

Department of Mechanical, Materials and Aerospace Engineering

Department of Mechanical, Materials and Aerospace Engineering

243 Engineering 1 Building
10 W. 32nd St.
Chicago, IL 60616
312.567.3175
dept@mmae.iit.edu
www.mmae.iit.edu

Chair:
Jamal Yagoobi

Associate Chair, Graduate Programs:
Kevin Cassel

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 an interdisciplinary program in manufacturing engineering.

Degrees Offered

Master of Science in Mechanical and
Aerospace Engineering

Master of Science in Materials Science and Engineering

Master of Engineering in Manufacturing via Internet

Master of Mechanical and Aerospace Engineering

Master of Materials Science and Engineering

Doctor of Philosophy in Mechanical and
Aerospace Engineering

Doctor of Philosophy in Materials Science and
Engineering

Interdisciplinary Programs

**With the Department of Chemical and
Environmental Engineering and the Department of
Electrical and Computer Engineering:**

Master of Manufacturing Engineering

Master of Science in Manufacturing Engineering

Master of Science 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 (fdrc.iit.edu)

Thermal Processing Technology Center (mmae.iit.edu/~tpc/)

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; 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, railroad engineering, 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 non-ferrous 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, and holographic interferometry; computational mechanics, fracture mechanics, cable dynamics and analysis of inelastic solids; theoretic

cal 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

Ralph L. Barnett, Professor. B.S., M.S., Illinois Institute of Technology. Structures and safety of machines.

Kevin W. Cassel, Associate Professor and Associate Chair for Graduate Programs. 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.

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

Herek L. Clack, Associate Professor. B.S., Massachusetts Institute of Technology; M.S., 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.

Michael R. Gosz, Associate Professor and Associate 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.

John S. Kallend, Professor and Associate Chair of Undergraduate Studies. B.A., M.A., Ph.D., Cambridge University (England). Computational methods of crystallographic texture analysis and properties of polycrystalline aggregates.

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

Sheldon Mostovoy, Associate Professor. B.S., Ph.D., Illinois Institute of Technology. Metallurgy, mechanical properties of materials, fatigue and fracture.

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

Sudhakar E. Nair, Professor and Associate Dean of Academic Affairs, Graduate College. 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.

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

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

Xiaoping Qian, Assistant Professor. B.S., M.S. Huazhong University, PhD University of Michigan. 3D object digitization, design and manufacturing, heterogeneous object modeling, layered manufacturing.

Faculty continued

Ganesh Raman, Associate Professor and Associate Dean for Research in the Graduate College. 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.

Dietmar Rempfer, Associate Professor. M.S., Ph.D., Universitaet Stuttgart (Germany). Fluid mechanics, especially theoretical studies of transitional and turbulent shear flows in open systems, numerical fluid mechanics, coherent structures in turbulent flows, nonlinear dynamical systems.

Francisco Ruiz, Associate Professor. 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.

Sammy Tin, Assistant Professor. B.S. California Polytechnic State University; M.S. Carnegie Mellon University; PhD University of Michigan. Processing and deformation characteristics of high-temperature structural materials, modeling the microstructure of Ni-base superalloy turbine disks during thermo-mechanical processing, understanding the mechanisms of creep and fatigue deformation in advanced high-refractory content single crystal turbine blades.

Murat Vural, Assistant Professor. B.S., M.S., 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.

Candace E. Wark, Professor and Associate Dean of Armour College. B.S., M.S., Michigan State University; Ph.D., Illinois Institute of Technology. Fluid dynamics, turbulence, digital data acquisition and processing.

David R. Williams, Professor 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.

Jamal S. Yagoobi, Professor and Chair of Department. B.S., Sharif University of Technology (Iran); M.S., Ph.D., University of Illinois, Urbana-Champaign. Experimental and theoretical studies in enhancement of heat transfer and mass transport with electrohydrodynamics, twophase systems, phase-change processes, heat and mass transfer in porous media, drying, and augmentation of heat and mass transfer with innovative impinging jets.

Research Faculty

Joseph C. Benedyk, 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.

