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 Mechanical and Aerospace Engineering
- Master of Materials Science and Engineering
- Master of Manufacturing Engineering
- Doctor of Philosophy in Mechanical and Aerospace Engineering
- Doctor of Philosophy in Materials Science and Engineering
- Master of Mechanical and Aerospace Engineering with specialization in Energy/Environment/Economics (E³)

### Interdisciplinary Program
- Master of Science in Mechanical and Aerospace Engineering with specialization in Energy/Environment/Economics (E³)

### 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, internal combustion engines, two-phase flow and heat-transfer, electrohydrodynamics, and combined heat and mass transfer; and research facilities for atomization, spray flames, and emissions from mobile and stationary combustion sources.

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 tools, tribology, frictional wear characteristics of ceramics, dynamic systems, and mechanical vibrations; thermal sciences, including phase change heat transfer, enhancement of heat transfer and mass transport in macro and micro scales, electrohydrodynamics, spray combustion, atomization, transport processes within gas-liquid and gas-solid dispersions and suspensions, 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, Mechanical, Materials, and Aerospace Engineering. 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, 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., Professor of Materials Science and 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 phenomena 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, geosphere environment imaging, estimation and monitoring.

Gosz, Michael R., Associate Professor of Mechanical and Materials Engineering and Vice Provost for Undergraduate Affairs. 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.

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.

Nagib, Hassan M., John T. Retallika 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.

Ostrogradsky, 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.

Qian, Xiaoping, Associate Professor of Mechanical and Aerospace Engineering. B.S., M.S. Huazhong University of Science and Technology (China); Ph.D., University of Michigan. 3D object digitization, design and manufacturing, Geometry processing, Shape and topology optimization.

Raman, Ganesh, Associate Professor of Mechanical and Aerospace Engineering and Associate Dean of the Graduate College for Research. B.T., 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.

Shadden, Shawn, Assistant Professor of Mechanical and Aerospace Engineering. B.S., University of Texas-Austin; Ph.D., California Institute of Technology. Dynamical systems theory, transport and mixing, modeling mechanical systems, biological flows.

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

Tin, Sammy, Associate 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 theromechanical 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.

Research Faculty

Benedyk, Joseph C., Research Professor. B.S., M.S., Illinois Institute of Technology; Ph.D., Case Western Reserve University. Metals and materials processing research and development and product development.

Frankfurt, Vladimir, Research Professor.

Hu, Zhiyong, Research Assistant Professor. B.S. Tianjin University, MS. PhD Institute of Metal Research, Chinese Academy of Sciences. Modeling the material processing (casting, extrusion, carburization, heat treatment), predicting the defects, temperature, stress and strain distribution in materials, optimizing the process parameters.

Mansy, Hansen, Research Associate Professor. B.S., M.S., Cairo University (Egypt); Ph.D., Illinois Institute of Technology. Biomedical acoustics, non-invasive measurement methods, biomedical fluid dynamics, flow-induced oscillations.

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 associate 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 Mechanical and Aerospace Engineering  
Master of Materials Science and Engineering  
Master of 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 Mechanical and Aerospace Engineering |
|-----------------------------|-----------------------------|
| Required Courses:          | Core courses as determined by major area of study |
|                            | Fluid Dynamics               |
| MMAE 501 Engineering Analysis I | MMAE 510 Fundamentals of Fluid Mechanics |
| AND one core course in major area of study | Thermal Sciences |
| AND one of the following: | MMAE 525 Fundamentals of Heat Transfer |
| MMAE 451 Finite Element Methods I | Solids and Structures |
| MMAE 502 Engineering Analysis II | MMAE 530 Advanced Mechanics of Solids |
| MMAE 517 Computational Fluid Dynamics | Dynamics and Controls |
| MMAE 532 Finite Element Methods II | MMAE 541 Advanced Dynamics |
| MMAE 538 Computational Techniques in FEM | Computer Aided Design and Manufacturing: |
| MMAE 544 Design Optimization | MMAE 545 Advanced CAD/CAM |
| OR MMAE 570 Computational Methods in Materials Processing | |
| AND elective courses as needed. | 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 Materials Science and Engineering

| Required Courses (for all students not specializing in ferrous metallurgy) |
| MMAE 563 Advanced Mechanical Metallurgy |
| MMAE 569 Advanced Physical Metallurgy |
| AND MMAE 468 Introduction to Ceramic Materials |
| OR MMAE 486 Properties of Ceramics |
| AND one of the following: |
| MMAE 470 Introduction to Polymer Science |
| MMAE 579 Characterization of Polymers |
| OR MMAE 580 Structure and Properties Polymers |
| Required Courses (for students specializing in ferrous metallurgy) |
| MMAE 563 Advanced Mechanical Metallurgy |
| MMAE 569 Advanced Physical Metallurgy |
| MMAE 574 Ferrous Transformations |
| MMAE 575 Ferrous Products: Metallurgy and Manufacture |
| MMAE 578 Fiber Composite Materials |
| 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 |
Department of Mechanical, Materials, and Aerospace Engineering

Course Requirements for Master of 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 Process and Quality Control

AND
one course in materials science and engineering

AND one course emphasizing numerical methods:
MMAE 451 Finite Element Methods I
MMAE 517 Computational Fluid Dynamics
MMAE 532 Finite Element Methods II
MMAE 538 Computational Techniques in FEM
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 Process and Quality Control

AND one of the following:
MMAE 445 CAD/CAM with Numerical Control
MMAE 545 Advanced CAD/CAM
MMAE 546 Advanced Manufacturing Engineering

OR
MMAE 576 Materials and Process Selection

AND one of the following:
MMAE 475 Powder Metallurgy
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 I
MMAE 517 Computational Fluid Dynamics
MMAE 532 Finite Element Methods II
MMAE 538 Computational Techniques in FEM
MMAE 544 Design Optimization

OR
MMAE 570 Computational Methods in Materials Processing

AND elective courses as needed.

