MECHANICAL, MATERIALS, AND AEROSPACE ENGINEERING

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Chair
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Faculty with Research Interests
For more information regarding faculty visit the Department of Mechanical, Materials, and Aerospace Engineering website.

Illinois Institute of Technology’s (Illinois Tech) Mechanical, Materials, and Aerospace Engineering (MMAE) Department today has an excellent group of tenured/tenure-track faculty with national and international reputations, memberships in the National Academy of Engineering (NAE), journal editorships, and fellowships/major awards from all relevant professional societies (e.g., ASME, AIAA, APS, TMS, ASM). There are currently 27 tenure/tenure-track and full-time instructional faculty in the MMAE department, in addition, there are a number of adjunct faculty who support the department’s instructional and research missions. The major research strength areas are in the areas of dynamics and control, materials, fluid dynamics, thermal sciences, and mechanics.

The Dynamics & Control group is active in the area of autonomous systems with major funding/research-activity in navigation systems, robotics, self-driving cars, transportation systems, and others. This group houses major research laboratories in robotics, navigation, space weather, and transportation (engines).

The Materials group has research interests in material synthesis, material processing, and material design. The Thermal Processing of Materials Research Center is an industrial consortium supported by several industries. Other major laboratories and research areas include energy storage (e.g., batteries), energy conversion (e.g., thermoelectrics), high temperature materials and material coatings (e.g., nickel-alloys and thermal barrier coatings), ab-initio, MD and continuum calculations for material design, crystal growth, semiconductor materials and functional materials with unique thermal, acoustic, and structural properties.

The Fluid Dynamics group undertakes experimental and computational research in the areas of turbulence, shear flows, unsteady flows, flow control, flow-structure interactions, and noise. Application areas include aerospace, transportation, turbomachinery, biomedical, urban fluid dynamics, wind turbines, and power generation. Fluid dynamics facilities include the National Diagnostic Wind Tunnel Facility (NDF), the Morkovin and the Fejer wind tunnels, and compressed air facilities.

The Thermal Sciences group has activities in gas turbine heat transfer and aerodynamics, heat exchangers and energy-exchange systems, Internal Combustion (IC) engines, and crystal growth under terrestrial and microgravity conditions. Laboratory facilities include a fully-instrumented IC Engine Lab, Gas Turbine Heat Transfer Lab, and a laboratory for crystal growth studies.

The Mechanics group is involved with computational and experimental work including material design for phononic crystals, controlling acoustic (wave propagation) in solids, new computational approaches for multi-scale solid mechanics, optimization, dynamic response of solids, constitutive models, and microstructural characterization under loading. The department houses the Dynamic Testing Laboratory with servo-hydraulic, drop tower, and high temperature testing facilities and associated diagnostics.

Additional information on the Mechanical, Materials and Aerospace Engineering (MMAE) Department can be found on its website (engineering.iit.edu/mmae).

Research Centers
Thermal Processing Technology Center

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; laboratories in experimental mechanics; laboratories for research in robotics, guidance and navigation, computer integrated manufacturing, combustion, and internal combustion engines.
Materials science and engineering laboratories include facilities for research in metallography, heat treatment, and mechanical testing; optical, scanning, and transmission electron microscopes; powder metallurgy, and laser machining facilities. The department has numerous computers and workstations available for computational research activities.

**Research Areas**

The faculty conducts research activities in fluid dynamics, including aeroacoustics, flow control, turbulent flows, unsteady and separated flows, instabilities and transition, turbulence modeling, flow visualization techniques, and 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, and 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-aided 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, 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, and robotics devices for laser machining; and dynamic analysis and control of complex systems.

**Admission Requirements**

**Minimum Cumulative Undergraduate GPA**

3.0/4.0

**Minimum GRE Scores**

300 (quantitative + verbal), 3.0 (analytical writing)

**Minimum TOEFL Scores**

80/550 (internet-based/paper-based test scores)

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

The chair for graduate programs serves as a temporary 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 website and in the MMAE main office (John T. Retalliaita Engineering Center, Suite 243) 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 Ph.D. students and M.S. students engaged in thesis research are required to register each semester for the departmental seminar MMAE 593.