Dajun Chen, Assistant Research Professor, Manager of Electron Microscope Lab, B.S. Shanghai University of Technology, M.S. Shanghai Jiao Tong University, Ph.D. South Dakota School of Mines and Technology. Microstructure characterization of materials; electron microscopy; phase transformation theory and applications, fracture mechanics and failure analysis, heat treatment processes, and materials manufacturing processes.

Zhiyong Hu, 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.

John Kiedaisch, Research Assistant Professor; B.S., M.S., and Ph.D. Illinois Institute of Technology. Experimental fluid dynamics with emphasis on active control of separated flows in aircraft, helicopter, and tiltrotor applications, actuator development, wind tunnel testing and instrumentation.

Hansen Mansy, 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.

Paul Reinhard, Research Associate; B.S. Illinois Institute of Technology; current M.S. student. Control of separated flow through various active techniques in order to reduce drag or enhance operational envelopes.

Cesar A. Sciammarella, Research Professor. Dipl.Eng. C.E., Buenos Aires University (Argentina); Ph.D., Illinois Institute of Technology. Experimental mechanics of solids with particular emphasis on optics applied to mechanics of materials and stress analysis and fracture mechanics.

Federico Sciammarella, Research Assistant Professor. B.S., M.S. and Ph.D., Illinois Institute of Technology. Materials processing and laser-cladding.

Department of Mechanical, Materials and Aerospace Engineering

Admission Requirements

Cumulative minimum undergraduate GPA: 3.0/4.0

GRE score minimum:

For tests taken prior to Oct. 1, 2002: 1600

(combined)

For tests taken on or after Oct. 1, 2002: 1000

(quantitative + verbal) 3.0 (analytical writing)

Typical admitted quantitative score is 650 minimum.

TOEFL minimum: 550/213*

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 studies serves as a temporary adviser 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 adviser. 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://mmae.iit.edu>) 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. 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.

Maintaining the minimum GPA requirement does not guarantee admission to MMAE graduate degree programs. No more than nine credit hours of coursework taken as a non-degree graduate student may be completed before filing a subsequent program of study for an advanced degree.

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

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

30 credit hours

These programs are designed for working professionals, and are aimed at broadening student potential, enhancing technical versatility and, in some instances, providing the opportunity for changes in career path. The Professional Master's programs are course-only, professionally oriented degree programs and require a minimum of 30 credit hours. There is no thesis or comprehensive examination requirement. Full-time graduate students enrolled in the program should select a perma-

nent adviser prior to completing their first semester of graduate study. A graduate student working for the degree on a part-time basis should select a permanent adviser before registering for the twelfth credit hour. The student, in consultation with his or her adviser, 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

MMAE504 Engineering Analysis Ia

AND one of the following:

MMAE451 Finite Element Methods in Engineering

MMAE502 Engineering Analysis II

MMAE505 Numerical Methods in Engineering

MMAE517 Computational Fluid Dynamics

MMAE532 Advanced Finite Element Methods

MMAE538 Computational Techniques in Finite Element Methods

MMAE539 Nonlinear Finite Element Analysis

MMAE577 Lasers in Manufacturing

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.

Department of Mechanical, Materials and Aerospace Engineering

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 course selected from the following:

MMAE 467 Fundamental Principles of Polymeric Materials

MMAE 578 Fiber Composite Materials

MMAE 579 Characterization of Polymers

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

To complete the degree requirements, students may choose from a list of courses and may apply up to nine credit hours of 400-level non-core 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.

Master of Science in Mechanical and Aerospace Engineering Master of Science in Materials Science and 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 adviser, 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 adviser. Graduate students pursuing the M.S. degree on a part-time basis should select a permanent adviser before registering for their twelfth credit hour. The student, in consultation with the adviser, prepares a program of study that reflects individual needs and interests. The adviser 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 adviser 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 Ib

MMAE 502 Engineering Analysis II

AND

The required core course in the student's major area of study

AND

Six to 13 credit hours of non-core courses in the major area

AND

Elective courses if needed.

