X SCHOOL OF ENGINEERING

Joseph Lestingi, Dean
Donald Moon, Associate Dean

The School of Engineering offers programs leading to master's and doctor's degrees in various areas of engineering. These graduate programs permit both departmental and interdisciplinary study to meet the specialized and continuing educational needs of the engineer. Sufficient flexibility allows the student to specialize or to pursue a broad field of study. Current graduate programs in the School of Engineering lead to the following degrees:

- Master of Science in Aerospace Engineering
- Master of Science in Chemical Engineering
- Master of Science in Civil Engineering
- Master of Science in Electrical Engineering
- Master of Science in Electro-Optics
- Master of Science in Engineering
- Master of Science in Engineering Management
- Master of Science in Engineering Mechanics
- Master of Science in Materials Engineering
- Master of Science in Mechanical Engineering
- Master of Science in Management Science

Doctor of Engineering
- Major in Aerospace Engineering
- Major in Electrical Engineering
- Major in Materials Engineering
- Major in Mechanical Engineering

Doctor of Philosophy in Engineering
- Major in Aerospace Engineering
- Major in Electrical Engineering
- Major in Materials Engineering
- Major in Mechanical Engineering

Doctor of Philosophy in Electro-Optics

Programs and the courses appropriate to each of these degrees are described later in this chapter under subject designations, which are alphabetical.

ASSISTANTSHIPS AND FELLOWSHIPS

Assistantships and fellowships are available at the University of Dayton for the encouragement of graduate work and the promotion of research. These are administered by the academic departments. Detailed information relative to application may be secured from the director of graduate engineering studies.

MASTER'S DEGREE REGULATIONS

Admission Requirements

To be considered for admission to a master's degree program in the School of Engineering, a student should have received an undergraduate degree from an accredited program in engineering, physics, chemistry, or applied mathematics, and should have earned a minimum of a 3.0 cumulative grade point average based on a 4.0 scale. Students who apply to a graduate program different from their undergraduate degree may be required to complete undergraduate courses in the new area.

Students whose grade point average is below a 3.0 will be considered for acceptance on a conditional basis, in which case particular attention will be given to their last 60 semester hours of undergraduate course work, engineering experience, and recommendations. In some cases a limited number of undergraduate courses may be required to show competence in engineering sciences and design. Those who do not have an undergraduate degree in the above areas may be required to take additional semesters of undergraduate work. All undergraduate prerequisites should be completed satisfactorily before graduate courses are taken.

The minimum mathematics requirement is three semester hours of differential equations. Computer literacy is expected. In addition there may be special department requirements.

Acceptance into a graduate program must be approved by the department chair or program director and the Associate Dean of Graduate Engineering Programs and Research.

Unclassified Status

Students anticipating acceptance into a degree granting program may register for only six semester hours of graduate course work without approval of the associate Dean of Graduate Engineering Programs and Research. There is no guarantee that any hours taken before acceptance will count toward a degree. An application for graduate study should be submitted as soon as possible to ensure that courses taken are compatible with degree requirements. Performance in graduate courses taken before acceptance to a graduate program does not change admission requirements.

Advising

Each student accepted into a master's program is assigned an academic advisor. A change of academic advisor is permissible upon request of the student. The academic advisor shall be a member of the program faculty and be approved by the department chair or program director, and the Associate Dean of Graduate Engineering Programs and Research. The academic advisor will assist the student in the preparation of a plan of study.

Plan of Study

A student must complete a minimum of 30 semester hours of graduate work. The specific courses should be itemized and approved on a plan of study form to be submitted to the Office of Graduate Engineering Programs and Research, prior to registration for the 10th graduate semester hour (excluding transfer credits), or before registration for the third semester. It is the student's responsibility to obtain approval from the academic advisor for any changes in the plan of study and to submit to the academic advisor all deletions and additions in written form before the fourth week of the student's final semester. The plan of study and any amendments must be approved by the student's academic advisor, the department chair or program director, and the Associate Dean of Graduate Engineering Programs and Research.

Transfer of Credit

Up to 6 semester hours, or the equivalent, of graduate studies outside the University of Dayton may be accepted toward the master's degree. The transfer credit must be of B or higher grade level, cannot have been used to satisfy the requirements of an undergraduate degree, and must be verified by an official transcript from the granting institution. It is the responsibility of the student to have the transcript(s) sent to the Office of Graduate Applications & Records.

Thesis

Each student whose plan of study requires a thesis must prepare it in accordance with the format outlined in A Manual for the Preparation of Graduate Thesis and Dissertation, copies of which are available in the Office of Graduate Applications & Records, and in the Office of Graduate Engineering Programs and Research. The thesis must be based on the student's own work. Joint authorship is not permitted. The thesis advisor's responsibilities are supervising and approving the work, and assisting in forming the thesis committee and scheduling a defense. The thesis advisor may or may not be the academic advisor. The thesis defense may be either oral or written or both. The thesis must be presented to and approved by a committee of at least three members, at least one of whom is on the graduate faculty. The committee must receive the thesis at least one week prior to an oral defense. No student shall be allowed to defend the thesis more than twice.

A pass/failed grade will be assigned to the quality of the work. A final approved copy of the thesis is due in the Office of Graduate Engineering Programs and Research no later than one week before graduation.

Academic Standards

Master's degree students are required to maintain and graduate with a minimum cumulative grade point average of a B (3.0) in course work, with no more than six semester hours of C. Grades received from a thesis are passed/failed, and do not count toward the minimum grade point average of 3.0. Students who fail to meet these standards are placed on academic probation or dismissed from the program.

Time Limit

All requirements for a master's degree must be satisfied within seven calendar years from the time of matriculation.

ACCELERATED MASTER'S PROGRAM

University of Dayton students who have demonstrated above-average scholastic achievement during their first three years of undergraduate work are eligible to participate in an accelerated program leading to a master's degree. The student may take graduate courses that satisfy master's degree requirements while finishing the bachelor's degree. All other School of Engineering and department/program requirements apply to the accelerated master's program. Undergraduate students who are interested in this program should contact their department chair.

ADDITIONAL REQUIREMENTS

Any other specific requirements and sequences leading to these degrees are described in the following sections or in departmental and program documents.

DOCTORAL DEGREES

The School of Engineering offers programs leading to the Doctor of Philosophy (Ph.D.) in Engineering and in Electro-Optics, and Doctor of Engineering (D.E.). The programs leading to the Ph.D. in Engineering and D.E. degrees encompass major fields of study in Aerospace Engineering, Electrical Engineering, Materials Engineering, and Mechanical Engineering.

DOCTOR OF PHILOSOPHY (Ph.D.)

The Ph.D. is granted in recognition of superior achievement in independent research and course work. The research must demonstrate that the student possesses capacity for original thought, talent for research, and ability to organize and present findings.

The minimum credit hours required for the Ph.D. degree are 60 semester hours beyond the master's degree. This includes a minimum of 30 semester hours for the Ph.D. dissertation and a minimum of 30 semester hours of course work. A Ph.D.-seeking student is required to complete a minimum of 12 semester hours in advanced mathematics.

The Ph.D. dissertation must either add to the fundamental knowledge of the field or provide a new and better interpretation of facts already known. It is expected to result in one or more manuscripts suitable for publication in a refereed journal.

DOCTOR OF ENGINEERING (D.E.)

The D.E. is granted in recognition of superior achievement in course work and an independent project. The project will usually be broad in scope, involve more than one discipline or subdiscipline, and be closely tied to an industrial-like application.

The minimum credit hours required for the D.E. degree is 60 semester hours beyond the master's degree. This includes a minimum of 21 semester hours credit for the D.E. dissertation and a minimum of 39 semester hours of course work. A D.E.-seeking student is required to complete a minimum of 21 semester hours in the major (covering the domains of at least two subdisciplines), 9 semester hours in advanced mathematics and 9 semester hours in a synergistic area of engineering or science.

The D.E. dissertation must address an integrated industrial-like project. It is expected to result in a manuscript suitable for publication in an applied engineering journal and/or to documentation leading to a patent.

Admission Requirements

Normally, a student must earn a master's degree in the same or related area before being admitted to the doctoral program. Only the most promising students with a graduate GPA of 3.2/4.0 or above and good academic references may be admitted. Additional admission requirements may be stipulated by the individual graduate program. Admission means only that the student will be permitted to pursue a doctoral plan of study. The student's admission to doctoral study does not imply that the student will be admitted to candidacy or will be able to achieve the doctoral degree.

Temporary Advisor

Immediately upon admission into the doctoral program, a student shall be assigned a temporary advisor. This temporary advisor will assist the student in the initial selection of courses for the first semester of enrollment.

Doctoral Advisory Committee

Before the end of the first enrolled semester, the student, in consultation with the department chair or program director, selects a major professor to serve as the chair of the doctoral advisory committee. The chair of the doctoral advisory committee will be a member of the graduate faculty. An advisory committee, consisting of the chair and at least two other graduate faculty members from the programs of the School of Engineering, will then be recommended for approval to the department chair or program director and to the associate dean of graduate engineering programs and research. Appointment of additional members of the committee from outside the student's program (i.e., other university faculty, adjunct professors, prominent researchers in industry or government) is encouraged. One additional graduate faculty member may be appointed by the Associate Dean of Graduate Engineering Programs and Research. The composition of the committee will generally reflect the student's area of study and research interest. The duties of the doctoral advisory committee shall include advising the student, assisting the student in preparing the program of study, administering and reporting the candidacy examination, assisting in planning and conducting research, approving the dissertation, and conducting and reporting the results of the dissertation defense. A dissertation advisor other than the chair of the doctoral advisory committee may be appointed by the doctoral advisory committee.

Plan of Study

The plan of study shall include all the specific courses beyond the master's degree that the student is required to complete. The plan shall indicate the time and manner in which these requirements are to be met. It is to be completed and approved by the doctoral advisory committee, the department chair or program director, and the Associate Dean of Graduate Engineering Programs and Research, before the end of the second semester of the student's enrollment.

Residency Requirement

After admittance to a doctoral program, the student must complete the residency requirements to be considered for the candidacy examination. This requirement must be met by completing 21 semester hours of graduate course work in four or fewer consecutive semesters which may or may not include the Summer.

Candidacy Examination

The candidacy examination for the doctoral degree is generally taken when most of the course work, as outlined on the approved plan of study, has been completed. Its purpose is to determine the student's eligibility to become a candidate for the doctoral degree. It will include two parts: (1) a written and an oral examination covering the domain of course work; and (2) an oral examination on the dissertation proposal. Part 2 must be completed within six months of the completion of part 1. At the discretion of the doctoral advisory committee, part 2 examination can be taken simultaneously with the oral portion of the part 1 examination.

The proposal outlining in detail the proposed area of dissertation research should clearly show the review of the literature in the area, the need for and the uniqueness of the research, the general approach, expected results, the laboratories and/or other facilities needed, and a schedule of work. No more than 6 semester hours of dissertation can be taken prior to successful presentation of the dissertation proposal. The student must make a copy of this proposal available to each doctoral advisory committee member at least one week prior to the part 2 examination.

The student must pass all parts of the examination to be admitted to candidacy. The student is considered to have passed only when the decision of the doctoral advisory committee is unanimous. All members must sign the examination report form with an indication of their decision noted prior to its being submitted to the Associate Dean of Graduate Engineering Programs and Research. If any part of the examination is unsatisfactory, the student will be notified in writing of the conditions for another examination. No student will be permitted to take any part of the examination more than twice. A second examination may not be given earlier than four months after the submission of the examination report.

A student must pass the candidacy examination at least six months prior to the dissertation defense.

Dissertation

A single author dissertation is required of each doctoral candidate who has passed the candidacy examination. The dissertation topic will be selected by the student in consultation with the advisor and the doctoral advisory committee. The dissertation topic must be approved by the doctoral advisory committee. The dissertation must be prepared in accordance with the instructions outlined in A Manual for the Preparation of Graduate Theses and Dissertations, copies of which are available in the office of Graduate Engineering Programs & Research or the office of Graduate Applications & Records. A manuscript prepared for an appropriate journal and an acknowledgment of receipt by the editor must also be submitted along with the dissertation.

The student must obtain approval from the doctoral advisory committee to undertake all or part of the dissertation in absentia. A letter requesting such permission, signed by the chair of the doctoral advisory committee, must be submitted to the Associate Dean of Graduate Engineering Programs and Research. This letter should outline in detail the relationship between the advisor and the candidate and the name and background of the person who will directly advise the candidate during the accomplishment of this independent research. This person will be added to the advisory committee.

The dissertation, three copies of the dissertation in final form, the journal manuscript and acknowledgment of receipt by the editor, and an abstract not to exceed 350 words must be submitted to the office of Graduate Engineering Programs & Research at least three weeks before the graduation date of the semester in which the degree is sought. These copies must bear the written approval of the advisor. The original copy of the dissertation shall be filed in the Roesch Library.

All doctoral dissertations are microfilmed by University Microfilms, Inc., Ann Arbor, Michigan. The candidate must sign an agreement with University Microfilms, Inc., which authorizes this firm to sell copies of the dissertation. Microfilmed dissertations may be copyrighted by the candidate. A fee will be assessed for the cost of copyrights.

Dissertation Defense

No earlier than six months after the successful candidacy examination, the candidate shall defend the doctoral dissertation in a public forum to demonstrate to the committee that all the preparation for which the doctoral degree is awarded has been met. The defense is open to all members of the University of Dayton faculty, student body, and interested outside parties. The members of the doctoral advisory committee, with the advisor acting as chair, will conduct this dissertation defense.

Before the announcement of this defense, the doctoral advisory committee must agree that the dissertation is ready for public defense. At least two weeks prior to the date of the defense, the candidate must provide the committee with copies of the nearly final dissertation and must ask the Associate Dean of Graduate Engineering Programs and Research to schedule the defense. For the defense to be satisfactory, the advisory committee members must agree that the dissertation defense has been successfully completed. If the candidate's defense is deemed unsatisfactory by only one member, the case will be referred to the Associate Dean of the Graduate Engineering Program and Research for appropriate action.

Additional Requirements

The student must satisfactorily complete the courses listed in the doctoral plan of study with a 3.0/4.0 or better cumulative GPA. One grade of "F" or more than one grade of "C" grade may be grounds for dismissal from the program pending recommendation of the doctoral advisory committee. Grades received from a dissertation are passed/failed, and do not count towards the GPA.

Two thirds of the semester hours required beyond the Master's degree should be earned at the University of Dayton. Generally, this is 48 semester hours beyond the Master's degree.

Candidates must be registered for a minimum of two semester hours every semester during their candidacy including the semester in which the dissertation is defended. Students are expected to complete the dissertation requirements for the doctoral degree within five years after the candidacy examination has been passed.

Any other specific requirements and sequences leading to these degrees are described in the following sections or in departmental and program documents.

AEROSPACE ENGINEERING (AEE)

Glen E. Johnson,
Chair of the Department

Aerospace Engineering is a major concentration for both the Doctor of Philosophy in Engineering and the Doctor of Engineering. See Doctor's Degree Regulations in the introductory section of this chapter and consult with the department chair.

PROGRAM REQUIREMENTS

The program of study leading to the Master of Science in Aerospace Engineering must include a minimum of 30 semester hours of credit consisting of the following:

1. Twelve semester hours in the major area. Major areas of study include Aerodynamics, Aircraft Propulsion, Aircraft Structures, and Flight Vehicle Dynamics.
2. Twelve semester hours of core electives. Core electives will be selected from current course offerings which best satisfy the student's requirements and meet with the advisor's approval. At least one mathematics course is strongly recommended.
3. Six semester hours of research leading to a master's thesis. Research may be replaced by 6 semester hours of additional course work with the approval of the advisor and the department chair.

See also Master's Degree Regulations in the introductory section of this chapter and consult with the advisor.

COURSES OF INSTRUCTION

AEE 500. INTRODUCTION TO NUMERICAL METHODS: Numerical analysis topics include the solution of systems of linear and nonlinear algebraic equations; matrix eigenvalue problems; ordinary differential equations; optimization techniques; numerical integration and interpolation. Engineering applications presented. Computer programming required. *3 sem. hrs.*

AEE 501. ADVANCED AERODYNAMICS I: Fundamentals of aerodynamics including viscosity and compressibility phenomena for subsonic, supersonic, and transonic flow. Emphasis on force and moment determination for bodies, including theory of lift. *3 sem. hrs.*

AEE 502. ADVANCED AERODYNAMICS II: Advanced analytical development of compressible aerodynamics as applied to lifting surfaces and slender bodies. Approximations to lifting surface theory and numerical solution. Introduction to unsteady aerodynamics. Prerequisite: AEE 501. *3 sem. hrs.*

AEE 503. INTRODUCTION TO CONTINUUM MECHANICS: Tensors, calculus of variations, Lagrangian and Eulerian descriptions of motion. General equations of continuum mechanics, constitutive equations of mechanics, thermodynamics of continua. Specialization to cases of solid and fluid mechanics. Prerequisite: EGM 303. *3 sem. hrs.*

AEE 504. FUNDAMENTALS OF FLUID MECHANICS: An advanced course in fluid mechanics with emphasis on the derivation of conservation equations and the application of constitutive theory. Navier-Stokes equations. Ideal fluid approximation. Exact and approximate solutions to classical viscous and inviscid problems. Compressible and incompressible flows. Co-requisite: MEE/AEE 503. *3 sem. hrs.*

AEE 506. MECHANICAL BEHAVIOR OF MATERIALS: Description of the state of stress and strain in materials, plastic deformation, fatigue, fracture, creep, and rupture. Prerequisite: EGM 303 or consent of instructor. *3 sem. hrs.*

AEE 507. ORBITAL DYNAMICS: Solution of the two-body problem; coordinate systems; time measurement; orbital elements. Basic orbital maneuvers; transfers; rendezvous; groundtracks. Methods of orbit determination. Restricted three-body problem and introduction to artificial satellite theory. Prerequisites: MTH 219 and EGM 202 or equivalent. *3 sem. hrs.*

AEE 508. AIRCRAFT PERFORMANCE AND CONTROL: Elementary development of aircraft equations of motion; performance in level flight; climbing and descending performance; turning performance; takeoff and landing performance; static stability and control in all three axes. Prerequisite: AEE 501. *3 sem. hrs.*

AEE 510. INTRODUCTION TO THE FINITE ELEMENT METHOD: Introductory development of the Finite Element Method (FEM), and solution of one- and two-dimensional field problems from fluid, solid, and thermal mechanics. Principles of virtual work and Hamilton; approximate methods; description of stiffness, nodal force, and mass matrices; matrix assembly procedures. Course emphasis on a broad understanding of FEM theory and applications. Not open to structures majors. Prerequisite: EGM 303. *3 sem. hrs.*

AEE 513. PROPULSION: Principles of propulsive devices, aerothermodynamics diffuser and nozzle flow, energy transfer in turbo-machinery, turbojet, turbo-fan, prop-fan engines, turbo-prop and turboshaft engines. RAM and SCRAM jet analysis and a brief introduction to related materials and air frame-propulsion interaction. Prerequisite: MEE 418. *3 sem. hrs.*

AEE 515. CONDUCTION HEAT TRANSFER: Steady state and transient state conduction. Evaluation of temperature fields by formal mathematics, numerical analysis. Emphasis on approximate solution techniques. *3 sem. hrs.*

AEE 516. CONVECTION HEAT AND MASS TRANSFER: Development of governing differential equations for convection. Methods of solution including similarity methods, integral methods, superposition of solutions, eigenvalue problems.

