6605. Transmission Electron Microscopy Laboratory. 1 hour. Students gain hands-on experience in TEM, electron diffraction, EDS, STEM, and sample preparation equipment. Closely follows the MTSE 6600 lecture course, and concurrent enrollment in both courses is strongly recommended. Prerequisite(s): MTSE 5620. MTSE 6600 must be completed prior to or concurrently with this laboratory.

6610. Diffraction Science. 3 hours. Diffraction theory; scattering and diffraction experiments; kinematic theory; dynamical theory; x-ray topography; crystal structure analysis; disordered crystals; quasi-crystals. Prerequisite(s): MTSE 5600, 5610 or consent of department.

6620. Advanced Electron and Ion Microscopy. 2 hours. Gives students with existing electron and ion microscopy backgrounds the opportunity to gain theoretical and practical knowledge of advanced analytical techniques. Specific advanced topics include focused ion beam specimen preparation and patterning, Z-contrast scanning transmission electron microscopy, advanced diffraction and defect analysis, electron energy loss spectroscopy and energy filtered imaging in the transmission electron microscope, high resolution transmission electron microscopy imaging and 3D imaging of nanostructures using focused ion beam and tilt-series transmission electron microscopy. Specific applications of these techniques to modern problems in materials science are stressed. Prerequisite(s): MTSE 6600 and MTSE 6605.

6625. Advanced Electron and Ion Microscopy Laboratory. 1 hour. Gives students with existing electron and ion microscopy backgrounds the opportunity to gain hands-on knowledge of advanced analytical microscopy techniques. Specific advanced topics include focused ion beam specimen preparation and patterning, Z-contrast scanning transmission electron microscopy, advanced diffraction and defect analysis, electron energy loss spectroscopy and energy filtered imaging in the transmission electron microscope, high resolution transmission electron microscopy imaging and 3D imaging of nanostructures using focused ion beam and tilt-series transmission electron microscopy. Specific applications of these techniques to modern problems in materials science are stressed. Prerequisite(s): MTSE 6600 and MTSE 6605. MTSE 6620 must be completed prior to or concurrently with this laboratory.

6800. Selected Topics in Materials Science. 3 hours. Topics from specialized areas of materials science, physics and chemistry. May be repeated for credit as topics vary.

6900-6910. Special Problems. 1–3 hours each. Special problems in experimental or theoretical for advanced materials science graduate students. Problem chosen by the student with the approval of the supervising professor.

6940. Individual Research. 1–3 hours. To be scheduled by the doctoral candidate engaged in research. May be repeated for credit.

6950. Doctoral Dissertation. 3, 6 or 9 hours. To be scheduled only with consent of department. 12 hours credit required. No credit assigned until dissertation has been completed and filed with the graduate dean. Doctoral students must maintain continuous enrollment in this course subsequent to passing qualifying examination for admission to candidacy. May be repeated for credit.

6970. Seminar for Doctoral Candidates. 3 hours. Demonstration of competence in a specific area of materials science as evidenced by criteria established by the faculty of each discipline. May be repeated for credit.

6990. Postdoctoral Research. 3 hours. For postdoctoral fellows to further training and research experience in developing and solving problems independently. Prerequisite(s): consent of department. May be repeated for credit.

Mathematics

The content of courses will vary from time to time, reflecting current trends and recent developments.

Mathematics, MATH

5000. Instructional Issues for the Professional Mathematician. 3 hours. Focus on various instructional issues from the perspective of the professional mathematician. Some major topics include course planning, the content of a course syllabus, lecture styles, the preparation and mechanics of lectures, the conduct of problem solving sessions, classroom management, the student-instructor relationship, examination formats, the preparation, administration and grading of examinations and the management of teaching assistants and graders. Prerequisite(s): consent of department.

5010. Foundations of Mathematics. 3 hours. Mathematical logic and set theory; axiomatic methods; cardinal arithmetic; ordered sets and ordinal numbers; the axiom of choice and its equivalent forms; the continuum hypothesis. Prerequisite(s): consent of department.

