MATERIALS SCIENCE

http://www.uvm.edu/matsci/

OVERVIEW

UVM's graduate program in Materials Science is engaged in interdisciplinary education and research on the fundamental physical, chemical, electrical and mechanical properties and applications of materials. Our internationally recognized faculty and our graduate students focus on a variety of theoretical and experimental research topics ranging from electronic materials to bio-polymers. Current interests include nanomechanics, graphene and quantum magnetism, dynamics of quantum systems, spin-dependent phenomena in semiconductors, real-time X-ray scattering and thin film microfabrication, synthesis of novel organometallics and small molecule semiconductors, supramolecular nanomaterials, computational multiscale modeling of complex materials, as well as materials for biomedical applications. Experimental and computational on-campus facilities include state-of-the-art transport, microscopy, spectroscopy (optical and X-ray) characterization and a supercomputing center. Our experimental faculty and graduate students work in close collaboration with scientists from national laboratories such as the Brookhaven National Lab and the National Renewable Energy Lab.

We offer students the opportunity to follow customized curricula by selecting disciplinary-appropriate courses among 6 core categories that prepare them to be successful in their chosen research area. Research and teaching graduate assistantships are available for full-time students on a competitive basis and the program also welcomes self–supporting part-time students in partnership with industry.

DEGREES

Materials Science AMP

Materials Science M.S.

Materials Science Ph.D.

FACULTY

Badireddy, Appala Raju; Assistant Professor, Department of Civil and Environmental Engineering; PHD, University of Houston
Clougherty, Dennis Paul; Professor, Department of Physics; PHD, Massachusetts Institute of Technology
Doiron, Amber L.; Assistant Professor; Department of Electrical and Biomedical Engineering; PHD, University of Texas Austin
Dubief, Yves C.; Associate Professor Department of Mechanical Engineering; PHD, Institut National Polytechnique de Grenoble
Fletcher, Douglas G.; Professor, Department of Mechanical Engineering; PHD, University of Virginia
Floreani, Rachael Ann; Associate Professor, Department of Mechanical Engineering; PHD, Colorado State University
Headrick, Randall L.; Professor, Department of Physics; PHD, University of Pennsylvania
Kotov, Valeri N.; Professor, Department of Physics; PHD, Clarkson University
Kozen, Alexander; Assistant Professor, Department of Physics; PHD, University of Maryland
Landry, Christopher C.; Professor, Department of Chemistry; PHD, Harvard University
Ma, Jihong; Assistant Professor, Department of Mechanical Engineering, PHD, University of Minnesota, Twin Cities
Ma, Wen; Assistant Professor, Department of Physics; PHD, University of Illinois at Urbana-Champaign
Punihaole, David; Assistant Professor, Department of Chemistry, PHD, University of Pittsburgh
Sansoz, Frederic P.; Professor, Department of Mechanical Engineering; PHD, Ecole Des Mines de Paris
Schadler, Linda S.; Acting Provost and Senior Vice President; Professor, Department of Mechanical Engineering; PHD, University of Pennsylvania
Waterman, Rory; Professor, Department of Chemistry; PHD, University of Chicago
White, Matthew S.; Associate Professor, Department of Physics; PHD; University of Colorado Boulder
Xia, Tian; Professor, Department of Electrical and Biomedical Engineering; PHD, University of Rhode Island

Chemistry Courses

CHEM 5300. Topics in Analytical Chemistry. 1-3 Credits.
Selected topics of current interest in analytical chemistry. New techniques and methodologies, especially in chemical instrumentation. See Schedule of Courses for specific titles. May be repeated for credit with different content. Topics vary by offering; periodic offering at intervals that may exceed four years. Prerequisites: Graduate student.

CHEM 5320. Gr Instrumental Analysis. 3 Credits.
Systematic survey of modern methods of chemical analysis. Fundamental principles and applications of spectroscopy, electrochemistry, and separation techniques. Credit not awarded for both CHEM 5320 and CHEM 3320. Prerequisite: Graduate student.

CHEM 5400. Gr Advanced Inorganic Chem. 3 Credits.
Molecular symmetry and group theory with an emphasis on applications (vibrational and electronic spectra, bonding and reactivity); introduction to transition metal processes; bioinorganic chemistry. Credit not awarded for both CHEM 5400 and CHEM 3400. Prerequisite: Graduate student.