Core courses as determined by area of study

Computer Aided Design and Manufacturing:

MMAE 546 Advanced Manufacturing Engineering

Dynamics and Control:

MMAE 541 Advanced Dynamics

Fluid Dynamics:

MMAE 510 Fundamentals of Fluid Mechanics

Solids and Structures:

MMAE 530 Advanced Mechanics of Solids

Thermal Sciences:

MMAE 520 Advanced Thermodynamics

No more than two 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.

Department of Mechanical, Materials and Aerospace Engineering

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 course selected from the following:

MMAE 467 Fundamental Principles of Polymeric Materials

MMAE 578 Fiber Composite Materials

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.

Master of Engineering in Manufacturing via Internet

30 credit hours

The professional Master of Engineering in Manufacturing 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.

Courses

(Select 30 credit hours)

MMAE 433 Design of Thermal Systems (3 credit hours)

MMAE 445 CAD/CAM with Numerical Control (3 credit hours)

MMAE 474 Metals Processing (3 credit hours)

MMAE 481 Introduction to Joining Processes (3 credit hours)

MMAE 540 Robotics and Mechatronics (3 credit hours)

MMAE 545 Advanced CAD/CAM (3 credit hours)

MMAE 546 Advanced Manufacturing Engineering (3 credit hours)

MMAE 547 Computer-Integrated Manufacturing (3 credit hours)

MMAE 557 Advanced Computer-Integrated Manufacturing (3 credit hours)

MMAE 560 Statistical Quality and Process Control (3 credit hours)

hours)

MMAE 563 Advanced Mechanical Metallurgy (3 credit hours)

MMAE 589 Applications in Reliability Engineering I (3 credit hours)

MMAE 590 Applications in Reliability Engineering II (3 credit hours)

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

MMAE 715 Project Management (2 credit hours)

MMAE 720 Design Assurance (2 credit hours)

Required core courses

MMAE 545 Advanced CAD/CAM (3 credit hours)

MMAE 546 Advanced Manufacturing Engineering (3 credit hours)

MMAE 547 Computer-Integrated Manufacturing (3 credit hours)

MMAE 560 Statistical Quality and Process Control (3 credit hours)

AND

One materials course:

MMAE 563 Advanced Mechanical Metallurgy (3 credit hours)

AND

One course with emphasis on numerical methods:

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

Department of Mechanical, Materials and Aerospace Engineering

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) of courses 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.

In order to maintain the standards expected in this degree program, there are requirements that must be satisfied. Primarily, the Ph.D. candidate should meet the requirements for a master's degree or present evidence that he or she has reached an equivalent level of proficiency.

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 back-

ground 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 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 year's 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 Mechanical and Aerospace Engineering

MMAE 501 Engineering Analysis Ib
 MMAE 502 Engineering Analysis II
 MMAE 503 Advanced Engineering Analysis
 MMAE 507 Introduction to Continuum Mechanics
AND
 12 or more credit hours of coursework in major area of study
AND
 The required core course in a second area:
 Computer Aided Design and Manufacturing:
 MMAE 546 Advanced Manufacturing Engineering

Dynamics and Control:
 MMAE 541 Advanced Dynamics

Fluid Dynamics:
 MMAE 510 Fundamentals of Fluid Mechanics

Solids and Structures:
 MMAE 530 Advanced Mechanics of Solids

Thermal Sciences:
 MMAE 520 Advanced Thermodynamics

AND
 Elective courses as needed.

Course Requirements for Material Science and Engineering

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 course selected from the following:

MMAE 467 Fundamental Principles of Polymeric Materials
 MMAE 578 Fiber Composite Materials
 MMAE 579 Characterization of Polymers
 MMAE 580 Structure and Properties of Polymers
AND
 36–60 credit hours of non-core courses.