5050. Linear Programming. 3 hours. Convex polyhedra, simplex method, duality theory, network flows, integer programming, ellipsoidal method, applications to modeling and game theory. Prerequisite(s): consent of department.

5110-5120. Introduction to Analysis. 3 hours each. A rigorous development for the real case of the theories of continuous functions, differentiation, Riemann integration, infinite sequences and series, uniform convergence and related topics; an introduction to the complex case.

5200. Topics in Dynamical Systems. 3 hours. Dynamical systems in one and higher dimensions. Linearization of hyperbolic fixed points. Hamiltonian systems and twist maps. The concept of topological conjugacy and structural stability. Anosov diffeomorphisms, geodesic flow and attractors. Chaotic long-term behavior of these hyperbolic systems. Measures of complexity. Prerequisite(s): consent of department.

5210-5220. Numerical Analysis. 3 hours each. A rigorous mathematical analysis of numerical methods: norms, error analysis, linear systems, eigenvalues and eigenvectors, iterative methods of solving non-linear systems, polynomial and spline approximation, numerical differentiation and integration, numerical solution or ordinary and partial differential equations. Prerequisite(s): FORTRAN programming or consent of department.

5290. Numerical Methods. 3 hours. A non-theoretical development of various numerical methods for use with a computer to solve equations, solve linear and non-linear systems of equations, find eigenvalues and eigenvectors, approximate functions, approximate derivatives and definite integrals, solve differential equations and solve other such problems of a mathematical nature. Errors due to instability of method and those due to the finite-precision computer will be studied. Prerequisite(s): a programming language and consent of department.

5310-5320. Functions of a Real Variable. 3 hours each.

5310. Sets and operations; descriptive set properties; cardinal numbers; order types and ordinals; metric spaces; the theory of Lebesque measure; metric properties of sets.

5320. Set functions and abstract measure; measurable functions; types of continuity; classification of functions; the Lebesque integral; Dini derivatives and the fundamental theorem of the calculus.

5350. Markov Processes. 3 hours. The ergodic theorem; regular and ergodic Markov chains; absorbing chains and random walks; mean first passage time; applications to electric circuits, entropy, genetics, games, decision theory and probability.

5400. Introduction to Functions of a Complex Variable. 3 hours. Algebra of complex numbers and geometric representation; analytical functions; elementary functions and mapping; real-line integrals; complex integration; power series; residues, poles, conformal mapping and applications. Only one course, MATH 5400, 5500 or 5600, may be used towards satisfying the course work requirements for a graduate degree in mathematics.

5410-5420. Functions of a Complex Variable. 3 hours each. The theory of analytic functions from the Cauchy-Riemann and Weierstrass points of view.

5450. Calculus on Manifolds. 3 hours. Introduction to differential geometry and topology. Topics include implicit and inverse function theorems, differentiable manifolds, tangent bundles, Riemannian manifolds, tensors, curvature, differential forms, integration on manifolds and Stokes' theorem. Prerequisite(s): consent of department.

5460-5470. Differential Equations. 3 hours each. Calculation of solutions to systems of ordinary differential equations, study of algebraic and qualitative properties of solutions, study of partial differential equations of mathematical physics, iterative methods for numerical solutions of ordinary and partial differential equations and introduction to the finite element method. Prerequisite(s): MATH 5110-5120 and linear algebra.

5500. Introduction to the Theory of Matrices. 3 hours. Congruence (Hermitian); similarity; orthogonality, matrices with polynomial elements and minimal polynomials; Cayley-Hamilton theorem; bilinear and quadratic forms; eigenvalues. Only one course, MATH 5400, 5500 or 5600, may be used towards satisfying the course work requirements for a graduate degree in mathematics.

5520. Modern Algebra. 3 hours. Groups and their generalizations; homomorphism and isomorphism theories; direct sums and products; orderings; abelian groups and their invariants. Prerequisite(s): MATH 3510 or equivalent.