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.

**Degrees Offered**

- Master of Computational Engineering, Computational Mechanics Track
- Master of Engineering Management, Product Design and Development Track
- Master of Engineering in Advanced Manufacturing
  - Additive Manufacturing Track
  - Digital Manufacturing Track
- Master of Engineering in Energy Systems, Energy Generation and Sustainability Track
- Master of Engineering in Manufacturing Engineering
- Master of Engineering in Manufacturing Engineering via Internet
• Master of Engineering in Materials Science and Engineering
• Master of Engineering in Mechanical and Aerospace Engineering
• Master of Science in Autonomous Systems and Robotics
• Master of Science in Manufacturing Engineering
• Master of Science in Materials Science and Engineering
• Master of Science in Mechanical and Aerospace Engineering
• Doctor of Philosophy in Materials Science and Engineering
• Doctor of Philosophy in Mechanical and Aerospace Engineering

Interdisciplinary Programs
• Master of Engineering in Materials Science and Engineering with Specialization in Energy/Environment/Economics (E3)
• Master of Engineering in Mechanical and Aerospace Engineering with Specialization in Energy/Environment/Economics (E3)
• Master of Science in Materials Science and Engineering with Specialization in Energy/Environment/Economics (E3)
• Master of Science in Mechanical and Aerospace Engineering with Specialization in Energy/Environment/Economics (E3)

Certificate Program
• Computer Integrated Design and Manufacturing
• Product Quality and Reliability Assurance
Course Descriptions

ENGR 502
Medical Device Regulations and Commercialization
This course helps prepare students for commercializing medical devices within a highly-regulated environment. Concepts include protecting intellectual property, the structure and scope of the Federal Drug Administration (FDA), developing, testing, producing and marketing medical devices under FDA regulations, total product lifecycle, and quality management.
Lecture: 3 Lab: 0 Credits: 3

ENGR 510
Strategic Engineering Management
This course will review technology-based enterprises and the driving forces that impact corporate strategy. Students will learn how to apply engineering knowledge to determine technology/product direction and make/buy/partnering decisions. Relationships between research and development, operations, finance, marketing, and other functions within engineering-based organizations that drive strategic decisions will be examined. Strategy development and competitive analysis will be included. Case studies from the industry relevant to the student's engineering track will be reviewed.
Lecture: 3 Lab: 0 Credits: 3

ENGR 520
Best Practices in Engineering Project Management
Many engineering projects suffer due to weak business cases, schedule slippages, and cost overruns. This course presents commonly used tools and techniques and best practices to build an effective business case, develop a realistic schedule and budget, and successfully execute and complete a project. Students are introduced to a generic project management life cycle model, review basic project management principles, tools, and techniques, and learn engineering-tailored best practices used by high performing, project-centric organizations. Students have an opportunity to apply selected tools in the form of short classroom exercises.
Lecture: 3 Lab: 0 Credits: 3

ENGR 521
Risk Management in Engineering Projects
In project management, a risk is considered an uncertain event that may have a positive or a negative impact on project objectives. Managing identified threats individually through customized strategies is key to project success. Similarly, opportunities must be leveraged for better project outcomes. Implementation of an effective risk management process is imperative for today's complex projects. This course presents a five-step process to manage project threats as well as opportunities. On every project, students will be able to identify and analyze risks and develop response strategies for each identified risk and take proper response action to manage the risks. Industry best practices and quantitative tools and simulations are used to analyze risk.
Lecture: 3 Lab: 0 Credits: 3

ENGR 529
Robotic Motion Planning
Configuration space. Path planning techniques including potential field functions, roadmaps, cell decomposition, and sampling-based algorithms. Kalman filtering. Probabilistic localization techniques using Bayesian methods. Trajectory planning.
Lecture: 3 Lab: 0 Credits: 3

ENGR 531
Urban Systems Engineering Design
ENGR 531 is a project-based course where students will explore integrated designs of urban systems. Each project will apply the students' engineering disciplines (such as structures, transportation, building science, construction engineering and management, environmental engineering) in a comprehensive analysis that considers the economic, human, and environmental issues associated with the project.
Lecture: 3 Lab: 0 Credits: 3