Turbulent flow convection; integral methods, eddy diffusivities for heat and momentum. Extensions to mass transfer. Prerequisite: MEE 410. *3 sem. hrs.*

AEE 517. RADIATION HEAT TRANSFER: Fundamental relationships of radiation heat transfer. Radiation characteristics of surfaces. Geometric considerations in radiation exchange between surfaces. Emissivity and absorptivity of gases. Introduction to radiative exchange in gases. *3 sem. hrs.*

AEE 519. ANALYTICAL DYNAMICS: Dynamical analysis of a system of particles and of rigid bodies. Lagrangian and Hamiltonian formulation of equations of motion; classical integrals of motion. Stability analysis of linear and nonlinear systems. Prerequisites: MTH 219 and EGM 202 or equivalent. *3 sem. hrs.*

AEE 521. FLIGHT VEHICLE DYNAMICS: Dynamics of flight vehicles that emphasize the fundamental theory of flight and its application to aerospace systems. Static and dynamic stability including the characteristic longitudinal and lateral perturbation motions about the equilibrium state. Prerequisite: AEE 501. *3 sem. hrs.*

AEE 527. AUTOMATIC CONTROL THEORY: Stability and performance of automatic control systems. Classical methods of analysis including transfer functions, time-domain solutions, root locus and frequency response methods. Modern control theory techniques including state variable analysis, transformation to companion forms, controllability, pole placement, observability and observer systems. Prerequisite: ELE 432 or MEE 435 or equivalent. *3 sem. hrs.*

AEE 528. OPTIMAL FLIGHT TRAJECTORIES: Relative and global optimization of single and multiple variables; constrained optimization; steady state methods; energy state approximation; variational methods; numerical techniques; aerospace applications. Prerequisite: AEE 508. *3 sem. hrs.*

AEE 532. ACOUSTICS: Physics of sound propagation, psychological effects of noise, noise control criteria and regulations, transmission phenomena, acoustics of walls and enclosures, resonators and filters, acoustic properties of materials, acoustic consideration in structural and machine design. *3 sem. hrs.*

AEE 535. MECHANICAL VIBRATIONS: Review of undamped, damped, natural and forced vibrations of one and two degrees of freedom systems. Lagrange's equation, eigenvalue/eigenvector problem, modal analysis for discrete and continuous systems. Computer application for multi-degree of freedom, nonlinear problems. Prerequisites: Computer Programming and MEE 319. *3 sem. hrs.*

AEE 536. RANDOM VIBRATIONS: Introduction to probability distribution; characterization of random vibrations; harmonic analysis; auto- and cross-correlation and spectral density; coherence; response to single and multiple loadings; Fast Fourier Transform (FFT); applications in vibrations, vehicle dynamics, fatigue, etc. Prerequisites: Computer Programming and MEE 319. *3 sem. hrs.*

AEE 538. INTRODUCTION TO AEROELASTICITY: The study of the effect of aerodynamic forces on a flexible aircraft. Flexibility coefficients and natural modes of vibration. Quasi-steady aerodynamics. Static aeroelastic problems; wing divergence and dynamic aeroelasticity; wing flutter. An introduction to structural stability augmentation with controls. Prerequisite: AEE 501. *3 sem. hrs.*

AEE 541. EXPERIMENTAL MECHANICS OF COMPOSITE MATERIALS: Introduction to the mechanical response of fiber-reinforced composite materials with emphasis on the development of experimental methodology. Analytical topics include stress-strain behavior of anisotropic materials, laminate mechanics, and strength analysis. Theoretical models are applied to the analysis of experimental techniques used for characterizing composite materials. Lectures are supplemented by laboratory sessions in which characterization tests are performed on contemporary composites. Prerequisite: EGM 303. *3 sem. hrs.*

AEE 543. ANALYTICAL MECHANICS OF COMPOSITE MATERIALS: Analytical models are developed for predicting the mechanical and thermal behavior of fiber-reinforced composite materials as a function of constituent material properties. Both continuous and discontinuous fiber-reinforced systems are considered. Specific topics include basic mechanics of anisotropic materials, micromechanics, lamination theory, free-edge effects, and failure criteria. Prerequisite: EGM 303. *3 sem. hrs.*

AEE 544. MECHANICS OF COMPOSITE STRUCTURES: Comprehensive treatment of laminated beams, plates, and sandwich structures. Effect of heterogeneity and anisotropy on bending under lateral loads, buckling, and free vibration are emphasized. Shear deformation and other higher order theories and their range of parametric application are also considered. Prerequisite: MAT 543 or consent of instructor. *3 sem. hrs.*

AEE 545. COMPUTATIONAL METHODS FOR DESIGN: Modeling of mechanical systems and structures, analysis by analytical and numerical methods, development of mechanical design criteria and principles of optimum design, selected topics in mechanical design and analysis, use of the digital computer as an aid in the design of mechanical elements. Prerequisite: Computer Programming. *3 sem. hrs.*

AEE 546. FINITE ELEMENT ANALYSIS I: Fundamental development of the Finite Element Methods (FEM), and solution to field problems and comprehensive structural problems. Variational principles and weak-forms; finite element discretization; shape functions; finite elements for field problems; bar, beam, plate, and shell elements; isoparametric finite elements, stiffness, nodal force, and mass matrices; matrix assembly procedures;

computer coding techniques; modeling decisions; program output interpretation. Course emphasis on a thorough understanding of FEM theory and modeling techniques. Prerequisites: EGM 503 or EGM 533. *3 sem. hrs.*

AEE 547. FINITE ELEMENT ANALYSIS II: Advanced topics: heat transfer; transient dynamics; nonlinear analysis; substructuring and static condensation; effects of inexact numerical integration and element incompatibility; patch test; frontal solution techniques; selected topics from the recent literature. Prerequisite: AEE 546. *3 sem. hrs.*

AEE 551. VISCOUS FLOW; Fundamentals of fluid mechanics with emphasis on the derivation of conservation equations and the application of constitutive theory. Navier-Stokes equations. Exact and approximate solutions to classical viscous flow problems. Introduction to boundary layers. Prerequisite: AEE 503. *3 sem. hrs.*

AEE 552. BOUNDARY LAYERS; Development of the Prandtl boundary layer approximation in two and three dimensions for both compressible and incompressible flow. Exact and approximate solutions for laminar flows. Unsteady boundary layers. Linear stability theory and transition to turbulence. Empirical and semi-empirical methods for turbulent boundary layers. Higher order boundary layer theory. Prerequisite: AEE 504 or equivalent. *3 sem. hrs.*

AEE 553. COMPRESSIBLE FLOW: Fundamental equations of compressible flow. Introduction to flow in two and three dimensions. Two-dimensional supersonic flow, small perturbation theory, method of characteristics, oblique shock theory. Introduction to unsteady one-dimensional motion and shock tube theory. Method of surface singularities. Prerequisite: AEE 504 or equivalent. *3 sem. hrs.*

AEE 554. TRANSONIC AERODYNAMICS: Inviscid theory related to planar flows, axisymmetric flow and shock free solutions. Viscous consideration for compressible boundary layers and flow separation and reattachment. Numerical methods of relaxation time dependent, gradient dependent and integral solutions. Consideration, limitation and correlation of wind tunnel and flight testing. Design of supercritical wings. Prerequisite: AEE 504. *3 sem. hrs.*

AEE 555. TURBULENCE: Origin, evolution, and dynamics of fully turbulent flows. Description of statistical theory, spectral dynamics, and the energy cascade. Characteristics of wall-bounded and free turbulent shear flows. Reynolds stress models. Prerequisite: AEE 504 or equivalent. *3 sem. hrs.*

AEE 556. HYPERSONIC AERODYNAMICS: Hypersonic prediction techniques, similarity rules, Newtonian impact theory, high-temperature equilibrium properties of gases; wake characteristics; heat transfer, chemical kinetics and reacting gas flows, simulation and testing techniques. Prerequisite: AEE 504. *3 sem. hrs.*

AEE 558. COMPUTATIONAL AERODYNAMICS: Numerical solution to Navier-Stokes equations and approximations such as the boundary layer equations for air-flow about a slender body. Numerical techniques for the solution of the transonic small disturbance equations. Numerical determination of fluid instabilities. Prerequisite: AEE 551 or consent of instructor. *3 sem. hrs.*

AEE 565. FUNDAMENTALS OF COMBUSTION: Heat of combustion and flame temperature calculations; rate of chemical reaction and Arrhenius relationship; theory of thermal explosions and concept of ignition delay and critical mass; phenomena associated with hydrocarbon-air combustion; specific applications of combustion. *3 sem. hrs.*

AEE 566. COMBUSTION THEORY: Theory of detonation (Rankine-Hugoniot relationships) and flame propagation rates in pre-mixed gas systems; turbulent flames and the well-stirred reactor; theory of diffusion flames; fuel droplet combustion; steady burning of solid materials; ignition and flame spreading across solid materials. *3 sem. hrs.*

AEE 570. FRACTURE MECHANICS: Application of principles of fracture mechanics to fatigue and fracture in engineering structures. Prerequisite: AEE 506 or consent of instructor. *3 sem hrs.*

AEE 580. AEROSPACE ENGINEERING PROJECT: Student participation in an aerospace research, design, or development project under the direction of a project advisor. The student must show satisfactory progress as determined by the project advisor and must present a written report at the conclusion of the project. *3-6 sem. hrs.*

AEE 590. SELECTED READINGS IN AEROSPACE ENGINEERING: Directed readings in the designated area to be arranged and approved by the student's advisor and the program director. May be repeated. *1-3 sem. hrs.*

AEE 595. SPECIAL PROBLEMS IN AEROSPACE ENGINEERING: Special assignments in aerospace engineering subject matter to be approved by the student's faculty advisor and the program director. *1-6 sem. hrs.*

AEE 599. THESIS *3-6 sem. hrs.*

AEE 622. ADVANCED VEHICLE DYNAMICS: Advanced topics in vehicle dynamics including the coupling of the elastic degrees of freedom with the rigid body motions. Response to controls, flight in a turbulent atmosphere, human pilots and handling qualities as well as inverse problems. *3 sem. hrs.*

AEE 624. OPTIMAL CONTROL: Review of observability, controllability, and modern linear feedback control. Variational methods for the minimization of functions and functionals. Optimal linear feedback control; regulator, tracking and minimum time problems. Perturbation control and numerical methods for optimal paths. Prerequisite: AEE 527 or equivalent. *3 sem. hrs.*

AEE 628. AIRCRAFT FLIGHT CONTROL: Autopilots, stability augmentation, and flight control system analysis and design. Digital control theory and techniques. Prerequisites: AEE 521 and 527. *3 sem. hrs.*

AEE 690. SELECTED READINGS IN AEROSPACE ENGINEERING: Directed readings in aerospace engineering to be arranged and approved by the student's advisory committee and the program director. May be repeated. *1-3 sem. hrs.*

AEE 695. SPECIAL PROBLEMS IN AEROSPACE ENGINEERING: Special assignments in aerospace engineering. Subject matter to be arranged and approved by the student's advisory committee and the program director. May be repeated. *1-3 sem. hrs.*

AEE 698. D.E. DISSERTATION: An original investigation as applied to aerospace engineering practice. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*

AEE 699. Ph.D. DISSERTATION: Research in aerospace engineering. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*

Department of

CHEMICAL ENGINEERING (CME)

Tony E. Saliba,
Chair of the Department

MASTER'S PROGRAM REQUIREMENTS

The program of study leading to the Master of Science in Chemical Engineering must include a minimum of 30 semester hours of credit consisting of the following:

1. Fifteen semester hours of Chemical Engineering graduate courses, including CME 505 or 507, 521 or 522, 542 or 543, and 581 or 582.
2. Nine semester hours of electives as approved by the advisor and the department chair.
3. Six semester hours on an approved thesis project; a final examination is required at the completion of the thesis. Upon the request of the student and with the approval of the faculty advisor and chair of the department, six hours of additional course work plus three hours of special problem work may be substituted for the thesis.

A final examination is required at the completion of the thesis or course work. See also Master's Degree Regulations in the introductory section of this chapter and consult with the advisor.

The program of study allows concentrations in:

Combustion
Environmental Engineering
Materials Engineering
Process Modeling and Control

COURSES OF INSTRUCTION

CME 505. THERMODYNAMICS OF SOLIDS: Laws of thermodynamics, auxiliary functions, thermodynamic relations, phase transitions, thermodynamic equilibrium, thermodynamic properties of solid solutions, surfaces and interfaces. Prerequisite: MAT 501 or consent of instructor. *3 sem. hrs.*

CME 507. ADVANCED THERMODYNAMICS: Entropy balance. Thermodymanics of energy conversion. Mixtures. Equilibria. Current applications. *3 sem. hrs.*

CME 508. ADVANCED TOPICS IN CHEMICAL ENGINEERING: Study and discussion of current problems in chemical engineering research. Prerequisites: CME 521, 581, or consent of instructor. *3 sem. hrs.*

CME 509. INTRODUCTION TO POLYMER SCIENCE: Introduction to polymers. An overview of the field, including the nature of polymers, polymer production, characterization, and processing. Prerequisites: College chemistry and calculus. *3 sem. hrs.*

CME 510. PHYSICAL PROPERTIES OF POLYMERS: Intensive discussion of the interrelations between molecular and gross physical properties of polymers. Prerequisites: Background in differential equations, organic or physical chemistry, or CME 509. *3 sem. hrs.*

CME 511. PRINCIPLES OF CORROSION: Application of electrochemical principles, corrosion reactions, passivation, cathodic and anodic protection, stress corrosion, and high-temperature oxidation. Prerequisite: MAT 501. *3 sem. hrs.*

CME 515. STATISTICAL THERMODYNAMICS: Microscopic thermodynamics; Boltzmann, Bose-Einstein, Fermi-Dirac statistics; statistical interpretation of thermodynamic quantities. Applications to perfect and real gases, liquids, crystalline solids, and thermal radiation. Prerequisites: CME 305, MTH 219. *3 sem. hrs.*

CME 521. ADVANCED TRANSPORT PHENOMENA: Applications of the principles of momentum, heat and mass transfer to steady state and transient problems. Molecular concepts. Transport in turbulent flow. Boundary layer theory. Numerical applications. Prerequisites: CME 324 and 381 or equivalent. *3 sem. hrs.*

CME 522. ADVANCED TOPICS IN TRANSPORT PHENOMENA: The equations of change for multicomponent systems. Turbulent mass transport. Interphase transport in multicomponent systems. Combustion analysis. Macroscopic balances. Prerequisites: CME 325 and 581 or equivalent. *3 sem. hrs.*

CME 541. PROCESS DYNAMICS: Mathematical modeling and computer simulation of process dynamics and control for chemical engineering processes. *3 sem. hrs.*

CME 542. CHEMICAL ENGINEERING KINETICS: Reaction kinetics. Heterogeneous catalytic reactions. Transport processes with fluid-solid heterogeneous reactions. Noncatalytic gas-solid reactions. Catalyst deactivation. Gas-liquid reactions. Prerequisites: CME 406 and 381 or equivalent. *3 sem. hrs.*

CME 543. CHEMICAL REACTOR ANALYSIS AND DESIGN: Design for optimum selectivity. Stability and transient behavior of the mixed flow reactor. Nonideal flow and balance models. Fixed and fluidized bed reactors. Multiphase flow reactors. Prerequisites: CME 406 and 381 or equivalent. *3 sem. hrs.*

CME 550. AGITATION: Agitator design and scaleup for blending and motion, solids suspension, gas dispersion, and viscous operations; experimental, computational, and design tools of agitation; static mixing; and mixing with chemical reaction. Prerequisite: CME 412 or consent of instructor. *3 sem. hrs.*

CME 562. PHYSICAL AND CHEMICAL WASTEWATER TREATMENT PROCESSES: The design of physical and chemical unit processes to treat wastewater originating primarily from domestic and industrial sources. Industry pretreatment technologies and the basis for their development. Prerequisites: CHM 123 and CME 411 or consent of instructor. *3 sem. hrs.*