5530. Selected Topics in Modern Algebra. 3 hours. Ring and field extensions, Galois groups, ideals and valuation theory.

5600. Introduction to Topology. 3 hours. Point set topology; connectedness, compactness, continuous functions and metric spaces. Only one course, MATH 5400, 5500 or 5600, may be used towards satisfying the course work requirement for a graduate degree in mathematics.

5610-5620. Topology. 3 hours each. A rigorous development of abstract topological spaces, mappings, metric spaces, continua, product and quotient spaces; introduction to algebraic methods.

5810-5820. Probability and Statistics. 3 hours each.

5810. Important densities and stochastic processes; measure and integration; laws of large numbers; limit theorems.

5820. Markov processes and random walks; renewal theory and Laplace transforms; characteristic functions; infinitely divisible distribution; harmonic analysis.

5900-5910. Special Problems. 1–3 hours each.

5940. Seminar in Mathematical Literature. 1–3 hours.

5950. Master's Thesis. 3 or 6 hours. To be scheduled only with consent of department. 6 hours credit required. No credit assigned until thesis has been completed and filed with the graduate dean. Continuous enrollment required once work on thesis has begun. May be repeated for credit.

6010. Topics in Logic and Foundations. 3 hours. Mathematical logic, metamathematics and foundations of mathematics. May be repeated for credit.

6110. Topics in Analysis. 3 hours. Measure and integration theory, summability, complex variables and functional analysis. May be repeated for credit.

6130. Infinite Processes. 3 hours. Topics selected from infinite series, infinite matrices, continued fractions, summation processes and integration theory.

6150. Functional Analysis. 3 hours. Normed linear spaces; completeness, convexity and duality. Topics selected from linear operators, spectral analysis, vector lattices and Banach algebras. May be repeated for credit.

6170. Differential Equations. 3 hours. Existence, uniqueness and approximation of solutions to linear and non-linear ordinary, partial and functional differential equations. Relationships with functional analysis. Emphasis is on computer-related methods. May be repeated for credit.

6200. Topics in Ergodic Theory. 3 hours. Basic ergodic theorems. Mixing properties and entropy. Oseledec's multiplicative ergodic theorem and Lyapunov exponents. Applications to dynamical systems. Rational functions and Julia sets. Wandering across Mandelbrot set. Sullivan's conformal measure. Thermodynamical formalism and conformal measures applied to compute Hausdorff measures and packing measures of attractors, repellors and Julia sets. Dimension invariants (Hausdorff, box and packing dimension) of these sets. Prerequisite(s): consent of department. May be repeated for credit.

6310. Topics in Combinatorics. 3 hours. Selected topics of current interest in combinatorics such as enumeration, combinatorial optimization, Ramsey theory, topological graph theory, random methods in combinatorics (random graphs, random matrices, randomized algorithms, etc.), combinatorial designs, matroids, formal languages and combinatorics on words, combinatorial number theory, combinatorial and symbolic methods in dynamical systems. May be repeated for credit.

6510. Topics in Algebra. 3 hours. Groups, rings, modules, fields and other algebraic structures; homological and categorical algebra. Multiplicative and additive number theory, diophantine equations and algebraic number theory. May be repeated for credit.

6610. Topics in Topology and Geometry. 3 hours. Point set and general topology, differential geometry and global geometry. May be repeated for credit.

6620. Algebraic Topology. 3 hours. Topics from algebraic topology such as fundamental group, singular homology, fixed point theorems, cohomology, cup products, Steenrod powers, vector bundles, classifying spaces, characteristic classes and spectral sequences. Prerequisite(s): MATH 5530 and 5620. May be repeated for credit.

6710. Topics in Applied Mathematics. 3 hours. Optimization and control theory, perturbation methods, eigenvalue problems, generalized functions, transform methods and spectral theory. May be repeated for credit.

6810. Probability. 3 hours. Probability measures and integration, random variables and distributions, convergence theorems, conditional probability and expectation, martingales, stochastic processes. May be repeated for credit.

6900-6910. Special Problems. 1–3 hours each.

6940. Individual Research. Variable credit. To be scheduled by the doctoral candidate engaged in research. May be repeated for credit.

