided Design and an associated finite element analysis technique. A series of exercises and instruction in Pro/ENGINEER will be completed. The operation of Mecanica (the associated FEM package) will also be introduced. Previous experience with CAD and FEA will definitely speed learning, but is not essential.
(2-0-2)

MMAE 707
High-Temperature Structural Materials
Creep mechanisms and resistance. The use of deformation mechanisms maps in alloy design. Physical and mechanical metallurgy of high-temperature, structural materials currently in use. Surface stability: High-temperature oxidation, hot corrosion, protective coatings. Alternative materials of the 21st century. Elements of process metallurgy.
(2-0-2)

MMAE 709
Overview of Reliability Engineering
This course covers the role of reliability in robust product design. It dwells upon typical failure mode investigation and develops strategies to design them out of the product. Topics addressed include reliability concepts, systems reliability, modeling techniques, and system availability predications. Case studies are presented to illustrate the cost-benefits due to pro-active reliability input to systems design, manufacturing and testing.
(2-0-2)

MMAE 710
Dynamic & Nonlinear Finite Element Analysis
Provides a comprehensive understanding of the theory and practice of advanced finite element procedures. The course combines lectures on dynamic and nonlinear finite element analysis with selected computer labs. The lectures cover implicit and explicit time integration techniques, stability of integration algorithms, treatment of material and geometric nonlinearity, and solution techniques for nonlinear finite element equations. The computer labs train student to solve practical engineering problems in solid mechanics and heat transfer using ABQUS and Hypermesh. Special emphasis is placed on proper time step and convergence tolerance selection, mesh design, and results interpretation. A full set of course notes will be provided to class participants as well as a CD-ROM containing course notes, written exercises, computer labs, and all worked out examples.
Prerequisite(s): [(MMAE 704)]
(2-0-2)

MMAE 713
Engineering Economic Analysis
Introduction to the concepts of Engineering Economic Analysis, also known as micro-economics. Topics include equivalence, the time value of money, selecting between alternative, rate of return analysis, compound interest, inflation, depreciation, and estimating economic life of an asset.
(2-0-2)

MMAE 715
Project Management
This course will cover the basic theory and practice of project management from a practical viewpoint. Topics will include project management concepts, recourses, duration vs. effort, project planning and initiation, progress tracking methods, CPM and PERT, reporting methods, replanning, team project concepts, and managing multiple projects. Microsoft Project software will be used extensively.
(2-0-2)

MMAE 724
Introduction to Acoustics
This short course provides a brief introduction to the fundamentals of acoustics and the application to product noise prediction and reduction. The first part focuses on fundamentals of acoustics and noise generation. The second part of the course focuses on applied noise control.
(2-0-2)