Certificate Programs

Computer Integrated Design and Manufacturing

Required courses (select four)

MMAE 445	CAD/CAM with Numerical Control (3 credit hours)
MMAE 540	Robotics and Mechatronics (3 credit hours)
MMAE 545	Advanced CAD/CAM (3 credit hours)
MMAE 547	Computer Integrated Manufacturing (3 credit hours)
MMAE 557	Advanced Computer Integrated Manufacturing (3 credit hours)

Product Quality and Reliability Assurance

Required courses

MMAE 560	Statistical Quality and Process Control (3 credit hours)
MMAE 589	Applications in Reliability Engineering I (3 credit hours)
MMAE 590	Applications in Reliability Engineering II (3 credit hours)
MMAE 720	Introduction to Design Assurance (2 credit hours)

Course Descriptions

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

MMAE 501

Engineering Analysis Ib

Matrices, Gauss-Jordan elimination, rank of a matrix, linear vector spaces and transformations, eigenvalue problems. Functions of matrices and Cayley-Hamilton theorem. Hilbert space and Fourier series. Differential eigenvalue problems. Sturm-Liouville equation. Calculus of variations, Euler-Lagrange equations. Rayleigh-Ritz and finite element approximations. Hamilton's principle. Complex variables, functions of a complex variable, analytic functions and Cauchy-Riemann equations. Multiple-valued functions and branch cuts. Integration in the complex plane. Goursat theorem. Cauchy integral theorem. Evaluation of real integrals. Conformal mapping. Laplace equation. Applications in steady-state heat conduction and incompressible fluids. Prerequisites: MMAE 350, MATH 331, MATH 333, or MATH 461. (4-0-4)

MMAE 502

Engineering Analysis II

Generalized functions. Green's functions, integral equations. Fredholm and Volterra equations, Hilbert-Schmidt theory, singular integral equations. Integral transforms: Fourier, Laplace, Hankel and Mellin transforms. Prerequisite: MMAE 501. (3-0-3)

MMAE 503

Advanced Engineering Analysis

Ordinary differential equations in the complex domain. Elementary properties. Series solutions. Riemann's P-function. Normal and subnormal solutions. Classification of ODE by singularities. Classical polynomials and special functions of ODE. Solutions by definite integrals and integral transforms. Asymptotic series. Methods of Laplace, steepest descents, and stationary phase. Stokes phenomenon. Asymptotic solutions by WKB, Langer and Olver methods. Prerequisite: MMAE 502. (3-0-3)

MMAE 504

Engineering Analysis Ia

Matrices, linear vector spaces and transformations, eigenvalue problems. System of first-order differential equations. Functions of matrices and Cayley-Hamilton theorem. Hilbert space and Fourier series. Differential eigenvalue problems. Sturm-Liouville equation. Calculus of variations, Euler-Lagrange equations, Legendre transformation. Mini-max problems. Rayleigh-Ritz and Finite element approximations. Hamilton's principle. Prerequisite: MMAE 350, MATH 331, MATH 333 or MATH 461. (3-0-3)

MMAE 505

Numerical Methods in Engineering

Introduction to numerical methods in engineering. Polynomial interpolation. Solution of scalar nonlinear equations by interactive methods. Solution of linear systems of equations by direct methods. Discussion of error estimation and convergence criteria. Finite difference techniques for initial value problems and two-point boundary value problems.

Department of Mechanical, Materials and Aerospace Engineering

Introduction to finite difference techniques for partial differential equations. Prerequisite: B.S. degree in engineering and familiarity with a computer programming language. (3-0-3.)

MMAE 506
Computational Methods in Engineering Analysis

Numerical methods applied to engineering analysis. Methods for solving nonlinear equations, numerical linear algebra, approximation of functions, numerical integration, finite difference methods. Applications to mechanics and mechanical and aerospace engineering problems. Survey and use of various software libraries including IMSL. Prerequisite: MMAE 505. (3-0-3)

MMAE 507
Introduction to Continuum Mechanics

A unified treatment of those topics that are common to solid and fluid continua. General discussion of Cartesian tensors. Deformation, strain, strain invariants, rotation, compatibility conditions. Motion, velocity, deformation. Momentum, moment of momentum, energy, stress. Principles of balance of local momenta, equations of motion. Principles of frame indifference. Constitutive relations for fluids, elastic and plastic solids. Corequisite: MMAE 501. (4-0-4)