ENGR 532
Urban Systems Engineering Seminar
ENGR 532 is an active seminar course that emphasizes current topics in urban systems engineering. Invited speakers will include researchers and representatives from current practice, such as municipal and regional planners and consultants. Appropriate readings will be assigned in advance of each speaker to guide students in preparation for active discussion with each speaker. Each student will also write a term paper on an urban systems engineering topic of their choice, connecting material from the assigned reading, the speakers, and additional references selected by the student.
Lecture: 3 Lab: 0 Credits: 3

ENGR 534
Product Design and Innovation
This course covers all aspects of planning new products or services that are commercially viable and add to a company's suite of offerings. It includes such topics as user research, market analysis, need/problem identification, creative thinking, ideation, concepting, competitive benchmarking, human factors, prototyping, evaluation, and testing. The course includes creative, analytical, and technical skills in a balanced approach using such teaching methods as case studies, individual exercises, and group projects.
Lecture: 3 Lab: 0 Credits: 3

ENGR 539
Construction Cost Accounting and Control
Lecture: 3 Lab: 0 Credits: 3
ENGR 573
Construction Contract Administration
Lecture: 3 Lab: 0 Credits: 3

ENGR 574
Economic Decision Analysis in Civil Engineering
Basic economic concepts including interest calculations, economic comparison of alternatives, replacement decisions, depreciation and depletion, tax considerations, and sensitivity analysis. Evaluation of public projects, the effect of inflation, decision making under risk and/or uncertainty, economic decision models. Case studies from the construction industry.
Lecture: 3 Lab: 0 Credits: 3

ENGR 575
Systems Analysis in Engineering
Management and system concepts, linear programming, graphical methods, Simplex, two-phase Simplex, the transportation problem, the assignment problem, integer programming, and sensitivity analysis. System modeling by activity networks; maximal-low flow, longest-path and shortest-path analyses, flow graphs, decision-tree analysis, stochastic-network modeling, queuing systems, and analysis of inventory systems. Case studies from the construction industry.
Lecture: 3 Lab: 0 Credits: 3

ENGR 576
Nano Manufacturing
This course covers the general methods used for micro- and nano-fabrication and assembly, including photolithography techniques, physical and chemical deposition methods, masking, etching, and bulk micromachining as well as self-assembly techniques. It also covers nanotubes, nanowires, nanoparticles, and the devices that use them, including both electronic and mechanical-electronic systems, as well as nano-structural materials and composites. Focus is on commercially available current processes as well as emerging technologies and evolving research areas. Sensing and instrumentation as well as nano-positioning and actuation are covered briefly.
Lecture: 3 Lab: 0 Credits: 3

ENGR 577
Introduction to Digital Manufacturing
This course is about the digital revolution taking place in the world of manufacturing and how students, workers, managers, and business owners can benefit from the sweeping technological changes taking place. It is about the change from paper-based processes to digital-based processes all through the design/ manufacturing/deliver enterprise, and across the global supply chain. It touches on digital design, digital manufacturing engineering, digital production, digital quality assurance, and digital contracting, from large companies to small. There is also a significant focus on cyber security and the new types of threats that manufacturers face in the new digital world. Other topics covered include intelligent machines, connectivity, the digital thread, big data, and the Industrial Internet of Things (IIoT).
Lecture: 3 Lab: 0 Credits: 3

ENGR 578
Additive Manufacturing
This course examines the fundamentals of a variety of additive manufacturing processes as well as design for additive manufacturing, materials available, and properties and limitations of materials and designs. It also examines the economics of additive manufacturing as compared to traditional subtractive manufacturing and other traditional techniques. Additive techniques discussed include 3D printing, selective laser sintering, stereo lithography, multi-jet modeling, laminated object manufacturing, and others. Advantages and limitations of all current additive technologies are examined as well as criteria for process selection. Processes for metals, polymers, and ceramics are covered. Other topics include software tools and connections between design and production, direct tooling, and direct manufacturing. Current research trends are discussed.
Lecture: 3 Lab: 0 Credits: 3