CME 563. HAZARDOUS WASTE ENGINEERING: Fundamental principles in the design and operation of hazardous waste remediation processes. Characterizing contaminated sites and conducting treatability studies for the selection of the most appropriate remediation strategy. Prerequisites: CHM 123 and CME 411 or consent of instructor. *3 sem. hrs.*

CME 564. SOLID WASTE ENGINEERING: Characterizing solid waste. Managing solid waste collection, transport, minimization, and recycling. Prerequisites: CHM 123 and CME 411 or consent of instructor. *3 sem. hrs.*

CME 574. FUNDAMENTALS OF AIR POLLUTION ENGINEERING I: Air pollution; combustion fundamentals; pollutant formation and control in combustion; pollutant formation and control methods in internal combustion engines; particle formation in combustion. Prerequisites: CME 305 or MEE 301, 302; CME 324 or MEE 410; or consent of instructor. *3 sem. hrs.*

CME 575. FUNDAMENTALS OF AIR POLLUTION ENGINEERING II: Review of the concepts of air pollution engineering; aerosols; removal of particles from gas streams; removal of gaseous pollutants from effluent streams; optimal air pollution control strategies. Prerequisites: CME 574 or consent of instructor. *3 sem. hrs.*

CME 576. ENVIRONMENTAL ENGINEERING SEPARATION PROCESSES: Discussion of the unit operations associated with environmental engineering separation processes of solid-liquid, liquid-liquid, and gas-liquid systems; general use, principles of operation, and design procedures for specific types of equipment. Prerequisite: consent of instructor. *3 sem. hrs.*

CME 581. ADVANCED CHEMICAL ENGINEERING CALCULATIONS I: Applications of ordinary and partial differential equations to engineering problems. Classical methods of solution. *3 sem. hrs.*

CME 582. ADVANCED CHEMICAL ENGINEERING CALCULATIONS II: Analyses and solutions of engineering problems described by differential equations. Numerical methods of solution. *3 sem. hrs.*

CME 583. PROCESS MODELING: Mathematical description of physical and chemical processes, solution methods, and prediction interpretation. Engineering applications. Prerequisite: CME 582 or equivalent. *3 sem. hrs.*

CME 595. SPECIAL PROBLEMS IN CHEMICAL ENGINEERING: Particular assignments to be arranged and approved by the chair of the department. *1-6 sem. hrs.*

CME 599. THESIS *3-6 sem. hrs.*

Department of

CIVIL AND ENVIRONMENTAL ENGINEERING (CIE)

Joseph E. Saliba
Chair of the Department

MASTER'S PROGRAM REQUIREMENTS

The program of study for the degree of Master of Science in Civil Engineering, developed in cooperation with an advisor assigned by the department chair, must include a minimum of 30 semester hours consisting of the following:

1. Fifteen to eighteen semester hours in Civil Engineering, Engineering Mechanics, and/or thesis-related courses selected from one of the following areas of concentration:
   - Engineering Mechanics
   - Environmental Engineering
   - Soil Mechanics
   - Structural Engineering
   - Transportation Engineering
2. Six to nine semester hours of engineering or basic science electives to be chosen from current course offerings. For the major concentration of Engineering Mechanics, six semester hours of mathematics (MTH 535 and 551) must be selected.
3. Six semester hours of research on a civil engineering thesis (CIE 599). Upon request of the student, and with the approval of the faculty advisor and the department chair, the six thesis hours may be replaced with six hours of coursework plus three hours of project (CIE 598). A final oral examination is required upon completion of the thesis or project.

See also Master's Degree Regulations in the introductory section of this chapter and consult with the advisor.

COURSES OF INSTRUCTION

CIE 500. ADVANCED STRUCTURAL ANALYSIS: Frames of variable cross section; arches; flat and folded plates; elastic stability of columns, frames, and plates; cylindrical, spherical, and barrel shells; structural dynamics of beams and frames. Prerequisite: CIE 317. *3 sem. hrs.*

CIE 501. STRUCTURAL ANALYSIS BY COMPUTER: Review of force and displacement methods. Introduction to direct element and substructure methods. Students write and execute computer programs to analyze plane and space trusses, grids, and frames. Prerequisite: CIE 317. *3 sem. hrs.*

CIE 502. PRESTRESSED CONCRETE: Discussion of the properties of concrete and prestressing steel. Theory and design of prestressed concrete beams, slabs, columns, frames, ties, and circular tanks. Prerequisite: CIE 412. *3 sem. hrs.*

CIE 503. INTRODUCTION TO CONTINUUM MECHANICS: Tensors, calculus of variations, Lagrangian and Eulerian descriptions of motion. General equations of continuum mechanics, constitutive equations of mechanics, thermodynamics of continua. Specialization to cases of solid and fluid mechanics. Prerequisite: EGM 303. *3 sem. hrs.*

CIE 504. STRUCTURAL DYNAMICS: Response of undamped and damped single and multidegree-of-freedom structures subjected to harmonic, periodic, and general dynamic loadings. Special topics include nonlinear structural response, response spectra, shear buildings, and simple systems with distributed properties. Prerequisites: EGM 303, CIE 317 or permission. *3 sem. hrs.*

CIE 505. PLASTIC DESIGN IN STEEL: Analysis and design procedures based on ultimate load capacity applied to steel beams, frames, and their connections. Concept of plastic hinge, necessary conditions for the existence of plastic moment, instability, deformations, repeated and reversed loading, and minimum weight design. Prerequisite: CIE 411. *3 sem. hrs.*

CIE 507. MASONRY DESIGN: Properties and performance criteria of bricks, concrete blocks, mortar and grout; codes and construction practices; design of masonry elements. Prerequisite: CIE 317. *3 sem. hrs.*

CIE 508. DESIGN OF TIMBER STRUCTURES: Study of basic wood properties and design considerations. Design and behavior of wood connectors, fasteners, beams, columns, and beam columns. Introduction to plywood and glued laminated members. Analysis and design of structural diaphragms and shear walls. Prerequisite: CIE 316. *3 sem. hrs.*

CIE 511. EXPERIMENTAL STRESS ANALYSIS: A study of the experimental analysis of stress as an aid to design for strength and economy with emphasis on electrical strain gages. Also, photoelasticity, brittle coatings, analogies, structural similitude. Two hours lecture and one three-hour laboratory period per week. Prerequisite: EGM 303. *3 sem. hrs.*

CIE 520. ADVANCED SOIL MECHANICS: Treatment of the theories of conventional soil mechanics. Detailed study and analysis of the static and dynamic properties of soils, with applications to foundation behavior. Prerequisite: CIE 312. *3 sem. hrs.*

CIE 524. FOUNDATION DESIGN: Analysis of earth pressure, stability of natural slopes, and bearing capacity of soil; design of spread foundations, pile foundations, beams on elastic foundations, anchored bulkheads, caissons, and cofferdams. Prerequisite: CIE 312. *3 sem. hrs.*

CIE 533. THEORY OF ELASTICITY: Three-dimensional stress and strain at a point; equations of elasticity in Cartesian and curvilinear coordinates; methods of formulation of equations for solution; plane stress and plane strain; energy formulations; numerical solution procedures. Corequisite: EGM 503. Prerequisite: EGM 303. *3 sem. hrs.*

CIE 534. THEORY OF PLATES AND SHELLS: Theory of plates: small and large displacement theories of thin plates; shear deformation; buckling; sandwich plate theory. Thin shell theory: theory of surfaces; thin shell equations in orthogonal curvilinear coordinates; bending, membrane, and shallow shell theories. Prerequisite: EGM 533. *3 sem. hrs.*

CIE 535. ADVANCED MECHANICAL VIBRATIONS: Review of undamped, damped, natural, and forced vibrations of one and two degrees of freedom systems. Lagrange's equation, eigenvalue/eigenvector problem, modal analysis for discrete and continuous systems. Computer application for multi-degree of freedom, nonlinear problems. Prerequisites: Computer Programming and MEE 319. *3 sem. hrs.*

CIE 539. THEORY OF PLASTICITY: Fundamentals of plasticity theory including elastic, viscoelastic, and elastic-plastic constitutive models; plastic deformation on the macroscopic and microscopic levels; stress-strain relations in the plastic regime; strain hardening; limit analysis; numerical procedures. Prerequisite: EGM 503 or 533. *3 sem. hrs.*

CIE 540. HIGHWAY GEOMETRIC DESIGN: Design controls and criteria, vehicle capacity, sight distance, intersection and interchange design. Prerequisite: CIE 403. *3 sem. hrs.*

CIE 544. TRAFFIC ENGINEERING: Characteristics of traffic, including the road user, the vehicle, origin, and destination surveys; traffic regulation, control devices and aids, design, administration, and planning. Prerequisite: CIE 403. *3 sem. hrs.*

CIE 546. FINITE ELEMENT ANALYSIS I: Fundamental development of the Finite Element Method (FEM), and solution of field problems and comprehensive structural problems. Variational principles and weak-forms; finite element discretization; shape functions; finite elements for field problems; bar, beam, plate, and shell elements; isoparametric finite elements, stiffness, nodal force, and mass matrices; matrix assembly procedures; computer coding techniques; modeling decisions; program output interpretation. Course emphasis on a thorough understanding of FEM theory and modeling techniques. Prerequisite: CIE 513 or 533. *3 sem. hrs.*

CIE 558. TRAFFIC ENGINEERING RESEARCH: Problems in control or capacity restraints based on studies of local situations. *3 sem. hrs.*

CIE 560. WASTEWATER ENGINEERING: Predicting and measuring the characteristics and quantity of wastewater produced from domestic and industrial sources. Principles in designing and operating wastewater treatment plants that primarily use microbiological treatment processes. Process selection criteria will be emphasized. *3 sem. hrs.*

CIE 562. PHYSICAL AND CHEMICAL WASTEWATER TREATMENT PROCESSES: The design of physical and chemical unit processes to treat wastewater originating primarily from industrial sources. Industry pretreatment technologies and the basis for their development will be investigated. *3 sem. hrs.*

CIE 563. HAZARDOUS WASTE ENGINEERING: The fundamental principles of the design and operation of hazardous waste remediation processes. Characterizing contaminated sites and conducting treatability studies for the selection of the most appropriate remediation strategy. *3 sem. hrs.*

CIE 564. SOLID WASTE ENGINEERING: Characterizing solid waste. Managing solid waste collection, transport, minimization, and recycling. The design of solid waste disposal and resource recovery facilities. *3 sem. hrs.*

CIE 565. ENVIRONMENTAL CHEMISTRY: Basic principles of safety engineering, environmental health, and partitioning and transformation of pollutants in the environment. Basic environmental analytical methodology including pollutant characterization and microbiological quantity and activity measurements. *3 sem. hrs.*

CIE 570. CIE COMPUTER APPLICATIONS: Applications of mainframe mini- and micro-computers to the solution of selected Civil Engineering problems, including data analysis, plotting, optimization, and simulation. *3 sem. hrs.*

CIE 580. HYDROLOGY AND SEEPAGE: The deposition, movement, and infiltration of water as related to the hydrologic cycle and groundwater hydraulics; a study of the theory of flow in porous media with application to dams, excavations, and other foundation problems. Prerequisites: CIE 312, 313. *3 sem. hrs.*

CIE 582. ADVANCED HYDRAULICS: Problems and study involving open channel flow, draw down curves, hydraulics of dams, spillway, models, and water distribution systems. Prerequisite: CIE 313. *3 sem. hrs.*

CIE 584. OPEN CHANNEL HYDRAULICS: Open channel flow in its various forms will be studied. Major topics to be covered include energy and momentum principles, uniform and gradually varied flow, rapidly varied flow, spatially varied flow, and unsteady flow. Pragmatic applications such as channel design, water surface profile computations, and culvert analysis will also be covered. Well-established solution approaches and widely accepted computer methods will be used to solve real-world problems. *3 sem. hrs.*

CIE 590. SELECTED READINGS IN CIVIL ENGINEERING: Directed readings in a designated area arranged and approved by the student's faculty advisor and the department chair. May be repeated. *1-3 sem. hrs. each*

CIE 595. SPECIAL PROBLEMS IN CIVIL ENGINEERING: Special assignments in civil engineering subject matter to be arranged and approved by the student's advisor and the department chair. *1-6 sem. hrs.*

CIE 598. PROJECT *1-6 sem. hrs. each*

CIE 599. THESIS *1-6 sem. hrs.*

ENGINEERING MECHANICS (EGM)

Joseph E. Saliba
Chair of the Department

MASTER'S PROGRAM REQUIREMENTS

The program of study for the degree of Master of Science in Engineering Mechanics requires a minimum of 33 semester hours of credit consisting of the following:

1. Twelve required semester hours in Engineering Mechanics: EGM 500, 503, 533, and 546.
2. Nine elective semester hours in Engineering Mechanics.
3. Six required semester hours in Mathematics: MTH 535 and 551.
4. Six semester hours of research on an approved project or thesis. Thesis or project research may be replaced by nine semester hours of additional course work only with the approval of both the advisor and the program director.

See also Master's Degree Regulations in the introductory section of this chapter and consult with the advisor.

COURSES OF INSTRUCTION

EGM 500. INTRODUCTION TO NUMERICAL METHODS: Numerical analysis topics include the solution of systems of linear and non-linear algebraic equations; matrix eigenvalue problems; ordinary differential equations; optimization techniques; numerical integration and interpolation. Engineering applications presented. Computer Programming required. *3 sem. hrs.*

EGM 502. ADVANCED ENGINEERING ANALYSIS: Detailed analysis of engineering problems using laws of nature, fundamental engineering principles, mathematics, computers, and practical experience to construct, resolve and test analytic models of physical events. Emphasis is on the use of the professional engineering approach which includes formulation of the problem, assumptions, plan or method of attack, solving the problem, checking and generalizing results. *3 sem. hrs.*

EGM 503. INTRODUCTION TO CONTINUUM MECHANICS: Tensors, calculus of variations, Lagrangian and Eulerian descriptions of motion. General equations of continuum mechanics, constitutive equations of mechanics, thermodynamics of continua. Specialization to cases of solid and fluid mechanics. Prerequisite: EGM 303. *3 sem. hrs.*

EGM 504. FUNDAMENTALS OF FLUID MECHANICS: An advanced course in fluid mechanics with emphasis on the derivation of conservation equations and the application of constitutive theory. Navier-Stokes equations. Ideal fluid approximation. Exact and approximate solutions to classical viscous and inviscid problems. Compressible and incompressible flows. Co-requisite: EGM 503. *3 sem. hrs.*

EGM 506. MECHANICAL BEHAVIOR OF MATERIALS: Description of the state of stress and strain in materials, plastic deformation, fatigue, fracture, creep, and rupture. Prerequisite: EGM 303, or consent of instructor. *3 sem. hrs.*

EGM 511. EXPERIMENTAL STRESS ANALYSIS: A study of the experimental analysis of stress as an aid to design for strength and economy with emphasis on electrical strain gages. Also, photoelasticity, brittle coatings, analogies, structural similitude. Two hours lecture and one three-hour laboratory period per week. *3 sem. hrs.*

EGM 519. ANALYTIC DYNAMICS: Dynamical analysis of a system of particles and of rigid bodies; Lagrangian and Hamiltonian formulation of equations of motion; classical integrals of motion; stability analysis of linear and nonlinear systems. Prerequisites: MTH 219 and EGM 202 or equivalent. *3 sem. hrs.*

EGM 531 . THEORY OF LINEAR VISCOELASTICITY: The principles of viscoelasticity; Kelvin and Maxwell models of viscoelastic materials; creep and relaxation phenomena; application of hereditary integral and complex compliance; correspondence principle wave propagation and vibrational response. Prerequisites: MTH 219 and EGM 303. *3 sem. hrs.*

EGM 533. THEORY OF ELASTICITY: Three-dimensional stress and strain at a point; equations of elasticity in Cartesian and curvilinear coordinates; methods of formulation of equations for solution; plane stress and plane strain; energy formulations; numerical solution procedures. Corequisite: EGM 503. Prerequisite: EGM 303. *3 sem. hrs.*

EGM 534. THEORY OF PLATES AND SHELLS: Theory of plates: small and large displacement theories of thin plates; shear deformation; buckling, sandwich plate theory. Thin shell theory: theory of surfaces; thin shell equations in orthogonal curvilinear coordinates; bending, membrane, and shallow shell theories. Prerequisite: EGM 533. *3 sem. hrs.*

EGM 535. ADVANCED MECHANICAL VIBRATIONS: Review of undamped, damped natural and forced vibrations of one and two degrees of freedom systems. Lagrange's equation, eigenvalue/eigenvector problem, modal analysis for discrete and continuous systems. Computer application for multi-degree of freedom, nonlinear problems. Prerequisites: Computer Programming and MEE 319. *3 sem. hrs.*

EGM 536. RANDOM VIBRATIONS: Introduction to probability distribution; characterization of random vibrations; harmonic analysis; auto- and cross-correlation and spectral density; coherence; response to single and multiple loadings; Fast Fourier Transform (FFT); applications in vibrations, vehicle dynamics, fatigue, etc. Prerequisites: Computer Programming and MEE 319. *3 sem. hrs.*

EGM 538. INTRODUCTION TO AEROELASTICITY: The study of the effect of aerodynamic forces on a flexible aircraft. Flexibility coefficients and natural modes of vibration. Quasi-steady aerodynamics. Static aeroelastic problems; wing divergence and dynamic aeroelasticity; wing flutter. An introduction to structural stability augmentation with controls. Prerequisite: AEE 501 or equivalent. *3 sem. hrs.*

EGM 539. THEORY OF PLASTICITY: Fundamentals of plasticity theory including elastic, viscoelastic, and elastic-plastic constitutive models; plastic deformation on the macroscopic and microscopic levels; stress-strain relations in the plastic regime; strain hardening; limit analysis; numerical procedures. Prerequisite: EGM 503 or 533. *3 sem. hrs.*