MMAE 508
Perturbation Methods

Asymptotic series, algebraic equations, evaluation of integrals using Laplace, steepest descent and stationary phase methods. Differential equations and solutions using stretched coordinates, multiple scales and WKB methods. Matched asymptotic technique and turning points. Boundary layers, oscillators and Floquet theory. Prerequisite: MMAE 502. (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. Corequisite: MMAE 501. (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: 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: 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: 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 their consequences; moving frames, compressibility, stratification, hydromagnetics. Nonlinear theory and energy methods. Transition to turbulence. Prerequisites: MMAE 502, 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 acquisition and processing. Prerequisite: MMAE 550. (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

Department of Mechanical, Materials and Aerospace Engineering

solution of the Navier-Stokes equations in the primitive-variables and vorticity-streamfunction formulations. Grids and grid generation. Numerical modeling of turbulent flows. Prerequisites: MMAE 510 and MMAE 505 or an undergraduate course in numerical methods. (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: MMAE 321 or equivalent. (3-0-3)

MMAE 521

Statistical Thermodynamics

Nature of statistical thermodynamics, kinetic description of dilute gases. Elementary kinetic theory of transport processes. Classical statistics of independent particles. Development of quantum mechanics. Application of quantum mechanics. Quantum statistics and thermodynamic properties of ideal gases. Prerequisite: MMAE 321 or instructor's consent. (3-0-3)

MMAE 522

Air Conditioning Analysis

Heating and cooling design for energy conservation. Transient load calculations. Computer simulation. Solar heating and air conditioning methods. Two-duct systems versus one-duct systems. Advanced system analysis and design. Prerequisite: MMAE 321. (3-0-3)

MMAE 523

Fundamentals of Power Generation

Thermodynamics and design aspects of steam-turbine and gas-turbine power generation. Cycle analysis and heat-rate evaluation. Cogeneration. Advanced concepts such as MHD and wind power. Economic considerations. Prerequisite: MMAE 321 or equivalent. (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: MMAE 321, MMAE 322 or instructor's 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: MMAE 322 or instructor's consent. (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. Prerequisites: MMAE 502, MMAE 525. (3-0-3)

MMAE 527

Heat Transfer: Convection and 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: MMAE 525. (3-0-3)

MMAE528

Liquid-Vapor Phase-Change Phenomena

This course focuses on basic elements of condensation and vaporization processes. Specifically, this course covers the thermodynamic and mechanical aspects of interfacial phenomena and phase transitions, boiling and condensation near immersed bodies, and internal flow convective boiling and condensation. Prerequisite: MMAE320, MMAE310 and MMAE322. (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 nonassociated 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: MMAE 530. (3-0-3). Same as CAE 588. (3-0-3)

Department of Mechanical, Materials and Aerospace Engineering

MMAE 530**Advanced Mechanics of Solids**

Analysis of stress and strain. Stress-strain relations. Two-dimensional problems in elasticity. Axisymmetrically loaded thick-walled cylinders and rotating disks. Plates and axisymmetrical shells. Energy methods. Torsion. Beams on elastic foundations. Unsymmetric bending of straight beams. Prerequisites: MMAE 303 or MMAE 304. Corequisite: MMAE 504 or MMAE 501. (3-0-3)

MMAE 531**Theory of Elasticity**

Notions 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: MMAE 530. (4-0-4)

MMAE 532**Finite Element Methods II**

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 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: MMAE 451 or CAE 442 or MMAE 51/CAE 442. (3-0-3)

MMAE 533**Fatigue and 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: MMAE 271, MMAE 304 or MMAE 303. (3-0-3)

MMAE 534**Mechanics of Composite Materials**

Basic concepts and definitions, constituent materials, micro-mechanics, macromechanics. Elastic behavior and strength of unidirectional lamina. Elastic behavior of multidirectional laminates, lamination theory. Stress analysis and strength of multidirectional laminates, failure theories. Prerequisite: MMAE 303 or 304 (2-0-2)

MMAE 535**Design and Analysis of Brittle Structures**

Analysis algorithm based on statistical fracture theory. Introduction to both conventional and extreme value statistics, combined stress theory, load redistribution models, and specimen testing and design. Design philosophies including structural reliability theory, destructive proof testing, and prestressing and segmenting. Applications to static design, thermal shock, and fragmentation of structures such as ceramic nose cones, leading edges and machine tools. Prerequisite: MMAE 303 or MMAE 304. (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: MMAE 271, MMAE 303 or MMAE 304. (3-2-4)