ENGR 592
Engineering Management Capstone Experience
Students apply the knowledge they have acquired in the Engineering Management program to a specific problem or case study. Projects will be identified and mentored in conjunction with faculty and industrial partners. A final report or business plan is required that reflects the focus of the capstone project.
Lecture: 3 Lab: 0 Credits: 3

ENGR 595
Product Development for Entrepreneurs
Elements of product development (mechanical and electrical), manufacturing and production planning, supply chain, marketing, product research, and entrepreneurship concepts are taught in this class. In this course, student teams will be required to create a compelling product that has potential to be sold in today's marketplace. They will be required to create functional prototypes of their product for people to use and critique. If successful, students will be allowed to put their product on Kickstarter.com and take orders for delivery after the class is complete while potentially fostering their own business as a result of this course.
Lecture: 3 Lab: 0 Credits: 3
ENGR 596
**Practical Engineering Training**
This course is a mentored, immersive practical engineering training. Students learn under the direction of professional engineers and practicing engineers by working on real engineering projects. The student will perform hands-on engineering, including learning and developing/applying engineering principles and concepts to complete the project assigned to the student. The student will apply engineering ethics and safety during their practical engineering training. Students will communicate the results of their work in written and oral communications. Students will receive assignments of varying complexity consistent with their graduate standing.

*Lecture:* 0  *Lab:* 0  *Credits:* 3

ENGR 598
**Graduate Research Immersion: Team Project**
This course provides a faculty-mentored immersive team-based research experience. Research topics are determined by the faculty mentor’s area of research. In addition to the mentored research, students participate in seminars, prepare a written report of their research findings, and present their research findings at a poster expo.

*Lecture:* 3  *Lab:* 0  *Credits:* 3

ENGR 599
**Graduate Research Immersion: Individual**
This course provides a faculty-mentored immersive research experience. Research topics are determined by the faculty mentor’s area of research. In addition to the mentored research, students participate in seminars, prepare a written report of their research findings, and present their research findings at a poster expo.

*Lecture:* 3  *Lab:* 0  *Credits:* 3

MMAE 500
**Data Driven Modeling**
This graduate level course focuses on the state of the art techniques in data driven modeling. The course covers an introduction to probability theory, elements of optimization, machine learning basics, deep learning basics including an introduction to learning methodologies and algorithms, elements of modern neural network architectures, and advanced topics in data driven modeling. The emphasis will be squarely on the application of modern data driven modeling tools to advanced engineering problems related to mechanics, dynamics, and controls.

-Corequisite(s): MMAE 501

*Prerequisite(s):* MMAE 350 with min. grade of C

*Lecture:* 3  *Lab:* 0  *Credits:* 3

MMAE 501
**Engineering Analysis I**

*Lecture:* 3  *Lab:* 0  *Credits:* 3

MMAE 502
**Engineering Analysis II**

*Prerequisite(s):* MMAE 501 with min. grade of C

*Lecture:* 3  *Lab:* 0  *Credits:* 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 with min. grade of C

*Lecture:* 3  *Lab:* 0  *Credits:* 3

MMAE 508
**Perturbation Methods**

*Prerequisite(s):* MMAE 501 with min. grade of C

*Lecture:* 3  *Lab:* 0  *Credits:* 3

MMAE 509
**Introduction to Continuum Mechanics**

*Prerequisite(s):* MMAE 501 with min. grade of C

*Lecture:* 3  *Lab:* 0  *Credits:* 3
MMAE 510
Fundamentals of Fluid Mechanics
Prerequisite(s): MMAE 501* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 4 Lab: 0 Credits: 4

MMAE 511
Dynamics of Compressible Fluids
Prerequisite(s): MMAE 510 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

MMAE 512
Dynamics of Viscous Fluids
Prerequisite(s): MMAE 510 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

MMAE 513
Turbulent Flows
Prerequisite(s): MMAE 510 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

MMAE 514
Stability of Viscous Flows
Prerequisite(s): MMAE 510 with min. grade of C and MMAE 502 with min. grade of C
Lecture: 4 Lab: 0 Credits: 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.
Lecture: 3 Lab: 0 Credits: 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, freestream flows, jets, grid turbulence and boundary layers. Digital signal acquisitions and processing. Instructor's consent required.
Lecture: 2 Lab: 3 Credits: 3