EGM 541. EXPERIMENTAL MECHANICS OF COMPOSITE MATERIALS:Introduction to the mechanical response of fiber-reinforced composite materials with emphasis on the development of experimental methodology. Analytical topics include stress-strain behavior of anisotropic materials, laminate mechanics, and strength analysis. Theoretical models are applied to the analysis of experimental techniques used for characterizing composite materials. Lectures are supplemented by laboratory sessions in which characterization tests are performed on contemporary composite materials. Prerequisite: EGM 303. *3 sem. hrs.*

EGM 543. ANALYTICAL MECHANICS OF COMPOSITE MATERIALS: Analytical models are developed for predicting the mechanical and thermal behavior of fiber-reinforced composite materials as a function of constituent material properties. Both continuous and discontinuous fiber-reinforced systems are considered. Specific topics include basic mechanics of anisotropic materials, micro-mechanics, and lamination theory, free edge effects, and failure criteria. Prerequisite: EGM 303. *3 sem. hrs.*

EGM 544. MECHANICS OF COMPOSITE STRUCTURES: Comprehensive treatment of laminated beams, plates, and sandwich structures. Effect of heterogeneity and anisotropy on bending under lateral loads, buckling, and free vibration are emphasized. Shear deformation and other higher-order theories and their range of parametric application are also considered. Prerequisite: EGM 543 or consent of instructor. *3 sem. hrs.*

EGM 545. COMPUTATIONAL METHODS FOR DESIGN: Modeling of mechanical systems and structures, analysis by analytical and numerical methods, development of mechanical design criteria and principles of optimum design, selected topics in mechanical design and analysis, use of the digital computer as an aid in the design of mechanical elements. Prerequisite: Computer Programming. *3 sem. hrs.*

EGM 546. FINITE ELEMENT ANALYSIS I: Fundamental development of the Finite Element Method (FEM), and solution of field problems and comprehensive structural problems. Variational principles and weak-forms; finite element discretization; shape functions; finite elements for field problems; bar, beam, plate, and shell elements; isoparametric finite elements; stiffness, nodal force, and mass matrices; matrix assembly procedures; computer coding techniques; modeling decisions; program output interpretation. Course emphasis on a thorough understanding of FEM theory and modeling techniques. Prerequisite: EGM 503 or EGM 533. *3 sem. hrs.*

EGM 547. FINITE ELEMENT ANALYSIS II: Advanced topics: heat transfer; transient dynamics; nonlinear analysis; substructuring and static condensation; effects of inexact numerical integration and element incompatibility; patch test; frontal solution techniques; selected topics from the recent literature. Prerequisite: EGM 546. *3 sem. hrs.*

EGM 548. ENERGY METHODS IN SOLID MECHANICS: Development of fundamental energy principles; virtual displacements, strain energy, Castigliano's theorems, minimum potential energy principles. Applications to engineering problems; redundant structures, buckling, static and dynamic analysis. Prerequisite: EGM 503 or EGM 533. *3 sem. hrs.*

EGM 549. THEORY OF ELASTIC STABILITY: Introduction to stability theory; buckling of plates and shells; influence of initial imperfections; nonlinear analysis; numerical solution methods. Prerequisite: EGM 533. *3 sem. hrs.*

EGM 552. BOUNDARY LAYERS: Development of the Prandtl boundary layer approximation in two and three dimensions for both compressible and incompressible flow. Exact and approximate solutions for laminar flows. Unsteady boundary layers. Linear stability theory and transition to turbulence. Empirical and semi-empirical methods for turbulent boundary layers. Higher-order boundary layer theory. Prerequisite: EGM 504 or equivalent. *3 sem. hrs.*

EGM 553. COMPRESSIBLE FLOW: Fundamental equations of compressible flow. Introduction to flow in two and three dimensions. Two-dimensional supersonic flow, small perturbation theory, method of characteristics, oblique shock theory. Introduction to unsteady one-dimensional motion and shock tube theory. Method of surface singularities. Prerequisite: EGM 503. *3 sem. hrs.*

EGM 570. FRACTURE MECHANICS: Application of principles of fracture mechanics to fatigue and fracture in engineering structures. Prerequisites: EGM 506 or consent of instructor. *3 sem. hrs.*

EGM 590. SELECTED READINGS IN ENGINEERING MECHANICS: Directed readings in a designated area, arranged and approved by the student's faculty advisor and the department chair. May be repeated. *1-3 sem. hrs. each.*

EGM 595. SPECIAL PROBLEMS IN ENGINEERING MECHANICS: Special topics, arranged and approved by the student's faculty advisor and the department chair. *1-6 sem. hrs.*

EGM 598. PROJECT *1-6 sem. hrs.*

EGM 599. THESIS *3-6 sem. hrs.*

Department of

ELECTRICAL & COMPUTER ENGINEERING (ECE)

Mohammad A. Karim,
Chair of the Department

Electrical Engineering is a major concentration for both the Doctor of Philosophy in Engineering and the Doctor of Engineering. See Doctor's Degree Regulations in the introductory section of this chapter and consult with the department chair.

PROGRAM REQUIREMENTS

The program of study leading to the Master of Science in Electrical Engineering must include a minimum of 30 semester hours of credit consisting of the following.

1. Six semester hours in basic and engineering sciences. It is possible to combine six semester hours from separate areas. Selected courses must meet with the approval of the advisor.
2. Nine hours in electrical engineering core courses selected from:
   - ELE 501. Introduction to Digital Systems
   - ELE 503. Random Processes
   - ELE 506. Solid State Devices
   - ELE 507. Electromagnetic Fields I
   - ELE 509. Analysis of Linear Systems
3. Nine hours in a specialization area approved by the advisor.
4. Six hours on an approved thesis or six hours of additional electrical engineering course work. Graduate Assistants must use the thesis option.

See also the Master's Degree Regulations in the introductory section of this chapter. Specific course requirements are listed in the Electrical and Computer Engineering department graduate brochure.

COURSES OF INSTRUCTION

ELE 501. CONTEMPORARY DIGITAL SYSTEMS: Introduction to sequential logic; state machines; high-performance digital systems: theory and application of modern design; alternative implementation forms and introduction to HDL; productivity, recurring and non-recurring costs, flexibility, and testability; software drivers; hardware/software integration. Prerequisite: ELE 215 or equivalent. *3 sem. hrs.*

ELE 503. RANDOM PROCESSES: An introduction to random variables and processes as applied to system theory, communications, signal processing and controls. Topics include probability, random variables and processes, autocorrelation, power spectral density and linear system theory with random inputs. Applications in filtering and estimation. Prerequisites: ELE 202 and ELE 211 or equivalent. *3 sem. hrs.*

ELE 506. SOLID STATE DEVICES: Introduction to the theory of solid state devices; energy band theory; bulk properties of semiconductors; p-n junction, bipolar junction transistor, metal-oxide semiconductor (MOS), MOS capacitor, MOS field-effect transistor-theory, devices, modeling and applications. Prerequisite: ELE 301 or equivalent. *3 sem. hrs.*

ELE 507. ELECTROMAGNETIC FIELDS I: Fundamental concepts, wave equation and its solutions; wave propagation, reflection and transmission; potential theory; construction of solutions; various electromagnetic theorems: concept of source, uniqueness, equivalence, induction and reciprocity theorems. Prerequisite: ELE 333 or equivalent. *3 sem. hrs.*

ELE 509. ANALYSIS OF LINEAR SYSTEMS: Signals, Systems, Orthogonal Decomposition, Fourier Analysis, Laplace Transforms, Z-Transforms, State Variables, and their application to the analysis of linear systems. *3 sem. hrs.*

ELE 510. MICROWAVE ENGINEERING: Microwave transmission, planar transmission lines, microwave components and filters. Microwave tubes, microwave communication, radar systems, and electronic support measures. Prerequisite: ELE 507. *3 sem. hrs.*

ELE 511. ANTENNAS AND RADIATION THEORY: Fundamental principles of antennas; analysis and synthesis of arrays; resonant antennas; broadband and frequency independent antennas; aperture and reflector antennas; applications to radar and communication systems. Prerequisite: ELE 442 or equivalent. *3 sem. hrs.*

ELE 516. ELECTROMAGNETIC COMPATIBILITY: Fundamental principles of electromagnetic compatibility (EMC) including nonideal behavior of components; radiated emissions and susceptibility; crosstalk; shielding and grounding; electrostatic discharge; system design for EMC. Prerequisite: undergraduate electromagnetics. *3 sem. hrs.*

ELE 518. ELECTROMAGNETIC FIELDS II: Classification and construction of solutions. Plane cylindrical and spherical wave functions. Integral equations, mathematical theory of diffraction. Green's function. Prerequisite: ELE 507. *3 sem. hrs.*

ELE 521. COMMUNICATION THEORY: Review of the fundamentals of analog and digital communications; analog and digital signal detection in the presence of Gaussian noise; multilevel signals; thresholding for minimizing error probability; comparison of performance in a high-noise environment. Prerequisite: ELE 401 or equivalent, ELE 503. *3 sem. hrs.*

ELE 522. DIGITAL COMMUNICATION: Fundamentals of digital communications systems including coding and channel capacity; detection and estimation; comparative performance of systems; synchronous vs. asynchronous methods; system synchronization; error control coding. Prerequisite: ELE 521. *3 sem. hrs.*

ELE 523. SPREAD SPECTRUM SYSTEMS: Fundamentals of Spread Sprectrum communication systems; direct sequence, pseudonoise, frequency hopping, time hopping modulation techniques; signal detection techniques; comparative analysis; applications. Prerequistite: ELE 521. *3 sem. hrs.*

ELE 533. COMPUTER DESIGN: Design considerations of the computer; register transfer operations; hardware implementation of arithmetic processors and ALU; instruction set format and design and its effect on the internal microengine; hardware and micro-programmed control design; comparative architectures. Prerequisite: ELE 501 or equivalent. *3 sem. hrs.*

ELE 536. MICROPROCESSOR APPLICATIONS: Project studies, applications of microprocessors in practical implementations; logic implementation using software; memory mapped I/O problems and interrupt structure implementation; use of assembler and/or cross assemblers; study of alternate microprocessor families including industrial controllers. Prerequisites: ELE 314 or equivalent and ELE 501. *3 sem. hrs.*

ELE 537. ADVANCED ENGINEERING SOFTWARE: Concepts, implementation and current practice in the utilization of programming capabilities contained in operating systems. Introduction to operating system calls. A practical approach emphasizing theory and principles together with case studies and implementations in engineering applications of modern operating systems. Prerequisite: C programming experience. *3 sem. hrs.*

ELE 538. OBJECT-ORIENTED PROGRAMMING APPLICATIONS: A semi-formal approach to the engineering applications of object-oriented programming. Application of the concepts of classes, inheritance, polymorphism in engineering problems. Introduction to the use of class libraries. Effective integration of the concepts of application programmer interfaces, language features and class libraries. Prerequisite: C programming experience. *3 sem. hrs.*

ELE 541. POWER ELECTRONICS: Power switching devices including diodes, thyristors, triacs, BJTs, and MOSFETs. Power electronic converters, power amplification, power regulation and power conversion control. *3 sem. hrs.*

ELE 542. ELECTRICAL MACHINES AND CONTROL: Generalized analysis of electrical machines. Transient solution of nonlinear, time-varying machine equations. Reference frame theory. Induction machines. Brushless DC machines. Stepper motors. Control of ac and dc machines. Prerequisite: ELE 414 or equivalent. *3 sem. hrs.*

ELE 545. AUTOMATIC CONTROL: Analog and Digital Control System Design. Analysis and synthesis of feedback control systems. Performance and stability analysis. Regulator and servomechanism design: time and frequency domain methods. State-space methods: SVF design and observers. Digital implementation issues. Prerequisite: ELE 509. *3 sem. hrs.*

ELE 546. INSTRUMENTATION DESIGN: Theory of measurements: errors, accuracy, precision and bias. Analysis of measuring devices for various physical quantities such as motion, dimension, force, pressure and flow. Computer-aided experimentation. Automated data collection, recording, transmission and analysis. Virtual instrument design. *3 sem. hrs.*

ELE 551. ELECTRICAL POWER SYSTEMS DYNAMICS: Basic structure of the electrical power transmission system; criteria for system stability; symmetrical components; synchronous machine equations of motion, transients and dynamics; transmission line surges, short circuit calculations. Prerequisites: ELE 333 and ELE 414. *3 sem. hrs.*

ELE 555. SYSTEMS DYNAMICS I: The methodology for modeling the dynamics of complex social-economic systems. Use of these models to study organizational policies and design for higher-order, multiple-loop, nonlinear feedback structures. *3 sem. hrs.*

ELE 556. SYSTEMS DYNAMICS II: The continuation of Systems Dynamics I with special emphasis on the study of large-scale corporate, urban, educational, and ecological systems. Prerequisite: ELE 555. *3 sem. hrs.*

ELE 561. DIGITAL SIGNAL PROCESSING I: A study of one-dimensional digital signal processing including a review of continuous system analysis and sampling. Topics include z-transform techniques, digital filter design and analysis, and fast Fourier transform processing techniques. Prerequisite: ELE 509. *3 sem. hrs.*

ELE 562. DIGITAL SIGNAL PROCESSING II: A study of the architectural requirements for one-dimensional digital signal processing. This includes the techniques for the design of both hardware and software elements needed for implementation of digital signal processors as well as application of those processors. Prerequisite: ELE 561. *3 sem. hrs.*

ELE 563. IMAGE PROCESSING: An introduction to image processing including the human visual system, image formats, two-dimensional transforms, image restoration, and image reconstruction. Prerequisite: ELE 561. *3 sem. hrs.*

ELE 572. LINEAR SYSTEMS AND FOURIER OPTICS: Mathematical techniques pertaining to linear systems theory; Fresnel and Fraunhoffer diffraction; Fourier transform properties of lenses; frequency analysis of optical systems, spatial filtering, application such as optical information processing and holography. Prerequisite: Acceptance into the EE graduate program or permission of the department chair. *3 sem. hrs.*

ELE 573. ELECTRO-OPTICAL DEVICES & SYSTEMS: Solid-state theory of optoelectronic devices; photoemitters; photodetectors; solar cells; detection and noise; displays; electro-optic, magneto-optic, and acousto-optic modulators; integration and application of electro-optical components in electro-optical systems of various types. Prerequisite: ELE 507, or permission of the department chair. *3 sem. hrs.*

ELE 574. GUIDED-WAVE OPTICS: Light propagation in slab and cylindrical waveguides; signal degradation in optical fibers; optical sources, detectors, and receivers; coupling; transmission link analysis; fiber fabrication and cabling; fiber sensor system. Prerequisite: ELE 507 or permission of the department chair. *3 sem. hrs.*

ELE 575. ELECTRO-OPTICS SENSORS: Optical sensors, including amplitude, phase, wavelength, polarization and modal interference based sensors. Photoelasticity effects in stressed optical materials. Quadrature point stabilization, linearity, dynamic range and sensitivity. Modulation and demodulation by both passive and active means. General sensor characteristics. Optical sources and detectors, optical signal-to-noise ratio analysis and general sensor characteristics. Fiber optic sensors and smart skin/structure technology. Prerequisite: ELE 574 or permission of the department chair. *3 sem. hrs.*

ELE 577L. ELECTRO-OPTICS LABORATORY: Experimentation with E-O systems emphasizing areas such as display technology, surveilance systems and components, and other disciplines in which electronic and optical elements are arranged to interact synergistically. *1 sem. hr.*

ELE 595. SPECIAL PROBLEMS IN ELECTRICAL ENGINEERING: Particular assignments to be arranged and approved by the department chair. *2-6 sem. hrs.*

ELE 599. THESIS: *1-6 SEM. HRS.*

ELE 603. APPLIED OPTIMAL ESTIMATION: Random processes and state-space analysis. Applied optimal estimation with emphasis on Kalman and Weiner filtering. Prerequisite: ELE 503, ELE 545 or equivalent. *3 sem. hrs.*

ELE 611. ADVANCED ANTENNA THEORY: Advanced topics in antennas including advanced arrays, antenna temperature, synthetic apertures, aperture antennas, microwave traveling wave antennas. Prerequisites: ELE 507 and ELE 511. *3 sem. hrs.*

ELE 612. METHODS IN RADAR CROSS SECTION: Solution of problems in radar cross section analysis and prediction. RCS of simple shapes and complex shapes. Reflection and transmission; impedance boundary condition, stratified media. RCS of antennas. Application of the physical theory of diffraction and the geometrical theory of diffraction to scattering problems. Prerequisites: ELE 507 and ELE 511. *3 sem. hrs.*

ELE 615. COMPUTATIONAL ELECTROMAGNETICS: This course deals with both the differential equation and integral equation based methods to solve Maxwell's equations for complex bodies. Methods studied include the Moment Method, Finite Element Method, and Finite Difference Time Domain Method. The course also deals with asymptotic techniques leading to the formulation to the GTD and PTD. Prerequisites: ELE 507 and ELE 518. *3 sem. hrs.*

ELE 631. MICROELECTRONICS SYSTEMS: Introduction to the design and application of engineering microelectronics; bipolar and MOS device theory and processing technology; CMOS logic and circuitry; design principles fundamental to chip design and fabrication; case studies employing introduction to HDL. Prerequisite: ELE 536. *3 sem. hrs.*

ELE 636. ADVANCED COMPUTER ARCHITECTURE: Comparative evaluation of advanced and experimental computer structures. Investigation of optical, multiprocessor, array, various hybrid and neural network architectures. This is an advanced seminar class using current computer design and experimental literature. Prerequisite: ELE 536. *3 sem. hrs.*