MMAE 537**Finite Element Applications**

A review of FEM with respect to application types (fluid, solid and thermal). Training in the use of FEM on industrial and research problems. Introduction to several kinds of mesh generation. Discussions on the major causes of error. Consideration of modeling techniques including symmetry considerations, boundary conditions and constraint equations. Prerequisite: MMAE 451 or CAE 442. (2-0-2)

MMAE 538**Computational Techniques in Finite Element Methods**

Survey of numerical methods as applied to FEM software. Database management, equation solvers, eigenvalue routines and schemes for direct integration (both implicit/explicit), all as employed in the development of a finite element program. Topics also covered include band and front minimizer, static and dynamic substructuring via superelements, and sensitivity studies. Same as CAE 534. Prerequisite: MMAE 451 or CAE 442. (3-0-3)

MMAE 539**Nonlinear Finite Element Analysis**

FEM as applied to nonlinear problems. Contact problems, the mechanics of large deformation, full and updated Lagrange formulations, review of plasticity, solution algorithms. Eulerian approaches. Same as CAE 535. Prerequisite: MMAE 507. (3-0-3)

MMAE 540**Robotics and Mechatronics**

Classification of robots, kinematics and inverse kinematics of manipulators, differential kinematics, trajectory planning, modeling of systems, integrative actuators, sensors, controllers and interfacing. Prerequisites: MMAE 305, PHYS 300. (3-0-3)

MMAE 541**Advanced Dynamics**

Kinematics of rigid bodies. Rotating reference frames and coordinate transformations; Inertia dyadic. Newton-Euler equations of motion.

Department of Mechanical, Materials and Aerospace Engineering

Gyroscopic motion. Conservative forces and potential functions. Generalized coordinates and generalized forces. Lagrange's equations. Holonomic and non-holonomic constraints. Lagrange multipliers. Kane's equations. Elements of orbital and spacecraft dynamics. Prerequisite: MMAE 305. Corequisite: MMAE 504 or 501. (3-0-3)

MMAE 542

Advanced Mechanical Vibrations

Multidegree of freedom discrete systems, continuous systems, approximate methods, finite element method, vibration control, random vibration, and nonlinear vibration. Prerequisite: MMAE 406. (3-0-3)

MMAE 543

Analog and Digital 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. Prerequisite: MMAE 443. Corequisite: MMAE 504 or MMAE 501 (3-0-3)

MMAE 544

Optimization Techniques in Computer-Aided Design

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: MMAE 505. (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: MMAE 445 or instructor's consent. (3-0-3)

MMAE 546

Advanced Manufacturing Engineering

Analytical, experimental and computer simulation techniques for the study of manufacturing processes (forming, machining, casting, joining and assembly). Effects of variables on the quality of manufactured products. Advances in processing of engineered materials. Manufacturing cells and flexible manufacturing systems. Prerequisite: MMAE 485 or instructor's consent. (3-0-3)

MMAE 547

Computer-Integrated Manufacturing

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 548

Principles of Minimum-Weight Design

Minimum weight designs of basic structural elements are developed for different behavior criteria including stiffness, elastic and plastic strength, and stability. A number of optimization techniques are used to explore various structural concepts, such as prestressing, statistical screening and energized systems. Prerequisite: MMAE 303. Corequisite: MMAE 530. (3-0-3)

MMAE 549

Tribology

Surface topography and integrity. Sliding and rolling friction. Temperature in sliding contact. Types, mechanisms, and theories of wear. Antifriction and wear-resistant materials. Boundary, hydrodynamic and elastohydrodynamic lubrication. High pressure and wear-resistant

additives. Solid lubricants. Examples of tribology applied to engineering design. Prerequisite: Instructor's consent. (3-0-3)

MMAE 550

Experimental Methods in Mechanical Engineering

Design and implementation of computer-based measurement systems. Analog and digital signal conditioning. Text and graphic-based programming for data acquisition and control. Digital processing of deterministic and stochastic data. Digital image acquisition and processing. Modern techniques for measurements of flow, temperature, position, strain, force, etc. Hands-on experience in laboratory sessions. Prerequisite: Familiarity with Fortran or C. (3-3-4)