Master of Manufacturing Engineering via Internet

30 credit hours

The Master of 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 CAD/CAM with Numerical Control
MMAE 474 Metals Processing
MMAE 481 Introduction to Joining Processes
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)
MMAE 720 Design Assurance (2 credit hours)
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 525 Fundamentals of Heat Transfer

**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 Core Courses (12 credit hours)**
- MMAE 563 Advanced Mechanical Metallurgy
- MMAE 569 Advanced Physical Metallurgy
- AND
- MMAE 468 Introduction to Ceramic Materials
  - OR
  - MMAE 486 Properties of Ceramics
- AND one of the following:
  - MMAE 470 Introduction to Polymer Science
  - MMAE 579 Characterization of Polymers
  - OR
  - MMAE 580 Structure and Properties of Polymers
- 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 Process and Quality Control

AND one course in materials science and engineering

AND one course emphasizing numerical methods:
- MMAE 451 Finite Element Methods I
- MMAE 517 Computational Fluid Dynamics
- MMAE 532 Finite Element Methods II
- MMAE 538 Computational Techniques in FEM
- 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 Process and Quality Control

AND one of the following:
- MMAE 445 CAD/CAM with Numerical Control
- MMAE 545 Advanced CAD/CAM
- MMAE 546 Advanced Manufacturing Engineering

OR
- MMAE 576 Materials and Process Selection

AND one of the following:
- MMAE 475 Powder Metallurgy
- 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 I
- MMAE 517 Computational Fluid Dynamics
- MMAE 532 Finite Element Methods II
- 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 Mechanical and Aerospace Engineering
Doctor of Philosophy in Materials Science and 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.

Course Requirements for Mechanical and Aerospace Engineering

Required Courses:
- MMAE 501 Engineering Analysis I
- MMAE 502 Engineering Analysis II
- Two courses from group EA (fluid dynamics, thermals sciences and solids and structures students must take MMAE 507 Continuum Mechanics)
- One core course in major area of study
- One core course in second area
- Nine or more credit hours of non-core courses in major area
- Elective courses as needed.

Core courses as determined by major area of study

Fluid Dynamics
- MMAE 510 Fundamentals of Fluid Mechanics

Thermal Sciences
- MMAE 525 Fundamentals of Heat Transfer

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 507 Introduction to Continuum Mechanics
- MMAE 508 Perturbation Methods
- 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 Systems Theory
- ECE 537 Optimal Feedback Control
- ECE 567 Statistical Signal Processing
Course Requirements for Materials Science and Engineering

MMAE 501 Engineering Analysis I
MMAE 563 Advanced Mechanical Metallurgy
MMAE 569 Advanced Physical Metallurgy
AND
MMAE 468 Introduction to Ceramic Materials
OR
MMAE 486 Properties of Ceramics
AND one of the following:
MMAE 470 Introduction to Polymer Science
MMAE 579 Characterization of Polymers
MMAE 580 Structure and Properties of Polymers
AND elective courses as needed.

Certificate Programs

Computer Integrated Design and Manufacturing

Required Courses (choose four)
MMAE 445 CAD/CAM with Numerical Control
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**

(3-0-3)

**MMAE 502 Engineering Analysis II**

(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 507 Introduction to Continuum Mechanics**

Prerequisite(s): [(MMAE 501*)] An asterisk (*) designates a course which may be taken concurrently.

(4-0-4)

**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 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**

(4-0-4)

**MMAE 514 Stability of Viscous Flows**

(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

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

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

MMAE 525
Fundamentals of Heat Transfer
MMAE 526
Heat Transfer: Conduction
Prerequisite(s): [(MMAE 502 and MMAE 525)]
(3-0-3)

MMAE 527
Heat Transfer: Convection & Radiation
Prerequisite(s): [(MMAE 525)]
(3-0-3)

MMAE 529
Theory of Plasticity
Prerequisite(s): [(MMAE 530)]
(3-0-3)

MMAE 530
Advanced Mechanics of Solids
Prerequisite(s): [(MMAE 501*)]
(3-0-3)

MMAE 531
Theory of Elasticity
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
(3-0-3)

MMAE 536
Experimental Solid Mechanics
Prerequisite: An undergraduate course in mechanics of solids.
(3-0-3)
MMAE 543 Modern Control Systems

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 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

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

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 are assigned 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

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. It 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
Microstructural Characterization of Materials

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  
(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.  
Research and thesis writing.  
(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  
Continuance of residence.  
(0-0-1)  

MMAE 691  
Research & Thesis Ph.D.  
Research and thesis writing.  
(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
(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 predicions. 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)