ELE 637. CONCURRENT PROCESSING: Introduction to the concepts and practices of parallel processing and concurrency. Multiprogramming and multitasking. Synchronous and asynchronous events. Critical sections, mutexes and semaphores. Use of shared memory in engineering applications. Atomicity on CISC and RISC machines. Applications of interval timers. Case studies in engineering applications. Prerequisites: ELE 537 and ELE 636 or equivalent. *3 sem. hrs.*

ELE 641. NONLINEAR CONTROL: A study of the major techniques of nonlinear system analysis including phase plane analysis, describing function analysis and Lyapunov Stability Theory. Application of the analytical techniques to control system design including feedback linearization, sliding mode control and an introduction to adaptive control. Prerequisites: ELE 509 and ELE 545. *3 sem. hrs.*

ELE 642. OPTIMAL CONTROL AND ESTIMATION: Optimal control of discrete-time systems. Cost-equivalent control of continuous-time systems. Optimal estimation. Prerequisites: ELE 517 and ELE 545. *3 sem. hrs.*

ELE 661. STATISTICAL SIGNAL PROCESSING: This course studies discrete methods of linear estimation theory. Topics include random vector, linear transformations, linear estimation, optimal filtering, linear prediction, and spectrum estimation. Prerequisite: ELE 561. *3 sem. hrs.*

ELE 662. ADAPTIVE SIGNAL PROCESSING: An overview of the theory, design, and implementation of adaptive signal processors. This includes discussions of various gradient search techniques, filter structures, and applications. An introduction to neural networks is also included. Prerequisite: ELE 661. *3 sem. hrs.*

ELE 663. STATISTICAL PATTERN RECOGNITION: This course provides a comprehensive treatment of the statistical pattern recognition problem. The mathematical models describing these problems and the mathematical tools necessary for solving them are covered in detail. Prerequisite: ELE 661. *3 sem. hrs.*

ELE 674. INTEGRATED OPTICS: Review of electromagnetic principles; dielectric slab waveguides; cylindrical dielectric waveguides; dispersion, shifting and flattening; mode coupling and loss mechanism; selected nonlinear waveguiding effects; integrated optical devices. Prerequisite: ELE 574. *3 sem. hrs.*

ELE 676. QUANTUM ELECTRONICS: Principles of the quantum theory of electron and photon processes; interaction of electromagnetic radiation and matter; applications to solid state and semiconductor laser systems. Prerequisite: ELE 506, or EOP 506/ELE 573 or equivalent. *3 sem. hrs.*

ELE 690. SELECTED READINGS IN ELECTRICAL ENGINEEERING: Directed Readings in electrical engineering areas to be arranged and approved by the chair of the student's doctoral advisory committee and the department chair. *1-3 sem. hrs.*

ELE 695. SPECIAL PROBLEMS IN ELECTRICAL ENGINEERING: Special topics in electrical engineering not covered in regular courses. Course sections arranged and approved by the chair of the student's doctoral advisory committee and the department chair. *1-3 sem. hrs.*

ELE 698. D.E. DISSERTATION: An original investigation as applied to electrical engineering practice. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*

ELE 699. Ph.D. DISSERTATION: An original research in electrical engineering which makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*

ELECTRO-OPTICS (EOP)

Mohammad A. Karim,
Program Director

The programs of study for the Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) in Electro-Optics are interdisciplinary programs administered by the School of Engineering with the cooperative support of the College of Arts and Sciences.

M.S. PROGRAM REQUIREMENTS

To be considered for admission to the M.S. program in electo-optics a student must have received an undergraduate degree with emphasis in engineering, physics, optics, chemistry, or applied mathematics. Students who have degrees in chemistry or applied mathematics, or in related sciences, are encouraged to apply, but they may be required to take a limited amount of undergraduate work to complete their preparation for graduate study in Electro-Optics. Students are expected to have competency in computer programming and modern electronics.

The program of study in electro-optics leading to a M.S. degree must include a minimum of 30 semester hours consisting of the following:

1. Twenty-one semester hours of core courses in Electro-Optics: EOP 501, EOP 502, EOP 505, EOP 506, EOP 513, EOP 514, EOP 541L, EOP 542L, EOP 543L.
2. Three semester hours of a technical elective.
3. Six semester hours of thesis work in the case of a thesis option or six semester hours of approved technical electives in the case of a non-thesis option.

While all students are expected to do a thesis, students supported by an assistantship are required to do a thesis.

Students who have received waiver of the thesis requirement will be examined by a three-person advisory committee just prior to their anticipated graduation date. This examination will be centered around an oral presentation on a topic mutually agreed to by the student and the advisory committee. At the discretion of the advisory committee, a written report may also be required. The examination may be repeated once, but not in the same academic term.

See also the Master's Degree Regulations in the introductory section of this chapter, and consult with the director of the Electro-Optics program.

Ph.D. PROGRAM REQUIREMENTS

To be considered for admission to the Ph.D. program in Electo-Optics, a student must have received a master's degree in Electro-Optics or its equivalent. Only the most promising students with a graduate GPA of 3.5/4.0 or higher, or equivalent, may be admitted.

The program of study in electro-optics leading to a Ph.D. degree must include a minimum of 90 semester hours beyond the bachelor's degree consisting of the following.

1. Twenty-one semester hours of core courses in Electro-Optics: EOP 501, EOP 502, EOP 505, EOP 506, EOP 513, EOP 514, EOP 541L, EOP 542L, EOP 543L, or equivalent.
2. Twelve semester hours of approved graduate mathematics courses.
3. Twelve semester hours of approved 600-level Electro-Optics courses.
4. Thirty semester hours of doctoral dissertation in Electro-Optics.

See also the Doctor's Degree Regulations in the introductory section of this chapter, and consult with the director of the Electro-Optics program.

COURSES OF INSTRUCTION

EOP 501. GEOMETRIC OPTICS: Wavefronts and rays; Fermat's principle; Gaussian optics of axially symmetrical systems; aperture stops; pupils and field lenses; Lagrange invariant; angular and visual magnification; optical systems; plane mirrors and prisms; aberration theory; introduction to computer ray tracing. Prerequisites: Acceptance into the graduate Electro-Optics program or permission of the program director. *3 sem. hrs.*

EOP 502. OPTICAL RADIATION AND MATTER: Maxwell's equations; electromagnetic waves; interaction of radiation with atomic electrons; molecular and lattice vibration; study of phenomena related to the interaction of optical radiation with matter; polarization; crystal optics; nonlinear dielectric effects. Prerequisites: acceptance into the graduate Electro-Optics program or permission of the program director. *3 sem. hrs.*

EOP 505. INTRODUCTION TO LASERS: Laser theory; coherence; Gaussian beams; optical resonators; properties of atomic and molecular radiation; laser oscillation and amplification; methods of excitation of lasers; characteristics of common lasers; laser applications. Prerequisites: EOP 502 or a working knowledge of Maxwell's Equations, and physical optics, or permission of the course instructor or program director. *3 sem. hrs.*

EOP 506. ELECTRO-OPTICAL DEVICES AND SYSTEMS: Solid state theory of optoelectronic devices; photoemitters; photodetectors; solar cells; detection and noise; displays; electro-optic magneto-optic, and acousto-optic modulators; integration and application of electro-optical components in electro-optical systems of various types. Prerequisite: EOP 502 or permission of instructor. *3 sem. hrs.*

EOP 513. LINEAR SYSTEMS AND FOURIER OPTICS: Mathematical techniques pertaining to linear systems theory; Fresnel and Fraunhoffer diffraction; Fourier transform properties of lenses; frequency analysis of optical systems, spatial filtering, application such as optical information processing and holography. Prerequisites: Acceptance into the graduate EO program or permission of the program director. *3 sem. hrs.*

EOP 514. GUIDED WAVE OPTICS: Light Propagation in slab and cylindrical wave guides; signal degradation in optical fibers; optical sources, detectors, and receivers; coupling; transmission link analysis; fiber fabrication and cabling; fiber sensor system. Prerequisites: EOP 502 or permission of the program director. *3 sem. hrs.*

EOP 523. TOPICS IN MODERN OPTICS: Infrared systems, including radiometry, blackbody and graybody sources, detectors, materials, and optics. Thin-film optical coatings. Polarization of light using Mueller matrices and Stokes vectors. Optical measurements and instruments based on polarization. Fast Fourier Transform (FFT) and its applications to optics. Prerequisites: EOP 506 and EOP 513, or permission of the program director. *3 sem. hrs.*

EOP 524. OPTICAL COMPUTING SYSTEMS: Arithmetic and recognition using analog optics; number representations; modified signed-digit and residue arithmetic; logic minimization; Fredkin and threshold logic; combinational and sequential arithmetic units; shadow-casting and symbolic substitution; matrix processing; optical computing devices. Prerequisites: EOP 513, and completion of a course in computer systems or permission of the program director. *3 sem. hrs.*

EOP 531. NEURAL NETWORKS: Nature and capabilities of Neural Networks; connectionism, self-organization, and adaptation; relations to fuzzy systems and genetic algorithms; back-propagation, adaptive resonance, associative memory, radial basis function, simulated annealing, and optically implementable neural networks. Prerequisites: MTH 302 or equivalent or permission of the program director. *3 sem. hrs.*

EOP 534. ELECTRO-OPTIC SENSORS: Optical sensors including amplitude, phase, wavelength, polarization, and modal interference based sensors. Photoelasticity effects in stressed optical materials. Quadrature point stabilization, linearity, dynamic range and sensitivity. Modulation and demodulation by both passive and active means. General sensor characteristics. Optical sources and detectors, optical signal-to-noise ratio analysis and general sensor characteristics. Fiber optic sensors and smart skin/structure technology. Prerequisite: EOP 514 or permission of the program director. *3 sem. hrs.*

EOP 541L. GEOMETRIC AND PHYSICAL OPTICS LABORATORY: Geometrical optics; characterization of optical elements; diffraction; interference; birefringence and polarization. Prerequisite: EOP 501 or permission of the program director. *1 sem. hr.*

EOP 542L. ELECTRO-OPTIC SYSTEMS LABORATORY: Fiber optic principles and systems: numerical aperture, loss, dispersion, single and multimode fibers, communications and sensing systems. Project oriented investigations of electro-fiber-optic systems and devices in general: sources, detectors, image processing, sensor instrumentation and integration, electro-optic component, display technology, nonlinear optical devices and systems. Prerequisite: EOP 514 or permission of the program director. *1 sem. hr.*

EOP 543L. ADVANCED ELECTRO-OPTICS LABORATORY: Project-oriented investigations of laser characterization, interferometry, holography, optical pattern recognition and spectroscopy. Emphasis is on the applications of optics, electronics, and computer data acquisition and analysis to measurement problems. Prerequisite: EOP 541L or permission of the program director. *1 sem. hr.*

EOP 595. SPECIAL PROBLEMS IN ELECTRO-OPTICS: Particular assignments to be arranged and approved by the director of the program. *2-6 sem. hrs.*

EOP 599. THESIS *3-6 sem. hrs.*

EOP 601. OPTICAL DESIGN: Chromatic aberrations: doublet lens; telephoto, wide-angle, and normal lenses; triplet lens design and variations; optimization methods and computer lens design; optical transfer functions; telescopes and microscopes; two-mirror telescope design: aspheric surfaces; prism and folded optical systems, rangefinders; gratings and holographic optical elements; anamorphic optical systems; zoom systems. Prerequisite: EOP 501. *3 sem. hrs.*

EOP 603. INTERFEROMETRY: Two-beam interference: wavefront division, amplitude division, localization of fringes, and interferometers; coherence; multiple-beam interference; Fabry-Perot interference and fringes of equal chromatic order; length measurements. Prerequisite: EOP 513. *3 sem. hrs.*

EOP 604. INTEGRATED OPTICS: Review of electromagnetic principles; dielectric slab waveguides; cylindrical dielectric waveguides; dispersion, shifting and flattening; mode coupling and loss mechanism; selected nonlinear waveguiding effects; integrated optical devices. Prerequisite: EOP 514. *3 sem. hrs.*

EOP 621. STATISTICAL OPTICS: Optical phenomena and techniques requiring statistical methods for practical understanding and application; relevant statistical techniques for the analysis of image processing systems and the design of laser radar systems; engineering applications of statistical techniques. Prerequisites: completion of the core courses of the graduate Electro-Optics program or by permission of the program director. *3 sem. hrs.*

EOP 622. TECHNIQUES OF OPTICAL PROCESSING: Techniques and applications of optical image and signal processing; coherent optics; matched filters; computer-generated holograms; spatial light modulators; incoherent optical processing; modulators for signal processing. Prerequisite: EOP 513 or permission of the program director. *3 sem. hrs.*

EOP 624. NONLINEAR OPTICS: Introduction and overview nonlinear optical interactions, classical and harmonic oscillator model, symmetry properties of nonlinear susceptibility tensor, coupled-mode formalism, sum- and difference- frequency generation, parametric oscillators, four-wave mixing, phase conjugation, optical solitons, stimulated Brillouin and Raman scattering, photorefractive effect, and resonant nonlinearities. Prerequisite: EOP 502 or equivalent. *3 sem. hrs.*

EOP 625. LASER PROBE TECHNIQUES: Applications of optical phenomena and lasers to nonintrusive measurements; absorption and emission spectroscopies; laser-induced fluorescence spectroscopy; high-sensitivity detection methods using lasers; spontaneous and coherent Raman spectroscopies; Rayleigh and Mie scattering techniques; laser Doppler techniques; gas flow and combustion diagnostics and other applications of laser spectroscopy and light scattering. Prerequisites: EOP 505 or permission of the program director. *3 sem. hr.*

EOP 626: QUANTUM ELECTRONICS: Principals of the quantum theory of electron and photon processes; interaction of electromagnetic radiation and matter; applications to solid state and semiconductor laser systems. Prerequisites: ELE 506 or EOP 506/ELE 573, or equivalent. *3 sem. hrs.*

EOP 690. SELECTED READINGS IN ELECTRO-OPTICS: Directed readings in electro-optics areas to be arranged and approved by the chair of the student's advisory committee and the program director. *1-3 sem. hrs.*

EOP 695. SPECIAL PROBLEMS IN ELECTRO-OPTICS: Special topics in electro-optics not covered in regular courses. Course sections arranged and approved by the chair of the student's advisory committee and program director. *1-3 sem. hrs.*

EOP 699. PhD DISSERTATION: An original research in electro-optics which makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*

ENGINEERING (EGR)

Donald L. Moon,
Program Director and
Associate Dean of Engineering

The Master of Science in Engineering allows flexibility for general or specialized program construction according to the needs of the individual student in conformance with the requirements of the School of Engineering and the University of Dayton. The program of study leading to the Master of Science in Engineering must include a minimum of 33 semester hours of the following.

1. Fifteen semester hours in a major area.
2. Fifteen semester hours of electives.
3. Three semester hours of research on an approved project.

See also Master's Degree Regulations in the introductory section of the Graduate Bulletin and consult with the director of the Master of Engineering Program.

ENGINEERING MANAGEMENT (ENM)

Patrick J. Sweeney, Chairperson

MASTER'S PROGRAM REQUIREMENTS

The program of study leading to the Master of Science in Engineering Management is designed to prepare the practicing engineer for the management of engineering activities in any environment—in industry, in government, in business, or the military. It must include a minimum of 36 semester hours consisting of the following:

1. Eighteen semester hours of core courses in Engineering Management. These are ENM 505, ENM 521, ENM 522, ENM 582, ENM 585, and ENM 590.
2. Nine semester hours of engineering electives. This requirement may be satisfied with nine semester hours of courses in any field of engineering.
3. Nine hours of electives to include MSC 500 and MSC 501 or equivalent courses or demonstrated knowledge of the subject, and approved by the advisor and the chair.

See also Master's Degree Regulations in the introductory section of this chapter and consult with the advisor from the department.