MMAE 517
Computational Fluid Dynamics
Prerequisite(s): MMAE 510 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

MMAE 518
Spectral Methods in Computational Fluid Dynamics
Application of advanced numerical methods and techniques to the solution of important classes of problems in fluid mechanics. Emphasis is in methods derived from weighted-residuals approaches, like Galerkin and Galerkin-Tau methods, spectral and pseudospectral methods, and dynamical systems modeling via projections on arbitrary orthogonal function bases. Finite element and spectral element methods will be introduced briefly in the context of Galerkin methods. A subsection of the course will be devoted to numerical turbulence modeling, and to the problem of grid generation for complex geometries.
Prerequisite(s): MMAE 510 with min. grade of C and MMAE 501 with min. grade of C
Lecture: 3 Lab: 0 Credits: 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.
Lecture: 3 Lab: 0 Credits: 3
MMAE 522
Nuclear, Fossil-Fuel, and Sustainable Energy Systems
Lecture: 3 Lab: 0 Credits: 3

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

MMAE 524
Fundamentals of Combustion
Lecture: 3 Lab: 0 Credits: 3

MMAE 525
Fundamentals of Heat Transfer
Lecture: 3 Lab: 0 Credits: 3

MMAE 526
Conduction and Diffusion
Prerequisite(s): MMAE 525 with min. grade of C and MMAE 502 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

MMAE 527
Heat Transfer: Convection and Radiation
Prerequisite(s): MMAE 525 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

MMAE 529
Theory of Plasticity
Prerequisite(s): MMAE 530 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

MMAE 530
Advanced Mechanics of Solids
Prerequisite(s): MMAE 501* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3
MMAE 531

Theory of Elasticity
Prerequisite(s): MMAE 530 with min. grade of C
Lecture: 3 Lab: 0 Credits: 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 with min. grade of C or MMAE 451 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

MMAE 533

Fatigue and Fracture Mechanisms
Lecture: 3 Lab: 0 Credits: 3

MMAE 534

Product Design and Innovation
This course covers all aspects of planning new products or services that are commercially viable and add to a company’s suite of offerings. It includes such topics as user research, market analysis, need/problem identification, creative thinking, ideation, concepting, competitive benchmarking, human factors, prototyping, evaluation, and testing. The course includes creative, analytical, and technical skills in a balanced approach using such teaching methods as case studies, individual exercises, and group projects.
Lecture: 3 Lab: 0 Credits: 3

MMAE 535

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

MMAE 536

Experimental Solid Mechanics
Review of applied elasticity. Stress, strain and stress-strain relations. Basic equations and boundary value problems in plane elasticity. Methods of strain measurement and related instrumentation. Electrical resistance strain gauges, strain gauge circuits and recording instruments. Analysis of strain gauge data. Brittle coatings. Photoelasticity; photoelastic coatings; moire methods; interferometric methods. Applications of these methods in the laboratory. Prerequisite: An undergraduate course in mechanics of solids.
Lecture: 3 Lab: 0 Credits: 3

MMAE 539

Robotic Motion Planning
Configuration space. Path planning techniques including potential field functions, roadmaps, cell decomposition, and sampling-based algorithms. Kalman filtering. Probabilistic localization techniques using Bayesian methods. Trajectory planning. Homework and project will require extensive programming in Matlab or similar environment.
Lecture: 3 Lab: 0 Credits: 3

MMAE 540

Robotics
Prerequisite(s): MMAE 501* with min. grade of C and MMAE 443 with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3
MMAE 541
Advanced Dynamics
Prerequisite(s): MMAE 501* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

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

MMAE 543
Modern Control Systems
Prerequisite(s): MMAE 501* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