6950. Doctoral Dissertation. 3, 6 or 9 hours. To be scheduled only with consent of department. 12 hours credit required. No credit assigned until dissertation has been completed and filed with the graduate dean. Doctoral students must maintain continuous enrollment in this course subsequent to passing qualifying examination for admission to candidacy. May be repeated for credit.

Mechanical and Energy Engineering

Mechanical and Energy Engineering , MEEN

5100. Advanced Energy Conversion. 3 hours. Axiomatic presentation of the law of thermodynamics including corollaries and applications related to energy conversion, the exergy method and entropy dissipation method for the evaluation of thermodynamic systems and cycles, thermodynamic equilibrium and stability, irreversible thermodynamics, chemical equilibria and applications in combustion.

5110. Alternative Energy Sources. 3 hours. Introduction to the physics, systems and methods of energy conversion from non-conventional energy sources, such as solar, geothermal, ocean-thermal, biomass, tidal, hydroelectric, wind and wave energy. Advantages and disadvantages of alternative energy sources and engineering challenges for the harnessing of such forms of energy; energy storage; fuel cells.

5112. Nuclear Energy. 3 hours. Atomic physics and the structure of the atom; radioactivity; interactions of neutrons with matter; nuclear cross-sections; nuclear fuels and fuel elements; elements of nuclear reactors; components and operation of nuclear power plants. Notable accidents of nuclear reactors. Breeder reactors.

5120. Advanced Fluid Dynamics. 3 hours. Fundamentals of vector and tensor notation and formulation of governing equations; model of inviscid and viscous flow, vorticity and circulation; exact solutions; turbulence; boundary layer theory; free surface flow; compressible flow. Prerequisite(s): MATH 2730, MEEN 3120.

5140. Advanced Mathematical Methods for Engineers. 3 hours. Provides an introduction to advanced mathematical methods used in engineering science, such as vector calculus, integral transforms, partial differential equations and numerical methods.

5200. Principles of HVAC. 3 hours. Thermodynamics and psychometrics applied to the HVAC system calculations, energy estimating methods, ducts and piping systems, heat pump and heat recovery systems, air-processing, refrigeration and heating equipment.

5210. Solar Energy. 3 hours. Fundamentals of radiation processes, blackbody and gray-body; and gray-body radiation; solar radiation flat-plate and parabolic collectors; concentration optics and practical solar concentration devices; central receivers, solar ponds, power cycles of solar plants; thermal storage subsystems and system design.

5220. Computational Fluid Dynamics and Heat Transfer. 3 hours. Finite difference, finite volume, and finite element computational methods; techniques for building geometry and meshing; commercial software; modeling and numerically solving real-world fluid flow and heat transfer problems. Prerequisite(s): MEEN 3120, MEEN 3210.

5250. Dispersed Multiphase Flow and Heat Transfer. 3 hours. Characteristics of particles, bubbles and drops; conservation equations, creeping flow solution, flow and heat transfer at higher Reynolds numbers; the treatment of non-spherical particles, bubbles, and drops; effects of rotation and shear; two-way effects of turbulence; effects of higher concentration, molecular and statistical description.

5800-5810. Topics in Mechanical and Energy Engineering. 3 hours. Selected topics of contemporary interest in mechanical engineering. Prerequisite(s): consent of instructor. May be repeated for credit as topics vary.

5900-5910. Special Problems in Mechanical and Energy Engineering. 1–6 hours. Special problems in mechanical and energy engineering for graduate students only. Prerequisite(s): Approval the student's supervisor and/or consent of department. May be repeated for credit.

5920. Cooperative Education in Mechanical and Energy Engineering. 3 hours. Supervised field work in a job directly related to the student's major, professional field of study or career objectives. Summary report required. Prerequisite(s): consent of department.

5950. Masters Thesis. 3 or 6 hours. A minimum of 6 hours of thesis work is required. No credit is assigned until the thesis is filed and approved by the dean of the graduate school. Continuous enrollment is required once thesis work has begun. Prerequisite(s): approval of the student's supervisor and/or consent of department.

Mechanical Engineering Technology

see *Undergraduate Catalog*