COURSES OF INSTRUCTION

ENM 505. MANAGEMENT OF ENGINEERING SYSTEMS I: This course is an introduction to the functions and tools of engineering management and the systems engineering process. Included as topics are the roles and relationships of engineering activities in the total enterprise, the models and techniques of systems analysis, engineering system design, and systems management. *3 sem. hrs.*

ENM 506. MANAGEMENT OF ENGINEERING SYSTEMS II: Continuation of ENM 505 with emphasis on selective quantitative methods in systems engineering and engineering management. Case studies and application of methods are an integral part of the course. Prerequisite: ENM 505 or equivalent. *3 sem. hrs.*

ENM 510. TECHNOLOGICAL FORECASTING: State-of-the-art techniques for technological forecasting in R & D and other related areas. Topics presented include the Delphi Method, techniques of technological forecasting, growth curves, and various relevant mathematical models. Areas of application are tailored to student interests. *3 sem. hrs.*

ENM 511. TECHNOLOGY ASSESSMENT: Examination of the impacts of technological change on society. Review of the impacts of several major technological changes of the past, including both anticipated and unanticipated changes. Methods for assessing and predicting the consequences of technological change. *3 sem. hrs.*

ENM 515. HUMAN FACTORS ENGINEERING: Introduction to the human factors criteria that should be considered in the design of man-machine systems, work situations, and man's physical environment. *3 sem. hrs.*

ENM 521. OPERATIONS RESEARCH I: An introduction to the deterministic models and methods of operations research, with emphasis on the solution of real problems in both the public and private sectors. Problem formulation, mathematical model building, and algorithmic solution procedures are discussed specifically in the areas of linear, integer, and nonlinear programming, network analysis, and deterministic inventory analysis. Use is made of the personal computer in finding optimal solutions to problems. *3 sem. hrs.*

ENM 522. OPERATIONS RESEARCH II: An introduction to the probabilistic models and methods of operations research. The course focuses on risk and uncertainty in the decision-making process. Topics include Markov processes, queueing theory, stochastic inventory models, reliability engineering, and forecasting. A major focus on the course is on simulation modeling. The personal computer is used to conduct simulations. Prerequisite: MSC 500 or equivalent. *3 sem. hrs.*

ENM 523. OPTIMIZATION I. An introduction to the nonlinear optimization with applications in engineering and management science. Both single variable and multi-variable as well as unconstrained and constrained problems are addressed. The course is a blend of theory (e.g. Kuhn-Tucker conditions), numerical search techniques (e.g. conjugate directions methods), and applications. The personal computer is used for problem solving. *3 sem. hrs.*

ENM 530. COST AND ECONOMIC ANALYSIS FOR ENGINEERS: Principles and methods of economic analysis of engineering activities. The time value of money, short-term and long-term investments, comparison of alternatives, depreciation analysis, replacement analysis, and minimum cost models. *3 sem. hrs.*

ENM 535. INTRODUCTION TO DECISION MAKING: Introduction to rational decision making with applications in the analysis and design of engineering and management systems. Decision making under uncertainty and risk as well as under certainty. Group decision making. Multiple-criteria decision making. Prequisite: MSC 500 or equivalent. *3 sem. hrs.*

ENM 541. PRODUCTION ENGINEERING: The study of the integration of man, machine, and material in producing a marketable product. The use of engineering techniques to design, develop, and implement the production system are covered. Topics include break-even analysis, learning curve theory, forecasting, resource balancing, inventory and production control, facility layout and location, job sequencing and scheduling and assembly line balancing. Modern production techniques such as just-in-time, MRP systems flexible manufacturing, and computer-integrated manufacturing are discussed. Prerequisite: ENM 521 or permission of the instructor. *3 sem. hrs.*

ENM 551. POLICY ANALYSIS AND PLANNING IN PUBLIC SYSTEMS I: Introduction to the qualitative and quantitative methods of formulating and assessing policy making and planning in the public sector. Emphasis is placed on modeling economic and social impacts of public policy. *3 sem. hrs.*

ENM 552. POLICY ANALYSIS AND PLANNING IN PUBLIC SYSTEMS II: Continuation of ENM 551 with emphasis on selected qualitative and quantitative methods of formulating and assessing policy making and planning. Case studies in application of the methods are an integral part of the course. Prerequisite: ENM 551 or equivalent. *3 sem. hrs.*

ENM 553. PUBLIC SYSTEMS ENGINEERING: Guided study of the application of policy analysis and planning techniques for public systems. Emphasis on urban-regional improvement and world systems of energy and food. Prerequisite: ENM 551 or equivalent. *3 sem. hrs.*

ENM 555. SYSTEM DYNAMICS I: Introduction to the methodology for modeling the dynamics of complex engineering, business, and socioeconomic systems. The use of these models to study the effect of organizational policies and design in higher-order, multiple-loop, nonlinear feedback systems. The Dynamo Simulation Language is used. *3 sem. hrs.*

ENM 556. SYSTEM DYNAMICS II: Continuation of ENM 555 with emphasis on the study of large-scale corporate, urban, educational, and ecological systems. Prerequisite: ENM 555 or equivalent. *3 sem. hrs.*

ENM 560. QUALITY ASSURANCE: Application of statistical principles of analysis and control to production processes, studies of process capabilities, quality control, and engineering experimentation. Special topics covered include Total Quality Management, ISO 9000, and other current QC issues. Prerequisite: MSC 501 or equivalent. *3 sem. hrs.*

ENM 561. DESIGN AND ANALYSIS OF EXPERIMENTS: Advanced topics in experimental design and analysis, including experimental design, response surface analysis, multiple and partial regression and correlation. The use of the digital computer is emphasized. Prerequisite: MSC 501 or equivalent. *3 sem. hrs.*

ENM 565. RELIABILITY ENGINEERING I: An introduction to the concepts and methodology of reliability engineering. The reliability, maintainability, and availability of components and multi-component systems are analyzed. Topics include exponential, Weibull, lognormal and normal failure laws, static reliability, hazard rate functions, state dependent failure rate models, redundancy, censoring, empirical models, curve fitting to failure data, and reliability growth testing. Prerequisite: MSC 501 or equivalent. *3 sem. hrs.*

ENM 566. RELIABILITY ENGINEERING II: Continuation of ENM 565. Advanced topics in reliability engineering, with emphasis on the design of systems to meet specified reliability, availability, and maintainability requirements. Prerequisite: ENM 565 or equivalent. *3 sem. hrs.*

ENM 572. SYSTEM SIMULATION: An introduction to stochastic simulation. Topics covered include the generation of random numbers and random variables, the analysis of input data, the computer modeling of real systems, the strategies, tactics, and experimentation in performing a simulation study, and the statistical analysis of simulation output. Prerequisites: MSC 501 and ENM or MSC 522. *3 sem. hrs.*

ENM 575. INTRODUCTION TO ARTIFICIAL INTELLIGENCE: Introduction to the methods of AI with an emphasis on engineering design and analysis. Topics include knowledge representation, search, rule-based systems, pattern matching, automated reasoning, natural language processing, computer vision, and robotics. Most applications are illustrated with small Common Lisp programs. *3 sem. hrs.*

ENM 577. INTRODUCTION TO EXPERT SYSTEMS: Introduction to the development and application of rule-based systems using an integrated environment of commands, rules, databases, spreadsheets, text processing, and forms. Topics include knowledge representation, inference, search, ID3 algorithm, and logic along with suitable applications and subsequent implementations. *3 sem. hrs.*

ENM 579. SELECTED TOPICS IN ARTIFICIAL INTELLIGENCE: Special topics include engineering applications using neural net architecture, object-oriented programming, genetic algorithm and advanced search methods illustrated in Common Lisp and a rule-based environment. Prerequisites: ENM/MSC 575 and ENM/MSC 577 or permission of the instructor. *1-3 sem. hrs.*

ENM 582. ORGANIZATIONAL DEVELOPMENT IN AN ENGINEERING ENVIRONMENT: The interpersonal and group skills needed by the engineering manager. Emphasis on establishing work environments which allow for communication, trust, high morale, satisfaction, and productive group activity. Special topics covered include TQM implementation, high performing teams, and other current issues. *3 sem. hrs.*

ENM 585. ORGANIZATIONAL SYSTEMS: Introduction to organizational theory and practice with emphasis on the design of organizational structures for the effective integration of production, research and development, and engineering activities. Special topics include high performing systems, the technical ad-hoc committee, matrix organization, and project management and other current issues. *3 sem. hrs.*

ENM 586. DESIGN OF ORGANIZATIONAL SYSTEMS: Guided study of the design and simulations of organizations. The emphasis is on the simulation and implementation of actual design to an organization. Prerequisite: ENM 585. *3 sem. hrs.*

ENM 590. CASE STUDIES IN ENGINEERING MANAGEMENT: Student participation in an engineering management project or study under the direction of a project advisor. A satisfactory written engineering report, as determined by the project advisor, is required at the completion of the project. Prerequisite: permission of the advisor. *3 sem. hrs.*

ENM 595. SPECIAL PROBLEMS IN ENGINEERING MANAGEMENT: Special assignments in engineering management to be arranged and approved by the advisor and the program director. *1-3 sem. hrs.*

MANAGEMENT SCIENCE (MSC)

Patrick J. Sweeney, Chair

PROGRAM REQUIREMENTS

The program leading to the Master of Science in Management Science is interdisciplinary and is administered by the School of Engineering with the cooperative support of the College of Arts and Sciences, the School of Business Administration, and the School of Education. Applications are invited from college graduates in all fields of study—business, education, engineering, the liberal arts, the physical sciences, and the social sciences. The applicant whose preparation does not include at least three semesters of analytic geometry and calculus and competence in a computer language will be expected to satisfactorily complete appropriate prerequisite courses prior to admission to the program.

The management scientist is the manager or staff specialist who is trained in the quantitative methodologies of operations research, systems analysis, and the decision sciences. The student is proficient in problem solving and decision making, system modeling and optimization, and the application of probability and statistical theory to management problems and must be familiar with a variety of other topics, such as quality control, inventory planning and control, reliability and maintainability, and system simulation.

The objective of this program is to develop quantitative management skills and capabilities appropriate to each student's needs and objectives. The program emphasizes the practical application of the techniques of management science in our modern society, and the importance of the computer as a tool for the management scientist is stressed throughout the program. The program of study must include a minimum of 36 semester hours consisting of the following:

1. Eighteen semester hours of courses in Management Science. These should provide depth in both deterministic and stochastic methods and will normally include MSC 521, 522, 535, and three courses selected in consultation with the advisor.
2. Nine semester hours in a cognate field appropriate to the student's objectives, as approved by the advisor. Approved fields of study for the cognate field include applied mathematics, artificial intelligence, business administration, computer science, educational administration, engineering, human factors, manufacturing, and public administration.
3. Nine semester hours of electives to include MSC 500 and MSC 501 or equivalent courses or demonstrated knowledge of the subject, and approved by the advisor and the chair.

See also Master's Degree Regulations in the introductory section of this chapter and consult with the advisor.

COURSES OF INSTRUCTION

MSC 500. PROBABILISTIC METHODS I. Advanced methods of engineering analysis for engineering managers and management scientists. Methods of operational calculus, probability modeling, and statistical analysis as applied to problems of analysis and design in engineering systems and management science. *3 sem. hrs.*

MSC 501. PROBABILISTIC METHODS II: Advanced methods of engineering analysis for engineering managers and management scientists. Methods of linear algebra and inferential and experimental statistics as applied to problems of analysis and design in engineering systems and management science. Prerequisite: MSC 500 or equivalent. *3 sem. hrs.*

MSC 521. OPERATIONS RESEARCH I: An introduction to the deterministic models and methods of operations research, with emphasis on the solution of real problems in both the public and private sectors. Problem formulation, mathematical model building and algorithmic solution procedures are discussed specifically in the areas of linear, integer, and nonlinear programming, network analysis, and deterministic inventory analysis. Use is made of the personal computer in finding optimal solutions to problems. *3 sem. hrs.*

MSC 522. OPERATIONS RESEARCH II: An introduction to the probabilistic models and methods of operations research. The course focuses on risk and uncertainty in the decision-making process. Topics include Markov processes, queueing theory, stochastic inventory models, reliability engineering, and forecasting. A major focus of the course is on simulation modeling. The personal computer is used to conduct simulations. Prerequisite: MSC 500 or equivalent. *3 sem. hrs.*

MSC 523. OPTIMIZATION I: An introduction to nonlinear optimization with applications in engineering and management science. Both single variable and multivariable as well as unconstrained and constrained problems are addressed. The course is a blend of theory (e.g. Kuhn-Tucker conditions), numerical search techniques (e.g. conjugate directions methods), and applications. The personal computer is used for problem solving. *3 sem. hrs.*

MSC 526. OPTIMIZATION II: Advanced topics in linear programming with application to real-world problems. Topics include the revised simplex method, dual-simplex, interior point algorithms, duality and sensitivity analysis, decomposition principle, trans-shipment problem network simplex, and goal and integer programming. Prerequisite MSC 521. *3 sem. hrs.*

MSC 527. OPTIMIZATION III: Advanced topics in nonlinear and dynamic programming and introduction to the calculus of variations, with application to real-world problems. Topics include convex and non-convex programming, geometric, fractional, and quadratic programming, separable programming, discrete and continuous dynamic programming with both finite and infinite planning horizons, and equivalence of solutions in dynamic and non-linear programming and calculus of variations. Prerequisites MSC 523 and MSC 526. *3 sem. hrs.*

MSC 535. APPLIED OPERATIONS RESEARCH/MANAGEMENT SCIENCE: This is a capstone course for the management science program integrating the concepts and techniques covered in earlier courses. The focus is on the methodology of conducting an OR/MS study. Case studies and applications are presented. An OR/MS project is an integral part of the course. Prerequisites: MSC or ENM 521 & 522 or equivalent. *3 sem. hrs.*

MSC 541. PRODUCTION ENGINEERING: The study of the integration of man, machine, and material in producing a marketable product. Engineering techniques used to design, develop, and implement the production system are covered. Topics include break-even analysis, learning curve theory, forecasting, resource balancing, inventory and production control, facility layout and location, job sequencing and scheduling, and assembly line balancing. Modern production techniques such as just-in-time, MRP systems flexible manufacturing, and computer integrated manufacturing are discussed. Prerequisite: ENM 521 or permission of the instructor. *3 sem. hrs.*

MSC 542. INVENTORY THEORY AND APPLICATION: An in depth coverage of inventory theory including both deterministic and stochastic models. Topics include EOQ models, quantity discounting, constrained inventory, the fixed reorder point model, the fixed review model, repairable inventory systems, and dynamic inventory/production models. Also discussed are system backorder and availability models. Applications include both the public and private sectors. Prerequisites: MSC 501, MSC 521, MSC 522 or equivalent. *3 sem. hrs.*

MSC 544. DISCRETE TIME SERIES: Emphasis on industrial application of open loop statistical forecasts. Techniques of describing a time series by very general classes of functions, including trigonometric functions. Prerequisites: MSC 501, MSC 522 or equivalent. *3 sem. hrs.*

MSC 546. QUEUING THEORY AND APPLICATION: Emphasis on application of queuing theory to engineering problems. Machine interference, mathematical queueing models, marketing models, servicing problems, Monte Carlo techniques, and computer simulation models. Prerequisites: MSC 501, MSC 522 or equivalent. *3 sem. hrs.*

MSC 555. SYSTEM DYNAMICS I: Introduction to the methodology for modeling the dynamics of complex engineering, business, socioeconomic systems. The use of these models to study the effect of organizational policies and design in higher order, multiple-loop, nonlinear feedback systems. The Dynamo Simulation Language is used. *3 sem. hrs.*

MSC 556. SYSTEM DYNAMICS II: Continuation of MSC 555 with emphasis on the study of large-scale corporate, urban, educational, and ecological systems. Prerequisite: MSC 555 or equivalent. *3 sem. hrs.*

MSC 560. QUALITY ASSURANCE: Application of statistical principles of analysis and control to production processes, studies of process capabilities, quality control, and engineering experimentation. Special topics covered include Total Quality Management, ISO 9000, and other current QC issues. Prerequisite: MSC 501 or equivalent. *3 sem. hrs.*

MSC 561. DESIGN AND ANALYSIS OF EXPERIMENTS: Advanced topics in experimental design and analysis, including experimental design, response surface analysis, multiple and partial regression and correlation. The use of the digital computer is emphasized. Prerequisite: MSC 501 or equivalent. *3 sem. hrs.*

MSC 565. RELIABILITY ENGINEERING I: An introduction to the concepts and methodology of reliability engineering. The reliability, maintainability, and availability of components and multi-component systems are analyzed. Topics include exponential, Weibull, lognormal and normal failure laws, static reliability, hazard rate functions, state dependent failure rate models, redundance, censoring, empirical models, curve fitting to failure data, and reliability growth testing. Prerequisites: MSC 501 or equivalent. *3 sem. hrs.*

MSC 566. RELIABILITY ENGINEERING II: Continuation of MSC 565. Advanced topics in reliability engineering, with emphasis on the design of systems to meet specified reliability, availability, and maintainability requirements. Prerequisite: MSC 565 or equivalent. *3 sem. hrs.*

MSC 572. SYSTEM SIMULATION. An introduction to stochastic simulation. Topics covered include the generation of random numbers and random variables, the analysis of input data, the computer modeling of real systems, the strategies, tactics, and experimentation in performing a simulation study, and the statistical analysis of simulation output. Prerequisites: MSC 501 and MSC 522 or equivalent. *3 sem. hrs.*

MSC 575. INTRODUCTION TO ARTIFICIAL INTELLIGENCE: Introduction to the methods of artificial intelligence, with emphasis on application to engineering design and analysis. Topics include knowledge representation, search, expert systems, pattern matching, automated reasoning, natural language processing, computer vision, and robotics. Most applications are illustrated with small Common Lisp programs. *3 sem. hrs.*

MSC 577. INTRODUCTION TO EXPERT SYSTEMS: Introduction to the development and application of rule-based systems using an integrated environment of commands, rules, databases, spreadsheets, text processing, and forms. Topics include knowledge representation, inference, search, ID3 algorithm, and logic along with suitable applications and subsequent implementation. *3 sem. hrs.*

MSC 579. SELECTED TOPICS IN ARTIFICIAL INTELLIGENCE: Special topics include engineering applications using neural net architecture, object-oriented programming, genetic algorithm and advanced search methods illustrated in Common Lisp and a rule-based environment. Prerequisites: ENM/MSC 575 and ENM/MSC 577 or permission of the instructor. *1-3 sem. hrs.*

MSC 595. CURRENT PROBLEMS: (Subject will vary.) Topics of current interest in specialized areas of Management Science. *3 sem. hrs.*

MSC 599. THESIS *6 sem. hrs.*

MATERIALS ENGINEERING (MAT)

James A. Snide,
Director of the Program

Materials Engineering is a major concentration for both the Doctor of Philosophy in Engineering and the Doctor of Engineering. See Doctor's Degree Regulations in the introductory section of this chapter and consult with the director of the programs.

PROGRAM REQUIREMENTS

The program of study leading to the Master of Science in Materials Engineering must include a minimum of 30 semester hours consisting of the following:

1. Twelve semester hours in the major field.
2. Twelve semester hours of approved electives from current course offerings which best suit the student's requirements.
3. Six semester hours of research on a Materials Engineering project or thesis. Upon the request of the student and with the approval of the advisor and the program director, this may be replaced by six semester hours of additional course work.

See also Master's Degree Regulations in the introductory section of this chapter, and consult with the advisor.