MMAE 544
Design Optimization
Optimization theory and practice with examples. Finite-dimensional unconstrained and constrained optimization, Kuhn-Tucker theory, linear and quadratic programming, penalty methods, direct methods, approximation techniques, duality. Formulation and computer solution of design optimization problems in structures, manufacturing and thermofluid systems. Prerequisite: An undergraduate course in numerical methods.
Lecture: 3 Lab: 0 Credits: 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. MMAE 445 (with min. grade of C)/equivalent or instructor consent as prerequisite of MMAE545.
Prerequisite(s): MMAE 445 with min. grade of C
Lecture: 3 Lab: 0 Credits: 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 processes. Prerequisite: An undergraduate course in manufacturing processes or instructor consent. Undergraduate engineering degree or concurrent enrollment in undergraduate engineering program or consent of instructor.
Lecture: 3 Lab: 0 Credits: 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. Prerequisite: Undergraduate engineering degree or concurrent enrollment in undergraduate engineering program or consent of instructor.
Lecture: 3 Lab: 0 Credits: 3

MMAE 549
Optimal Control
The course focuses on unconstrained and constrained optimal control problems for linear and non-linear deterministic systems. It uses basic optimization and principles of optimal control. The course covers introduction to convex optimization and nonlinear systems, dynamic programming, variational calculus, approaches based on Pontryagin's minimum principle, and model predictive control.
Prerequisite(s): MMAE 543 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

MMAE 550
Optimal State Estimation
Prerequisite(s): MMAE 501* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

MMAE 551
Experimental Mechatronics
Lecture: 2 Lab: 3 Credits: 3
MMAE 552
Intro to the Space Environment
Lecture: 3 Lab: 0 Credits: 3

MMAE 554
Electrical, Magnetic and Optical Properties of Materials
Lecture: 3 Lab: 0 Credits: 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 501* with min. grade of C and MMAE 443 with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

MMAE 556
Nano Manufacturing
This course covers the general methods used for micro- and nano-fabrication and assembly including photolithography techniques, physical and chemical deposition methods, masking, etching, and bulk micromachining as well as self-assembly techniques. It also covers nanotubes, nanowires, nanoparticles, and the devices that use them including both electronic and mechanical-electronic systems as well as nano-structural materials and composites. Focus is on commercially available current processes as well as emerging technologies and evolving research areas. Sensing and instrumentation as well as nano-positioning and actuation are covered briefly.
Lecture: 3 Lab: 0 Credits: 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. Prerequisite: Undergraduate engineering degree or concurrent enrollment in undergraduate engineering program or consent of instructor.
Lecture: 3 Lab: 0 Credits: 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. Prerequisite: Undergraduate engineering degree or concurrent enrollment in undergraduate engineering program or consent of instructor.
Lecture: 3 Lab: 0 Credits: 3

MMAE 561
Solidification and Crystal Growth
Lecture: 3 Lab: 0 Credits: 3

MMAE 562
Design of Modern Alloys
Phase rule, multicomponent equilibrium diagrams, determination of phase equilibria, parameters of alloy development, prediction of structure and properties. Prerequisite: A background in phase diagrams and thermodynamics.
Lecture: 3 Lab: 0 Credits: 3

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.
Lecture: 3 Lab: 0 Credits: 3
MMAE 564
Dislocations and Strengthening Mechanisms
Lecture: 3 Lab: 0 Credits: 3

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

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

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

MMAE 568
Diffusion
Theory, techniques and interpretation of diffusion studies in metals. Prerequisite: Background in crystal structures, defects, and thermodynamics.
Lecture: 2 Lab: 0 Credits: 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.
Lecture: 3 Lab: 0 Credits: 3

MMAE 570
Computational Methods in Materials Science and Engineering
Advanced theories and computational methods used to understand and predict material properties. This course will introduce energy models from classical and first-principles approaches, density functional theory, molecular dynamics, thermodynamic modeling, Monte Carlo simulations, and data mining in materials science. The course will also include case studies of computational materials research (e.g. alloy design, energy storage, nanoscale properties). The course consists of both lectures and computer labs. Background in thermodynamics is required.
Lecture: 3 Lab: 0 Credits: 3

MMAE 572
Crystallography and Crystal Defect
Geometrical crystallography: formal definitions of lattices, systems, point groups, etc. Mathematical methods of crystallographic analysis. Diffraction techniques: X-ray, electron and neutron diffraction. Crystal defects and their influence on crystal growth and crystal properties.
Lecture: 3 Lab: 0 Credits: 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.
Lecture: 3 Lab: 0 Credits: 3