CHEM 5580. Gr Advanced Organic Chem 1. 3 Credits.
Stereochemistry, conformational analysis, stereoelectronic effects, transition state theory, molecular orbital theory, and reactivity criteria are discussed in regards to reaction mechanisms and functional group manipulations. Credit not awarded for both CHEM 5580 and CHEM 4580. Prerequisite: Graduate student.

CHEM 5600. Gr Advanced Physical Chemistry. 3 Credits.
Advanced exploration of quantum chemistry, thermodynamics, and kinetics, with a significant level of mathematical rigor. Credit not awarded for both CHEM 5600 and CHEM 3600. Prerequisites: MATH 2248 or equivalent; Graduate student.

CHEM 5610. Gr Chemical Thermodynamics. 3 Credits.
Calculus-based exploration of the fundamental principles of thermodynamics (gases, equilibrium, free energy, laws of thermodynamics, statistical thermodynamics, phase transitions, mixtures, chemical reactions, solids), from an interdisciplinary perspective. This topic is a cornerstone of many scientific and engineering disciplines. Appropriate for students in Chemistry and other STEM fields. Prerequisites: Graduate student or Instructor permission; content knowledge of general chemistry, calculus, and introductory physics (mechanics) assumed. Cross-listed with: MATS 5610.

CHEM 5990. Special Topics. 1-18 Credits.
Selected topics of current interest that do not fall into one of the traditional areas of Chemistry.

CHEM 6010. Intro to Graduate Research. 1 Credit.
Introduction to graduate research in Chemistry. Overview of faculty research areas and department/university research resources. Prerequisite: Chemistry Graduate student.

CHEM 6015. Chemical Investigations. 1 Credit.
Current problems and literature. Prerequisite: Chemistry Graduate student.

CHEM 6020. Grad Seminar. 1 Credit.
Current problems and literature. Prerequisite: Chemistry Graduate student.

CHEM 6050. Topics in Current Chemistry. 0 or 1 Credits.
Survey of current topics in the Chemistry literature. May be repeated for credit with different content. Topics vary by offering; periodic offering at intervals that may exceed four years. Prerequisite: Chemistry Graduate student.

CHEM 6300. Topics in Analytical Chemistry. 3 Credits.
Selected topics of current interest in analytical chemistry. New techniques and methodologies, especially in chemical instrumentation. See Schedule of Courses for specific titles. May be repeated for credit with different content. Topics vary by offering; periodic offering at intervals that may exceed four years. Prerequisite: Graduate student.

CHEM 6391. Master's Lab Thesis Research. 1-18 Credits.
Research for the Master's Thesis.

CHEM 6392. Master's Lit Project Research. 1-12 Credits.
Reading and literature research culminating in the preparation of a comprehensive and critical review of a topic of current interest in Chemistry.

CHEM 6395. Advancement to Candidacy Exam. 2 Credits.
Students demonstrate the comprehensive, fundamental knowledge, in the context of their research, needed to pursue a Ph.D. degree. Preparation of a dossier consisting of an extensive introduction to the dissertation, a detailed record of research progress, and future directions. Culminates in the Advancement to Candidacy Examination, which includes a presentation and a comprehensive oral examination. Prerequisite: CHEM 6015.

CHEM 6400. Topics in Inorganic Chemistry. 1-3 Credits.
Areas of current interest involving inorganic systems, particularly catalysis, solid state chemistry, and bioinorganic chemistry. See Schedule of Courses for specific titles. May be repeated for credit with different content. Topics vary by offering; periodic offering at intervals that may exceed four years. Prerequisites: CHEM 3400.

CHEM 6410. Organometallic Chemistry. 3 Credits.
Synthesis, structure, bonding, properties, reactions, and applications of organometallic systems; mechanisms of organometallic reactions including oxidative addition and insertion reactions with applications in catalysis. Prerequisite: Chemistry Graduate student.

CHEM 6460. Physical Inorganic Chemistry. 3 Credits.
Determination of molecular and electronic structure of inorganic complexes using spectroscopic techniques. Introduction to magnetism. Interpretation of spectroscopic data within the frameworks of group theory and electronic structure calculations. Prerequisite: Chemistry Graduate student.

CHEM 6500. Topics in Organic Chemistry. 1-3 Credits.
Advanced level discussion of specific topics in organic chemistry of current interest such as photochemistry, carbenes, bioorganic chemistry, magnetic resonance, etc. See Schedule of Courses for specific titles. May be repeated for credit with different content. Topics vary by offering; periodic offering at intervals that may exceed four years. Prerequisite: Chemistry Graduate student.