COURSES OF INSTRUCTION

MAT 501. PRINCIPLES OF MATERIALS I: Structure of engineering materials from electronic to atomic and crystallographic considerations. Includes atomic structure and interatomic bonding, imperfections, diffusion, mechanical properties, strengthening mechanisms, failure, phase diagrams, phase transformations and processing. Prerequisites: College chemistry, physics and MTH 219. *3 sem. hrs.*

MAT 502. PRINCIPLES OF MATERIALS II: Structure and behavior of ceramics, polymers, and composites to include mechanical behavior, corrosion, electrical, thermal, magnetic and optical properties. Prerequisite: MAT 501 or equivalent. *3 sem. hrs.*

MAT 503. X-RAY CRYSTALLOGRAPHY: A broad coverage of fundamental crystallography, the interaction of x-rays with matter, and the x-ray scattering techniques used to study materials. Prerequisite: MAT 501 or consent of instructor. *3 sem. hrs.*

MAT 504. TECHNIQUES OF MATERIALS ANALYSIS: Fundamentals and applications of the traditional analytical methods such as x-ray analysis, electron microprobe, and scanning microscopy. Techniques such as NMR, atomic absorption, Raman, Mossbauer, and field ion microscopy will be covered. Emphasis on applicability. Prerequisite: MAT 501 or consent of instructor. *3 sem. hrs.*

MAT 505. THERMODYNAMICS OF SOLIDS: Laws of thermodynamics, auxiliary functions, thermodynamic relations, phase transitions, thermodynamic equilibrium, thermodynamic properties of solid solutions, surfaces and interfaces. Prerequisite: MAT 501 or consent of instructor. *3 sem. hrs.*

MAT 506. MECHANICAL BEHAVIOR OF MATERIALS: Description of the state of stress and strain in materials, plastic deformation, fatigue, fracture, creep, and rupture. Prerequisite: Undergraduate course in Strength of Materials (EGM 303) or consent of instructor. *3 sem. hrs.*

MAT 507. INTRODUCTION TO CERAMIC MATERIALS: A brief history, the raw materials, processing methods and chemistry fundamentals associated with the technology of structural ceramics are discussed. The properties (physical, thermal, mechanical, electrical, magnetic and optical) and the methods for measuring these properties for ceramic materials are reviewed. Both conventional and advanced applications for ceramics are presented. Prerequisite: MAT 501. *3 sem. hrs.*

MAT 508. PRINCIPLES OF MATERIAL SELECTION: Basic scientific and practical consideration involved in the intelligent selection of materials for specific applications. Impact of new developments in materials technology and analytical techniques. Prerequisite: MAT 501 or consent of instructor. *3 sem. hrs.*

MAT 509. INTRODUCTION TO POLYMER SCIENCE: To provide a technical overview of the nature of synthetic macromolecules including the formation of polymers and their structure, structure-property relationships, polymer characterization and processing, and applications of polymers. Prerequisites: College chemistry, calculus, and organic chemistry. *3 sem. hrs.*

MAT 510. PHYSICAL PROPERTIES OF POLYMERS: Intensive discussion of the interrelations between molecular structure and gross physical properties of polymers. Emphasis on relating laboratory data to industrial applications. Prerequisite: Background in differential equations, organic or physical chemistry, or MAT 509. *3 sem. hrs.*

MAT 511. PRINCIPLES OF CORROSION: Application of electrochemical principles, corrosion reactions, passivation, cathodic and anodic protection, stress corrosion, and high-temperature oxidation. Prerequisite: MAT 501. *3 sem. hrs.*

MAT 512. MAGNETIC MATERIALS—PHYSICAL PRINCIPLES: Description of magnetic material properties. The magnetic circuit. Atomic magnetism. Types of magnetic order and spin structure. Intrinsic magnetization. Molecular field concept. Anistotropy. Magneto-striction, Magnetic resonances. Prerequisite: ELE 333 or consent of instructor. *3 sem. hrs.*

MAT 513. MAGNETIC MATERIALS FOR ENGINEERING APPLICATIONS: Magnetic domains. Technical magnetization and domain structure. A.C. properties, losses, eddy currents. Causes of coercivity. Metallic and ceramic materials for transformers, electrical machinery, permanent magnets, HF devices, data recording, computer memories. Metallurgy and crystallography of magnetic materials. Prerequisite: MAT 512 or consent of instructor. Note: Simultaneous attendance in MAT 513S is recommended. *3 sem. hrs.*

MAT 513S. MAGNETIC MATERIALS PROSEMINAR *1 sem. hr.*

MAT 514. APPLIED SUPERCONDUCTIVITY - AN INTRODUCTION: Basic phenomena. Theoretical concepts, superconductive materials - types, properties, physics, metallurgy, superconducting magnets. Other present and future engineering applications. Prerequisite: Consent of instructor. *3 sem. hrs.*

MAT 515. STATISTICAL THERMODYNAMICS: Microscopic thermodynamics; Boltzmann, Bose-Einstein, Fermi-Dirac statistics; statistical interpretation of thermodynamic quantities. Applications to perfect and real gases, liquids, crystalline solids, and thermal radiation. Prerequisites: MEE 301, MTH 219. *3 sem. hrs.*

MAT 516. SOLIDIFICATION OF METALS: Solidification, diffusion, phase diagrams, phase transformations—diffusional and diffusionless, microstructure. Prerequisite: MAT 501 or consent of instructor. *3 sem. hrs.*

MAT 517. PHASE DIAGRAMS: Introduction to phase equilibria; construction, interpretation, and application of phase diagrams for unary, binary, ternary, and higher order systems. Prerequisite: MAT 501. *3 sem. hrs.*

MAT 518. DIFFUSION IN SOLIDS: Considers the rate of response on condensed matter to changes in environmental conditions such as temperature. Specific topics include basic rate theory, heavy emphasis on diffusion, and phase transformation. Prerequisites: MAT 501, MAT 505. *3 sem. hrs.*

MAT 519. PHASE TRANSFORMATION: Classical treatment of phase transformation, nucleation and growth, recovery and recrystallization, and advanced processes in control of microstructures and properties. New developments in the area of phase transformations. Prerequisite: MAT 501. *3 sem. hrs.*

MAT 520. POWDER METALLURGY: Detailed treatment of scientific principles behind rapid solidification processing, powder production methods: metal and ceramic powders, powder analysis and powder consolidation, principles of mechanical alloying, processing methods and steps involved in producing P/M product forms, implications of powder metallurgy microstructures on mechanical behavior. Prerequisite: MAT 501. *3 sem. hrs.*

MAT 521. NONDESTRUCTIVE EVALUATION: Both theoretical and experimental treatment of flaw detection and material characterization techniques for metals as well as advanced composites using ultrasound and eddy current methods of NDE. Also, statistical analysis of reliability, probability of detection and quality assurance provided. Prerequisite: Consent of instructor. *3 sem. hrs.*

MAT 525. DESIGN OF MACROMOLECULAR SYSTEMS: Polymer preparation by chain polymerization and stepwise polymerization; copolymerization; stereospecific polymerizations; formation of network polymers: heterogeneous reaction systems; aging and stabilization. Prerequisites: CHM 314, MAT 510. *3 sem. hrs*

MAT 526. POLYMER ENGINEERING: Rheology of polymer materials; fundamentals of polymer processing; design of processing operation and their relation to the physical and mechanical behavior of polymers in molten and solid states; control of polymer processing through proper material selection. Prerequisites: MEE 308, MEE 410, MAT 510. *3 sem. hrs.*

MAT 527. METHODS OF POLYMER ANALYSIS: Modern laboratory techniques used in preparation and characterization of polymers; experimental investigations of polymer structure-property relations; measurement of molecular weight averages and distributions, thermal and mechanical properties, viscoelastic properties; transitions and crystallinity. Prerequisites: MAT 509, MAT 510. *3 sem. hrs.*

MAT 530. INTRODUCTION TO ANALYTICAL ELECTRON MICROSCOPY: This course is an introduction to the use of analytical transmission electron microscopy applied to the study of materials. Techniques and principles of the following will be covered: design and operation of the AEM, image formation, crystallography and the reciprocal space construction, selected area diffraction, convergent beam electron diffraction, energy dispersive X-ray microanalysis, and electron energy loss spectroscopy. Prerequisite: College physics. *3 sem. hrs.*

MAT 535. HIGH-TEMPERATURE MATERIALS: This course will provide the student with the basic material behavior concepts which control high-temperature properties of metals and alloys. A special emphasis will be given to creep behavior of metals which will include a comprehensive study of relationships between microstructure and high-temperature creep deformation of pure metals, single-phase alloys, multi-phase alloys and dispersion-strengthened materials. In addition, the properties and applications of high-temperature materials will be discussed, especially of these alloys used in the aerospace industry, such as titanium and nickel-based alloys. Prerequisite: MAT 501 or equivalent. *3 sem. hrs.*

MAT 541. EXPERIMENTAL MECHANICS OF COMPOSITE MATERIALS: Introduction to the mechanical response of fiber-reinforced composite materials with emphasis on the development of experimental methodology. Analytical topics include stress-strain behavior of anisotropic materials, laminate mechanics, and strength analysis. Theoretical models are applied to the analysis of experimental techniques used for characterizing composite materials. Lectures are supplemented by laboratory sessions in which characterization tests are performed on contemporary composites. Prerequisite: EGM 303. *3 sem. hrs.*

MAT 542. ADVANCED COMPOSITES: Materials and Processing. Comprehensive introduction to advanced fiber reinforced polymeric matrix composites. Constituent materials and composite processing will be emphasized with special emphasis on structure-property relationships, the role of matrix in composite processing, mechanical behavior and laminate processing. Specific topics will include starting materials, material forms, processing, quality assurance, test methods, and mechanical behavior. Prerequisites: MAT 501, MAT 509, or consent of the instructor. *3 sem. hrs.*

MAT 543. ANALYTICAL MECHANICS OF COMPOSITE MATERIALS: Analytical models are developed for predicting the mechanical and thermal behavior of fiber reinforced composite materials as a function of constituent material properties. Both continuous and discontinuous fiber reinforced systems are considered. Specific topics include basic mechanics of anisotropic materials, micromechanics, lamination theory, free-edge effects, and failure criteria. Prerequisite: EGM 303 *3 sem. hrs.*

MAT 544. MECHANICS OF COMPOSITE STRUCTURES: Comprehensive treatment of laminated beams, plates, and sandwich structures. Effect of heterogeneity and anisotropy on bending under lateral loads, buckling, and free vibration are emphasized. Shear deformation and other higher-order theories and their range of parametric application are also considered. Prerequisite: MAT 543 or consent of instructor. *3 sem. hrs.*

MAT 550. MATERIALS ENGINEERING PROJECT: Student participation in a materials engineering project under the direction of a project advisor. The student prepares a satisfactory written report, as determined by the project advisor, and presents an open seminar on the subject of the project. *1-6 sem. hrs.*

MAT 560. INTRODUCTION TO IMPACT DYNAMICS: Introduction to impact phenomena, characteristics of elastic stress waves in bars, elastic-plastic stress waves in bars and plates, introduction to shock waves, material characterization at high strain rates, experimental techniques, impact on ductile, brittle, and composite materials, computer codes for impact simulation. *3 sem. hrs.*

MAT 562. SHOCK WAVES AND PENETRATION MECHANICS: Shock waves in ductile, brittle and composite materials, penetration mechanics of projectiles in metals, composites, and brittle materials, analytical and computational modelling. Prerequisite: MAT 560. *3 sem. hrs.*

MAT 570. FRACTURE MECHANICS: Application of principles of fracture mechanics to fatigue and fracture in engineering structures. Prerequisite: MAT 506 or consent of instructor. *3 sem. hrs.*

MAT 575. FRACTURE AND FATIGUE OF METALS AND ALLOYS I: Treatment of the effects of microstructure on the fracture and fatigue of engineering metals and alloys with a special emphasis on static and dynamic brittle and ductile failures and crack initiation. Alloy fracture resistance, fracture toughness, and method to improve fracture behavior will be discussed in detail. Various analytical techniques in the failure analysis of structural components will be presented. Prerequisites: MAT 501, MAT 506 or consent of instructor. *3 sem. hrs.*

MAT 576. FRACTURE AND FATIGUE OF METALS AND ALLOYS II: This course will cover the areas of the effects of microstructure on fatigue crack propagation and of environment on fracture and fatigue. This will include fatigue life prediction, damage tolerance approach to component design and microstructural and structural synthesis for optimum behavior. Specific material-related aspects of fatigue mechanisms, fracture mechanics approach, and failure analysis will also be covered. Prerequisite: MAT 575 or equivalent. *3 sem. hrs.*

MAT 590. SELECTED READINGS IN MATERIALS ENGINEERING: Directed readings in selected areas of materials engineering arranged and approved by the student's advisor and the program director. *1-3 sem. hrs.*

MAT 595. SPECIAL PROBLEMS IN MATERIALS ENGINEERING: Special assignments arranged by the materials engineering faculty. *1-3 sem. hrs.*

MAT 599. THESIS *3-6 sem. hrs.*

MAT 601. SURFACE CHEMISTRY OF SOLIDS: The nature of solid surfaces as determined by the techniques of x-ray photoelectron and Auger electron spectroscopy, secondary ion mass spectrometry, and ion scattering spectroscopy. Prerequisite: MAT 501 or consent of instructor. *3 sem. hrs.*

MAT 690. SELECTED READINGS IN MATERIALS ENGINEERING: Directed readings in materials engineering area arranged and approved by the chair of the student's advisory committee and the program director. May be repeated. *1-3 sem. hrs.*

MAT 695. SPECIAL PROBLEMS IN MATERIALS ENGINEERING: Special assignments in materials engineering subject matter arranged and approved by the student's doctoral advisory committee and the program director. May be repeated. *1-3 sem. hrs.*

MAT 698. D.E. DISSERTATION: An original investigation as applied to materials engineering practice. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*

MAT 699. Ph.D. DISSERTATION: An original research effort which makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*

Department of

MECHANICAL ENGINEERING (MEE)

Glen Johnson,
Chair of the Department

Mechanical Engineering is a major concentration for both the Doctor of Philosophy in Engineering and the Doctor of Engineering. See Doctor's Degree Regulations in the introductory section of this chapter and consult with the department chair and the director of the programs.

PROGRAM REQUIREMENTS

For the Master of Science in Mechanical Engineering, major areas of concentration are Materials, Thermal Sciences, Fluid Mechanics, Solid Mechanics, Mechanical Design, and Integrated Manufacturing. Each program of study leading to this degree must include a minimum of 30 semester hours approved by the student's advisor, and consisting of the following:

1. Twelve semester hours in mechanical engineering courses to be selected from one of the following areas of concentration.

   Materials—MEE 501, 502, 503, 505, 506, 508, 509, 525, 541, 542, 543, 544, 570, 575, 576.

   Thermal Sciences—MEE 503, 504, 505, 511, 512, 513, 514, 515, 516, 517, 552, 565, 566, 567, 568, 569.

   Fluid Mechanics—MEE 503, 504, 513, 516, 540, 552, 553, 555.
   AEE 501, 502, 554, 556, 558.

   Solid Mechanics—MEE 503, 519, 533, 534, 535, 536, 538, 539, 543, 544, 545, 546, 547, 548, 549, 570, 575.
   Mechanical Design—MEE 503,

506, 527, 532, 533, 534, 535, 536, 538, 539, 540, 545, 546, 547, 548, 549, 570, 575, 582, 585.

Integrated Manufacturing—
MEE 527, 545, 580, 581, 582, 583, 584, 585.

2. Six semester hours of research on a mechanical engineering project or thesis. Both a written document and an oral presentation are required. Upon the request of the student and with the approval of the faculty advisor and the department chair, this requirement may be replaced by six semester hours of additional course work. A maximum of six semester hours may be taken in 550, 590, 595, and 599 courses.
3. Three semester hours of mathematics approved by the student's advisor.
4. Up to nine semester hours of electives, to be chosen from current course offerings which best suit the student's requirements and approved by the student's advisor.

See also Master's Degree Regulations in the introductory section of this chapter and consult with the advisor.