MMAE 578
Fiber Composites
Lecture: 3 Lab: 0 Credits: 3

MMAE 579
Advanced Materials Processing
Processing science and fundamentals in making advanced materials, particularly nanomaterials and composites. Applications of the processing science to various processing technologies including severe plastic deformation, melt infiltration, sintering, co-precipitation, sol-gel process, aerosol synthesis, plasma spraying, vapor-liquid-solid growth, chemical vapor deposition, physical vapor deposition, atomic layer deposition, and lithography.
Lecture: 3 Lab: 0 Credits: 3
MMAE 585
Engineering Optics and 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.
Lecture: 3 Lab: 0 Credits: 3

MMAE 586
Advanced Failure Analysis
Comprehensive coverage of both the "how" and "why" of metal and ceramic failures. Intellectual tools and understanding needed to analyze failures. Analytical methods including stress analysis, fracture mechanics, fatigue analysis, creep mechanisms, corrosion science, and nondestructive testing. Numerous case studies illustrating the application of basic principles of materials science and failure analysis to a wide variety of real-world situations.
Lecture: 3 Lab: 0 Credits: 3

MMAE 587
Introduction to Digital Manufacturing
This course is about the digital revolution taking place in the world of manufacturing and how students, workers, managers, and business owners can benefit from the sweeping technological changes taking place. It is about the change from paper-based processes to digital-based processes all through the design/manufacturing/deliver enterprise and across the global supply chain. It touches on digital design, digital manufacturing engineering, digital production, digital quality assurance, and digital contracting from large companies to small. There is also a significant focus on cyber security and the new types of threats that manufacturers face in the new digital world. Other topics covered include intelligent machines, connectivity, the digital thread, big data, and the Industrial Internet of Things (IIoT).
Lecture: 3 Lab: 0 Credits: 3

MMAE 588
Additive Manufacturing
This course examines the fundamentals of a variety of additive manufacturing processes as well as design for additive manufacturing, materials available, and properties and limitations of materials and designs. It also examines the economics of additive manufacturing as compared to traditional subtractive manufacturing and other traditional techniques. Additive techniques discussed include 3D printing, selective laser sintering, stereo lithography, multi-jet modeling, laminated object manufacturing, and others. Advantages and limitations of all current additive technologies are examined as well as criteria for process selection. Processes for metals, polymers, and ceramics are covered. Other topics include software tools and connections between design and production, direct tooling, and direct manufacturing. Current research trends are discussed.
Lecture: 3 Lab: 0 Credits: 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. Prerequisite: Undergraduate engineering degree or concurrent enrollment in undergraduate engineering program or consent of instructor.
Lecture: 3 Lab: 0 Credits: 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: Undergraduate engineering degree or concurrent enrollment in undergraduate engineering program or consent of instructor.
Lecture: 3 Lab: 0 Credits: 3

MMAE 591
Research and Thesis M.S.
Credit: Variable

MMAE 593
MMAE Seminar
Reports on current research. Full-time graduate students in the department are expected to register and attend.
Lecture: 1 Lab: 0 Credits: 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 596
Semiconductors for Energy Generation
Prerequisite(s): MS 201 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

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
Lecture: 0 Lab: 1 Credits: 1

MMAE 691
Research and Thesis Ph.D.
Credit: Variable

MMAE 704
Introduction to Finite Element Analysis
This course provides a comprehensive overview of the theory and practice of the finite element method by combining lectures with selected laboratory experiences. Lectures cover the fundamentals of linear finite element analysis, with special emphasis on problems in solid mechanics and heat transfer. Topics include: 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.
Lecture: 2 Lab: 0 Credits: 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.
Lecture: 2 Lab: 0 Credits: 2

MMAE 707
High-Temperature Structural Materials
Lecture: 2 Lab: 0 Credits: 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.
Lecture: 2 Lab: 0 Credits: 2

MMAE 710
Dynamic and 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 with min. grade of C
Lecture: 2 Lab: 0 Credits: 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.
Lecture: 2 Lab: 0 Credits: 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.
Lecture: 2 Lab: 0 Credits: 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.
Lecture: 2 Lab: 0 Credits: 2