CHEM 6580. Advanced Organic Chemistry 2. 3 Credits.
Modern synthetic organic methods and approaches to multi-step synthesis are discussed. Selected total syntheses are reviewed to highlight important concepts including diastereoselective and enantioselective processes. Prerequisite: Chemistry Graduate student.

CHEM 6600. Topics in Physical Chemistry. 1-3 Credits.
Selected topics of current interest in physical chemistry. See Schedule of Courses for specific titles. May be repeated for credit with different content. Topics vary by offering; periodic offering at intervals that may exceed four years. Prerequisites: CHEM 3600.

CHEM 6620. Computational Chemistry. 3 Credits.
Explores the techniques and applications of computational chemistry to model organic, inorganic, and biological molecules. Introduces basic level of classical and quantum modeling, cheminformatics and big chemical data, as well as computer-aided design of new materials and medicines. Prerequisite: Chemistry Graduate student.

CHEM 6990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

CHEM 6991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

CHEM 6993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

CHEM 6994. Teaching Assistantship. 1-3 Credits.
Student service as a teaching assistant, usually in an introductory-level course in the discipline, for which credit is awarded. Offered at department discretion. Prerequisite: Instructor permission.

CHEM 6995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

CHEM 7010. Research Problem Conception. 1 Credit.
Identification of a current research problem to be addressed by original, independent research. Prerequisite: Chemistry Graduate student.

CHEM 7015. Research Problem Solution. 1 Credit.
Solution to a current research problem to be addressed by original, independent research. Prerequisite: CHEM 7010.

CHEM 7491. Doctoral Dissertation Research. 1-18 Credits.
Research for the Doctoral Dissertation.

CHEM 7990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

Electrical Engineering Courses

EE 5310. Power System Analysis. 3 Credits.
Transmission system modeling, operations and planning and energy policy are discussed to prepare students for the electricity and energy industry and power/energy systems research. Topics include: transmission line models, generator capability curves, transformer modeling and control, per-unit conversion, power flow calculations and software, smart grid. Prerequisite: Graduate Electrical Engineering student or Instructor permission.

EE 5410. Digital VLSI Circuit Design. 0 or 3 Credits.
Covers the techniques for the design, analysis and layout of digital CMOS circuits and systems. Major topics include MOSFET basics (structure and behavior of a MOSFET, CMOS fabrication, and design rules), detailed analysis of the CMOS circuits and systems (static behavior, ratioed vs. ratioless design), noise margins, computing rise and fall times, delay models, resistance. Prerequisite: Electrical Engineering Graduate student or Instructor permission. Cross-listed with: CMPE 5410.

EE 5430. RF Circuit Design. 3 Credits.
Design and analysis of radio frequency and microwave circuits. Covers radio frequency and microwave behavior of passive components, various transmission line structures, electromagnetic (EM) wave propagation in dielectric media, reflection coefficient and load impedance, network properties and applications, impedance matching network design, scattering parameters and their usage for RF. Prerequisite: Electrical Engineering Graduate student or Instructor permission.

EE 5440. Gr Semiconductor Materials/Dev. 0 or 4 Credits.
Covers energy band theory, effective mass, band structure and electronic properties of semiconductors. Transport of electrons and holes in bulk materials and across interfaces. MOSFETs, BJTs, pn junctions, and Schottky barriers. Experimental portion of course will have a laboratory component for electronic measurements of semiconductor devices. Credit not awarded for both EE 5440 and EE 3440. Prerequisite: Graduate student or Instructor permission. Cross-listed with: PHYS 5675.

EE 5460. Microelec. Circuit Fabrication. 0 or 4 Credits.
Provides a firm knowledge base in modern semiconductor fabrication technology. This technology lies at the heart of all modern computer and communication systems. Analyze and evaluate the unit processes involved in creating semiconductor chips such as photolithography, plasma etch, ion implant and metallization. Explore the current state-of-the-art and demonstrate how these building blocks affect the electrical behavior of semiconductor devices. Prerequisites: Electrical Engineering, Materials Science, Mechanical Engineering, or Physics Graduate student; or Instructor permission. Cross-listed with: PHYS 5165.