COURSES OF INSTRUCTION

MEE 500. ADVANCED ENGINEERING ANALYSIS: Detailed analysis of engineering problems using laws of nature, fundamental engineering principles, mathematics, computers and practical experience to construct, resolve and test analytic models of physical events. Emphasis is on the use of the professional engineering approach which includes formulation of the problem, assumptions, plan or method of attack, solving the problem, checking and generalizing the results. *3 sem. hrs.*

MEE 501. PRINCIPLES OF MATERIALS I: Structure of engineering materials from electronic to atomic and crystallographic considerations. Includes atomic structure and interatomic bonding, imperfections, diffusion, mechanical properties, strengthening mechanisms, failure, phase diagrams, phase transformations and processing. Prerequisites: College chemistry, physics and MTH 219. *3 sem. hrs.*

MEE 502. PRINCIPLES OF MATERIALS II: Structure and behavior of ceramics, polymers and composites to include mechanical behavior, corrosion, electrical, thermal, magnetic and optical properties. Prerequisite: MAT 501 or equivalent. *3 sem. hrs.*

MEE 503. INTRODUCTION TO CONTINUUM MECHANICS: Tensors, calculus of variations, Lagrangian and Eulerian descriptions of motion. General equations of continuum mechanics, constitutive equations of mechanics, thermodynamics of continua. Specialization to cases of solid and fluid mechanics. Prerequisite: EGM 303. *3 sem. hrs.*

MEE 504. FUNDAMENTALS OF FLUID MECHANICS: An advanced course in fluid mechanics with emphasis on the derivation of conservation equations and the application of constitutive theory. Development and scope of the Navier-Stokes equations. Nature and role of vorticity transport. Exact and approximate solutions to classical viscous and inviscid problems. Compressible and incompressible flows. Co-requisite: MEE 503. *3 sem. hrs.*

MEE 505. THERMODYNAMICS OF SOLIDS: Laws of thermodynamics, auxiliary functions, thermodynamic relations, phase transitions, thermodynamic equilibrium, thermodynamic properties of solid solutions, surfaces and interfaces. Prerequisite: MAT 501 or consent of instructor. *3 sem. hrs.*

MEE 506. MECHANICAL BEHAVIOR OF MATERIALS: Description of the state of stress and strain in materials, plastic deformation, fatigue, fracture, creep, and rupture. Prerequisite: EGM 303 or consent of instructor. *3 sem. hrs.*

MEE 508. PRINCIPLES OF MATERIALS SELECTION: Basic scientific and practical consideration involved in the intelligent selection of materials for specific applications. Impact of new developments in materials technology and analytical techniques. Prerequisite: MEE 501 or consent of instructor. *3 sem. hrs.*

MEE 509. INTRODUCTION TO POLYMER SCIENCE: To provide a technical overview of the nature of synthetic macromolecules including the formation of polymers and their structure-property relationships, polymer characterization and processing, and applications of polymers. Prerequisites: College chemistry, calculus, and organic chemistry. *3 sem. hrs.*

MEE 511. CLASSICAL THERMODYNAMICS: Equilibrium, first law, second law, state principle, and zeroth law; development of entropy and temperature from availability concepts; chemical potential, chemical equilibrium, and phase equilibrium. Thermodynamics of irreversible processes; Onsager reciprocal relations; application of these concepts to direct energy conversion. *3 sem. hrs.*

MEE 512. MICROSCOPIC THERMODYNAMICS: Microscopic thermodynamics; kinetic theory; virial theorem of Clausius; transport phenomena; Gibbs, Boltzman, Bose-Einstein, Fermi-Dirac statistics. Connection between statistical and thermodynamic quantities. Applications to perfect and real gases, liquids, crystalline solids, and thermal radiation. Irreversible thermodynamics. *3 sem. hrs.*

MEE 513. PROPULSION: Principles of propulsive devices, aerothermodynamics, diffuser and nozzle flow, energy transfer in turbo-machinery, turbojet, turbo-fan, prop-fan engines, turbo-prop and turboshaft engines. RAM and SCRAM jet analysis and a brief introduction to related materials and air frame-propulsion interaction. Prerequisite: MEE 418. *3 sem. hrs.*

MEE 514. DIRECT ENERGY CONVERSION: Introduction to the principles of direct energy conversion. Irreversible thermodynamics; semiconductors; thermoelectric and photovoltaic devices; magnetohydrodynamics; thermionic devices; fuel cells. Prerequisite: MEE 410. *3 sem. hrs.*

MEE 515. CONDUCTION HEAT TRANSFER: Steady state and transient state conduction. Evaluation of temperature fields by formal mathematics and numerical analysis. Emphasis on approximate solution techniques. *3 sem. hrs.*

MEE 516. CONVECTION HEAT AND MASS TRANSFER: Development of governing differential equations for convection. Methods of solution including similarity methods, integral methods, and superposition of solutions. Turbulent flow convection; integral methods, eddy diffusivities for heat and momentum. Extensions to mass transfer. Prerequisite: MEE 410 or equivalent. *3 sem. hrs.*

MEE 517. RADIATION HEAT TRANSFER: Fundamental relationships of radiation heat transfer. Radiation characteristics of surfaces. Geometric considerations in radiation exchange between surfaces. Emissivity and absorptivity of gases. Introduction to radiative exchange in gases. *3 sem. hrs.*

MEE 518. PHASE CHANGE HEAT TRANSFER AND INTERFACIAL PHENOMENA: Interfacial thermodynamics of liquid-vapor-solid systems; surface wetting statics and dynamics; interfacial and phase stability; homogeneous and heterogeneous nucleation; and boiling heat transfer. Application to liquid-vapor phase change. *3 sem. hrs.*

MEE 519. ANALYTICAL DYNAMICS: Dynamical analysis of a system of particles and of rigid bodies; Lagrangian and Hamiltonian formulation of equations of motion; classical integrals of motion; stability analysis of linear and nonlinear systems. Prerequisites: MTH 219 and EGM 202 or equivalent. *3 sem. hrs.*

MEE 525. PRINCIPLES OF CORROSION: Application of electrochemical principles, corrosion reactions, passivation, cathodic and anodic protection, stress corrosion, and high-temperature oxidation. Prerequisite: MEE 501. *3 sem. hrs.*

MEE 527. AUTOMATIC CONTROL THEORY: Stability and performance of automatic control systems. Classical methods of analysis including transfer functions, time-domain solutions, root locus and frequency response methods. Modern control theory techniques including state variable analysis, transformation to companion forms. controllability, pole placement, observability and observer systems. Prerequisite: ELE 432 or MEE 435 or equivalent. *3 sem. hrs.*

MEE 532. ACOUSTICS: Physics of sound propagation, psychological effects of noise, noise control criteria and regulations, transmission phenomena, acoustics of walls and enclosures, resonators and filters, acoustic properties of materials, acoustic consideration in structural and machine design. *3 sem. hrs.*

MEE 533. THEORY OF ELASTICITY: Three-dimensional stress and strain at a point; equations of elasticity in Cartesian and curvilinear coordinates; methods of formulation of equations for solution; plane stress and plane strain; energy formulations; numerical solution procedures. Prerequisite: EGM 303: Corequisite: EGM 503. *3 sem. hrs.*

MEE 534. THEORY OF PLATES AND SHELLS: Theory of plates: small and large displacement theories of thin plates; shear deformation; buckling; sandwich plate theory. Thin shell theory: theory of surfaces; thin shell equations in orthogonal curvilinear coordinates; bending, membrane, and shallow shell theories. Prerequisite: EGM 533. *3 sem. hrs.*

MEE 535. ADVANCED MECHANICAL VIBRATIONS: Review of undamped, damped, natural and forced vibrations of one and two degrees of freedom systems. Lagrange's equation, eigenvalue/eigenvector problem, modal analysis for discrete and continuous systems. Computer application for multi-degree of freedom, nonlinear problems. Prerequisites: Computer Programming and MEE 319. *3 sem. hrs.*

MEE 536. RANDOM VIBRATIONS: Introduction to probability distribution; characterization of random vibrations; harmonic analysis; auto- and cross-correlation and spectral density; coherence; response to single and multiple loadings; Fast Fourier Transform (FFT); applications in vibrations, vehicle dynamics, fatigue, etc. Prerequisites: Computer Programming and MEE 319. *3 sem. hrs.*

MEE 538. INTRODUCTION TO AEROELASTICITY: The study of the effect of aerodynamic forces on a flexible aircraft. Flexibility coefficients and natural modes of vibration. Quasi-steady aerodynamics. Static aeroelastic problems; wing divergence and dynamic aeroelasticity; wing flutter. An introduction to structural stability augmentation with controls. Prerequisite: AEE 501 or equivalent. *3 sem. hrs.*

MEE 539. THEORY OF PLASTICITY: Fundamentals of plasticity theory including elastic, viscoelastic, and elastic-plastic constitutive models; plastic deformation on the macroscopic and microscopic levels; stress-strain relations in the plastic regime; strain hardening; limit analysis; numerical procedures. Prerequisite: EGM 503 or 533. *3 sem. hrs.*

MEE 540. BEARINGS AND BEARING LUBRICATION: Theoretical aspects of lubrication; determination of pressure distribution in bearings from viscous flow theory; application of hydrodynamic and hydrostatic bearing theories to the design of bearings; high-speed bearing design problems; properties of lubricants; methods of testing. *3 sem. hrs.*

MEE 541. EXPERIMENTAL MECHANICS OF COMPOSITE MATERIALS: Introduction to the mechanical response of fiber-reinforced composite materials with emphasis on the development of experimental methodology. Analytical topics include stress-strain behavior of anisotropic materials, laminate mechanics, and strength analysis. Theoretical models are applied to the analysis of experimental techniques used for characterizing composite materials. Lectures are supplemented by laboratory sessions in which characterization tests are performed on contemporary composites. Prerequisite: EGM 303. *3 sem. hrs.*

MEE 542. ADVANCED COMPOSITES: Materials and processing. Comprehensive introduction to advanced fiber reinforced polymeric matrix composites. Constituent materials and composite processing will be emphasized with special emphasis placed on structure-property relationships, the role of the matrix in composite processing, mechanical behavior and laminate processing. Specific topics will include starting materials, material forms, processing, quality assurance, test methods and mechanical behavior. Prerequisites: MEE 501, MEE 509, or consent of the instructor. *3 sem. hrs.*

MEE 543. ANALYTICAL MECHANICS OF COMPOSITE MATERIALS: Analytical models are developed for predicting the mechanical and thermal behavior of fiber-reinforced composite materials as a function of constituent material properties. Both continuous and discontinuous fiber-reinforced systems are considered. Specific topics include basic mechanics of anisotropic materials, micromechanics, lamination theory, free-edge effects, and failure criteria. Prerequisite: EGM 303. *3 sem. hrs.*

MEE 544. MECHANICS OF COMPOSITE STRUCTURES: Comprehensive treatment of laminated beams, plates, and sandwich structures. Effect of heterogeneity and anisotropy on bending under lateral loads, buckling, and free vibration are emphasized. Shear deformation and other higher-order theories and their range of parametric application are also considered. Prerequisite: MEE 543 or consent of instructor. *3 sem. hrs.*

MEE 545. COMPUTATIONAL METHODS FOR DESIGN: Modeling of mechanical systems and structures, analysis by analytical and numerical methods, development of mechanical design criteria and principles of optimum design, selected topics in mechanical design and analysis, use of the digital computer as an aid in the design of mechanical elements. Prerequisite: Computer Programming. *3 sem. hrs.*

MEE 546. FINITE ELEMENT ANALYSIS I: Fundamental development of the Finite Element Method (FEM), and solution of field problems and comprehensive structural problems. Variational principles and weak-forms; finite element discretization; shape functions; finite elements for field problems; bar, beam, plate, and shell elements; isoparametric finite elements; stiffness, nodal force, and mass matrices; matrix assembly procedures; computer dosing techniques; modeling decisions; program output interpretation. Course emphasis on a thorough understanding of FEM theory and modeling techniques. Prerequisite: MEE 503 or MEE 533. *3 sem. hrs.*

MEE 547. FINITE ELEMENT ANALYSIS II: Advanced topics: heat transfer; transient dynamics; nonlinear analysis; substructuring and static condensation; effects of inexact numerical integration and element incompatibility; patch test; frontal solution techniques; selected topics from the recent literature. Prerequisite: MEE 546. *3 sem. hrs.*

MEE 548. ENERGY METHODS IN SOLID MECHANICS: Development of fundamental energy principles; virtual displacements, strain energy, Castigliano's theorems, minimum potential energy principles. Applications to engineering problems; redundant structures, buckling, static and dynamic analysis. Prerequisite: MEE 503 or MEE 533. *3 sem. hrs.*

MEE 549. THEORY OF ELASTIC STABILITY: Introduction to stability theory: buckling of plates and shells; influence of initial imperfections; nonlinear analysis: numerical solutions methods. Prerequisite: MEE 533. *3 sem. hrs.*

MEE 550. MECHANICAL ENGINEERING PROJECT: Student participation in a departmental research, design, or development project under the direction of a project advisor. The student must show satisfactory progress as determined by the project advisor and present a written report at the conclusion of the project. *1-6 sem. hrs.*

MEE 552. BOUNDARY LAYER THEORY: Development of the Prandtl boundary layer approximation in two and three dimensions for both compressible and incompressible flow. Exact and approximate solutions for laminar flows. Unsteady boundary layers. Linear stability theory and transition to turbulence. Empirical and semi-empirical methods for turbulent boundary layers. Higher-order boundary layer theory. Prerequisite: MEE 504 or equivalent. *3 sem. hrs.*

MEE 553. COMPRESSIBLE FLOW: Fundamental equations of compressible flow, introduction to flow in two and three dimensions. Two-dimensional supersonic flow, small perturbation theory, method of characteristics, oblique shock theory. Introduction to unsteady one-dimensional motion and shock tube theory. Method of surface singularities. Prerequisite: MEE 504 or equivalent. *3 sem. hrs.*

MEE 555. TURBULENCE: Origin, evolution, and dynamics of fully turbulent flows. Description of statistical theory, spectral dynamics, and the energy cascade. Characteristics of wall-bounded and free turbulent shear flows. Reynolds stress models. *3 sem. hrs.*

MEE 565. FUNDAMENTALS OF COMBUSTION: Heat of combustion and flame temperature calculations: rate of chemical reaction and Arrhenius relationship: theory of thermal explosions and the concept of ignition delay and critical mass: phenomena associated with hydrocarbon-air combustion: specific applications of combustion. *3 sem. hrs.*

MEE 566. COMBUSTION THEORY: Theory of detonation (Rankine-Hugoniot relationships) and flame propagation rates in pre-gas mixed systems: turbulent flames and the well stirred reactor; theory of diffusion flames; fuel droplet combustion; steady burning of solid materials, ignition and flame spreading across solid materials. *3 sem. hrs.*

MEE 567. SOLAR HEATING ANALYSIS: Topics dealing with energy usage patterns; thermal insulation studies and energy conversion schemes; building heating load calculations; characteristics and measurement of solar radiation; analysis and testing of solar collectors; active and passive solar heating systems; economic trends of solar heating; heat pumps. *3 sem. hrs.*

MEE 568. INTERNAL COMBUSTION ENGINES: A study of combustion and energy release processes. Applications to spark and compression ignition, jet, rocket, and gas turbine engines. Special emphasis given to understanding of air pollution problems caused by internal combustion engines. Idealized and actual cycles are studied in preparation for laboratory testing of I.C. engines. *3 sem. hrs.*

MEE 569. HEATING AND AIR CONDITIONING: Topics dealing with thermal environments and methods of control, Included are psychometrics, solar radiation, heat transmission through solid boundaries, industrial and residential environments, residential heating and cooling load calculations. *3 sem. hrs.*

MEE 570. FRACTURE MECHANICS: Application of the principles of fracture mechanics to fatigue and fracture in engineering structures. Prerequisite: MEE 506 or consent of instructor. *3 sem. hrs.*

MEE 575. FRACTURE AND FATIGUE OF METALS AND ALLOYS I: Treatment of the effects of microstructure on the fracture and fatigue of engineering metals and alloys with a special emphasis on static and dynamic brittle and ductile failures and crack initiation. Alloy fracture resistance, fracture toughness, and method to improve fracture behavior will be discussed in detail. Various analytical techniques in the failure analysis of structural components will be presented. Prerequisites: MEE 501, MEE 506 or consent of instructor. *3 sem. hrs.*

MEE 576. FRACTURE AND FATIGUE OF METALS AND ALLOYS II: This course will cover the areas of the effects of microstructure on fatigue crack propagation and of environment on fracture and fatigue. This will include fatigue life prediction, damage tolerance approach to component design and microstructural and structural synthesis for optimum behavior. Specific material-related aspects of fatigue mechanisms, fracture mechanics approach, and failure analysis will also be covered. Prerequisite: MEE 575 or equivalent. *3 sem. hrs.*

MEE 580. PRODUCT AND PROCESS AUTOMATION: General introduction to the modern techniques utilized in mechanical product and manufacturing process design. Topics in the various technologies associated with CAE/CAD/CAM/CIM. *3 sem. hrs.*

MEE 581. COMPUTER-AIDED ENGINEERING: Treatment of topics associated with the initial design, analysis and stimulation phase of the product development process. Development and use of analysis and stimulation tools. *3 sem. hrs.*

MEE 582. AUTOMATED DESIGN: Perform activities associated with the detailed design, drafting, and documentation of mechanical parts and components. Address system programming, system management requirements, modeling techniques and data base requirements. *3 sem. hrs.*

MEE 583. AUTOMATED MANUFACTURING: Treatment of topics associated with manufacturing engineering functions and issues in automation. Discuss numerical control, process planning, quality assurance, process simulation, manipulators, and other related technologies. *3 sem. hrs.*

MEE 584. INTEGRATED MANUFACTURING SYSTEMS: Address topics associated with the design, implementation, planning and control of fixed and flexible manufacturing and assembly systems in conjunction with communications and computer technologies. Discuss issues associated with group technology and systems integration. *3 sem. hrs.*

MEE 585. DESIGN FOR PRODUCIBILITY: Concurrent treatment of product design and manufacturing process issues. Application of various methodologies, tools, and evaluation schemes on various product design, manufacturing, and assembly-related activities. *3 sem. hrs.*

MEE 590. SELECTED READINGS: Directed readings in a designated area arranged and approved by the student's faculty advisor and the departmental chair. May be repeated. (A) Materials, (B) Thermal Sciences (C) Fluid Mechanics, (D) Solids Mechanics, (E) Mechanical Design, (F) Intergrated Manufacturing. *1-6 sem. hrs. each*

MEE 595. SPECIAL PROBLEMS IN MECHANICAL ENGINEERING: Special assignments in mechanical engineering subject matter arranged and approved by the student's faculty advisor and the department chair. *1-6 sem. hrs.*

MEE 599. THESIS *1-6 sem. hrs.*

MEE 690. SELECTED READINGS: Directed readings in a designated area arranged and approved by the student's doctoral advisory committee and the departmental chair. May be repeated. (A) Materials, (B) Thermal Sciences, (C) Fluid Mechanics, (D) Solid Mechanics (E) Mechanical Design (F) Integrated Manufacturing. *1-6 sem. hrs. each*

MEE 695. SPECIAL PROBLEMS IN MECHANICAL ENGINEERING: Special assignments in mechanical engineering subject matter arranged and approved by the student's doctoral advisory committee and the department chair. May be repeated. *1-6 sem. hrs.*

MEE 698. D.E. DISSERTATION: An original investigation as applied to mechanical engineering practice. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*

MEE 699. Ph.D. DISSERTATION: An original research effort which makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication. *1-15 sem. hrs.*