MMAE 551

Advanced Robotics and Mechatronics

Equations of motion of manipulators by Newton-Euler and Lagrange formulations; independent joint control, multivariable control, feedback linearization, computer interfacing, trajectory control, compliant motion control. Prerequisite: MMAE 540 or equivalent. (3-0-3)

MMAE 552

Practical Machine Design

This course includes an introduction to Precision Engineering, Synthesis of Mechanics, and Case Studies in Engineering Design. This group of topics introduces the theory and practical techniques of machine design. Methods for achieving precision and for linkage design are used in nearly all mechanical industries. The series of cases provide study of actual engineering practice, and include applications of gearing, bearings, shafts and linkage analysis with consideration of economics and patents. (3-0-3)

MMAE 557

Advanced Computer-Integrated Manufacturing

Advanced topics in computer-integrated manufacturing, including control systems, group technology, cellular manufacturing, flexible man-

Department of Mechanical, Materials and Aerospace Engineering

ufacturing systems, automated inspection, lean production, just-in-time production, and agile manufacturing systems.
Prerequisite: MMAE 547. (3-0-3)

MMAE 560
Statistical Quality and 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

Properties of liquids, undercooling, solidification of single- and polyphase alloys, zone processes, controlled and directional solidification reactions.
Prerequisite: MMAE 361. (2-0-2)

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: MMAE 361. (2-0-2)

MMAE 563
Advanced Mechanical Metallurgy
Analysis of the general state of stress and strain in solids. Analysis of elasticity, plasticity 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: MMAE 271. (3-0-3)

MMAE 564
Dislocations and 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: MMAE 271 or instructor's consent. (3-0-3)

MMAE 565
Preferred Orientations

Measurement and analysis of preferred orientations (textures). Theory and control of texture development in metal processing. Influence on the properties and commercial use of metals. Prerequisite: MMAE 271. (2-0-2)

MMAE 566
Problems in High-Temperature Materials

Temperature-dependent mechanical properties. Creep mechanisms. Basic concepts in designing high-temperature materials. Metallurgy of basic alloy systems. Surface stability. High-temperature oxidation. Hot corrosion. Coatings and protection. Elements of process metallurgy. Prerequisite: MMAE 564 or instructor's consent. (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. Prerequisites: MMAE 361 and MMAE 271. (3-0-3)

MMAE 568
Diffusion
Theory, techniques and interpretation of diffusion studies in metals. Prerequisite: MMAE 361. (2-0-2)

MMAE 569
Advanced Physical Metallurgy
Thermodynamics and kinetics of phase transformations, theory of nucleation and growth, metastability, phase diagrams. Prerequisite: MMAE 464. (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 the finite element method. It will consist of three parts: (1) Lectures on fundamental theories and models, (2) computational and numerical methods, and (3) computer laboratories. Prerequisites: MMAE 362, MMAE 451. (3-0-3)

MMAE 571
Microstructural Characterization of Materials

Advanced optical microscopy. Scanning and transmission electron microscopies. x-ray microanalysis. Surface characterization. Quantitative microscopy. Elements of applied statistics. Prerequisite: instructor's consent. (2-3-3)

MMAE 572
Gas-Metal Reactions in the Surface Treatment of Steels
Theory of solid and gas carburizing, nitriding, and carbonitriding. Generation of exothermic, endothermic and special gas atmospheres; control of atmosphere carburizing potential by dew point and infrared detectors. Prerequisite: MMAE 361. (2-0-2)

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 microcharacterization techniques for morphological, crystallographic, and elemental analysis at high spatial resolutions at 10 nanometers in metallurgical and ceramic studies will also be covered. Prerequisite: Instructor's consent. (2-3-3)

MMAE 574

Ferrous Transformations

Allotropic modifications in iron and the 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: MMAE 361. (3-0-3)