EE 5503. Modern Signal Processing. 3 Credits.
Covers principles and methods for digital signal processing. The analysis and design of discrete-time systems as signal processing devices is provided in the context of filter design, adaptive processing, compress sensing, and topics on image processing. Topics covered: quantization, reconstruction of signals, z-transform, FIR/IIR, compress sensing, compress sensing processing, intro to images, pixel and region-based classification, and segmentation, among others.

EE 5540. Real-Time Control Systems. 3 Credits.
Digital control systems analysis and design. Topics include: difference equations, the Z-transforms, discrete-time transfer functions, state-space models, sampled-data systems, discretization, real-time control, microprocessor implementation, and optimal control. Project-based final. Prerequisite: Electrical Engineering Graduate student or Instructor permission. Cross-listed with: CMPE 5540.

EE 5550. Autonomy I. 3 Credits.
Students learn how to make engineered systems autonomous/intelligent. Covers logic and algorithms, real-time estimation and control of dynamical systems, optimization and optimal planning, path planning for robots and autonomous vehicles, basics of artificial intelligence and machine learning, and ethics of automation. Applications include hover flight of quadrotor drones, perception and navigation of robots including robotic arms and self-driving vehicles, and autonomous control of the power grid. Prerequisites: Graduate student or Instructor permission; content knowledge of control systems (such as EE 3515) assumed.

EE 5560. Autonomy II. 3 Credits.
Covers principles and methods for perception and localization of autonomous robotic systems within a systematic software framework. The analysis and design of practical methods for the deployment of control, path planning, localization and mapping, and safety of autonomous systems are provided in the context of the Robotic Operative Systems (ROS). Topics covered: introduction to ROS; perception using RGB-D cameras and lidar; Kalman filters for state estimation; SLAM; and path planning of robotic manipulators. Prerequisite: EE 5550.

EE 5610. Information Theory. 3 Credits.
Introduction to probability concepts of information theory; entropy of probability models; theoretical derivations of channel capacity; coding methods and theorems, sampling theorems. Prerequisite: Graduate student or Instructor permission. Cross-listed with: CS 5610, CMPE 5610.

EE 5810. Digital Computer Design. 3 Credits.
To gain a solid understanding of digital computer operating mechanisms and reconfigurable computing, and advance into hands-on experiences to design and debug digital computer system and embedded system. Field programmable gate arrays (FPGAs) will be utilized as the development platform. Prerequisite: Electrical Engineering Graduate student, Computer Science Graduate student, or Instructor permission. Cross-listed with: CMPE 5810, CS 5810.

EE 5915. Advanced Circuit Applications. 3 Credits.
Analog and digital circuit applications. Topics may include analog to digital converters, operational amplifiers, optical isolators (linear and non-linear), comparators, voltage to frequency converters, analog switches, voltage references, precision dividers, analog multipliers, multiplexers, phase locked loops, power supply monitoring circuits, instrumentation amplifiers and pulse width modulators. Prerequisites: Electrical Engineering Graduate student or Instructor permission; Knowledge of material in EE 3110 Electronics I.

EE 5990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

EE 5993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

EE 6110. System Theory. 3 Credits.
Linear vector spaces. State equations and solution. Diagonalization and Jordan canonical form. Orthogonal and biorthogonal projections. Quadratic forms. Spectral resolution. Principal component analysis, singular value decomposition and Karhunen-Loeve transform. Compressive sensing. Prerequisites: MATH 3230 or MATH 3201; MATH 2544; EE 3150 or ME 2120.

EE 6120. Stochastic Processes. 3 Credits.
Probability theory, random variables and stochastic processes. Response of linear systems to random inputs. Applications in engineering. Prerequisites: Graduate student in CEMS or Instructor permission.

EE 6130. Convex Optimization. 3 Credits.
Provides advanced mathematical tools to recognize optimization problems from applications, presents rigorous theory of convex optimization with an emphasis on results that are helpful for implementation/computation/modeling, providing student with the experience and understanding necessary to use the tools in their own research work or applications. Prerequisites: Linear Algebra, multi-variable calculus.

EE 6391. Master's Thesis Research. 1-18 Credits.

EE 6392. Master's Project Research. 1-3 Credits.
Master's Project.

EE 6520. Nonlinear System Theory. 3 Credits.
Basic nonlinear methods including computational and geometrical techniques for analysis of nonlinear systems. Describing function methods and bifurcation and catastrophe theory. Sensitivity and stability considerations. Prerequisite: MATH 3230 or MATH 3201. Pre/Co-requisite: EE 6110 recommended.