MMAE 575

Ferrous Products: Metallurgy and Manufacture

Relationships between the engineering properties of steels and the fundamental aspects of steelmaking and shaping technologies. Topics will include the behavior of high purity iron; effects of interstitial and substitutional alloying additions; metallurgical principles of strength, ductility and toughness; steelmaking and solidification; post-solidification processing; and micro-structure and crystallographic anisotropy. Prerequisite: MMAE 464. (3-0-3)

MMAE 576

Materials and 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 577

Lasers in Manufacturing

Lasers and components of laser systems. Applications of lasers in manufacturing processes, including thermal treatment, drilling, cutting, turning, milling, welding and prototyping. (3-0-3)

MMAE 579

Characterization of Polymers

Review of principles and practical applications of techniques for characterization of polymeric materials. Includes discussion of microscopy, diffraction and scattering methods, spectroscopy, thermal analysis, mechanical property measurements, trace analysis methods and rheological techniques. Prerequisite: MMAE 467 or instructor's consent. (3-0-3)

MMAE 580

Structure and Properties of Polymers

Molecular structure of amorphous, crystalline, and network polymers. Theories of the glassy state. Transition and melt temperatures. Model prediction of viscoelastic properties. Time-temperature superposition principle. Theory of rubber elasticity. Prerequisite: MMAE 467. (3-0-3)

MMAE 581

Theory of Mechanical Behavior of Polymers

Molecular theories for glass transitions and viscoelastic properties, strength of rubbery and glassy polymers. Deformation of crystalline polymers. Yield phenomena in glassy polymers. Photo-elastic properties of polymers. Prerequisite: MMAE 580. (2-0-2)

MMAE 582

Ferrous Technology

Production of ferrous materials in the steel mill, including treatment of the iron blast furnace and steel making in basic oxygen and electric-arc furnace. Processing of the materials in the plant and thermodynamic reaction considerations. Emerging processes will also be discussed. (3-0-3)

MMAE 584

Forging and Forming

Mechanical and metallurgical basis for successful production of forgings and stampings. Prerequisite: MMAE 271 or instructor's consent. (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: MMAE 589. (3-0-3)

Department of Mechanical, Materials and Aerospace Engineering

MMAE 591
Research and Thesis
for M.S. Degree**MMAE 593**
MMAE Seminar

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

MMAE 594
Project for Professional
Master Students

Design projects for the Master of Mechanical and Aerospace Engineering, Master of Materials Science and Engineering, and Master of Manufacturing Engineering degrees. (Variable credit.)

MMAE 597
Special Topics

Advanced topics in the fields of mechanics, mechanical and aerospace, materials science, and manufacturing engineering in which there is special student and staff interest. (Variable credit.)

MMAE 691
Research and Thesis
for Ph.D. Degree**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, isoparametric finite elements, numerical integration, development of finite element equations, 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. Note: This course is offered as an intersession short course. (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. Note: This course is offered as an intersession course. (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 and Nonlinear Finite
Element Analysis

This is a four-day course that 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 students to solve practical engineering problems in solid mechanics and heat transfer using ABAQUS 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. Note: This

class is offered as an intersession course. (2-0-2)

MMAE713
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 alternatives, rate of return analysis, compound interest, inflation, depreciation, and estimating economic life of an asset.

MMAE715
Project Management

This course covers the basic theory and practice of project management from a practical viewpoint. Topics include project management concepts, resources, duration vs. effort, project planning and initiation, progress tracking methods, CPM and PERT, reporting methods, re-planning, team project concepts, and managing multiple projects. Microsoft Project software will be used extensively.

MMAE720
Design Assurance

This course covers a range of analytical and procedural methods which support product and process development. Also referred to as Six Sigma, this approach ensures a more effective product by defining design requirements based on a comprehensive examination of the circumstances of the application. The methodology includes the use of such techniques as time line analysis, cause and effect analysis, failure mode analysis and Taguchi's robust design approach. Additionally, the importance of developmental testing is emphasized.

MMAE723
Discrete Event Simulation

Introduction to purposes, tools and concepts of Discrete Event Simulation with particular emphasis on simulation of production systems for the manufacturing and services sectors. Focus will be on theory and application rather than specific software packages, although one program will be used as an example. (2-0-2)