EE 6530. Estimation Theory. 3 Credits.
Foundations of linear and nonlinear least squares estimation, smoothing and prediction, computational aspects, Kalman filtering, nonlinear filtering, parameter identification, and adaptive filtering. Applications to students' research. Pre/co-requisite: STAT 2510.

EE 6990. Special Topics. 1-18 Credits.
Advanced topics of current interest in Electrical Engineering. Prerequisite: Instructor permission.

EE 6991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

EE 6993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

EE 6995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

EE 7491. Doctoral Dissertation Research. 1-18 Credits.
Research for the Doctoral Dissertation.

EE 7990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

EE 7991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

EE 7995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

Mathematics Courses

MATH 5230. Adv Ordinary Diff Equations. 3 Credits.
Linear and nonlinear systems, approximate solutions, existence, uniqueness, dependence on initial conditions, stability, asymptotic behavior, singularities, self-adjoint problems. Prerequisite: Graduate student or Instructor permission; knowledge of differential equations required.

MATH 5678. Combinatorial Graph Theory. 3 Credits.
Paths and trees, connectivity, Eulerian and Hamiltonian cycles, matchings, edge and vertex colorings, planar graphs, Euler's formula and the Four Color Theorem, networks. Prerequisite: Graduate student or Instructor permission.

MATH 5737. Gr Intro to Numerical Anyl. 3 Credits.
Error analysis, root-finding, interpolation, least squares, quadrature, linear equations, numerical solution of ordinary differential equations. Credit not awarded for both MATH 5737 and MATH 3737 or CS 3737. Prerequisite: Graduate student or Instructor permission. Cross-listed with: CS 5737.

MATH 5766. Gr Chaos,Fractals&Dynmcl Systm. 3 Credits.
Discrete and continuous dynamical systems, Julia sets, the Mandelbrot set, period doubling, renormalization, Henon map, phase plane analysis and Lorenz equations. Credit not awarded for both MATH 5766 and MATH 3766. Prerequisites: Graduate student or Instructor permission. Cross-listed with: CSYS 5766.

MATH 5788. Mathematical Biology&Ecol. 3 Credits.
Mathematical modeling in the life sciences. Topics include population modeling, dynamics of infectious diseases, reaction kinetics, wave phenomena in biology, and biological pattern formation. Prerequisites: Graduate student or Instructor permission; knowledge of linear algebra and differential equations required.

MATH 5990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

MATH 5993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

MATH 6230. Partial Differential Equations. 3 Credits.
Classification of equations, linear equations, first order equations, second order elliptic, parabolic, and hyperbolic equations, uniqueness and existence of solutions. Prerequisite: Knowledge of differential equations required.

MATH 6344. Algebraic Topology. 3 Credits.
Homotopy, Seifert-van Kampen Theorem; simplicial, singular, and Cech homology. Prerequisite: Knowledge of real analysis or topology required.

MATH 6391. Master's Thesis Research. 1-18 Credits.
Research for the Master's Thesis.

MATH 6441. Theory of Func of Complex Var. 3 Credits.
Complex functions, differentiation and the Cauchy-Riemann equations, power and Laurent series, integration, calculus of residues, contour integration, isolated singularities, conformal mapping, harmonic functions. Prerequisite: Two semesters of real analysis required.

MATH 6444. Thry Functions Real Variables. 3 Credits.
Lebesgue measure and integration theory, Monotone and Dominated Convergence Theorems and applications, product measures, basic theory of LP-spaces. Prerequisite: Two semesters of real analysis required.

MATH 6551. Abstract Algebra III. 3 Credits.
Advanced group theory and field theory. Prerequisite: Two semesters of abstract algebra required.

MATH 6555. Abstract Algebra IV. 3 Credits.
Ring theory and module theory at the graduate level, with emphasis on commutative algebra. Prerequisite: MATH 6551.

MATH 6678. Topics in Combinatorics. 3 Credits.
Topics will vary each semester and may include combinatorial designs, coding theory, topological graph theory, cryptography. Course is repeatable for credit. Prerequisite: MATH 3551 or MATH 5678.

MATH 6701. Principles of Complex Systms 1. 3 Credits.
Introduction to fundamental concepts of complex systems. Topics include: emergence, scaling phenomena, and mechanisms, multi-scale systems, failure, robustness, collective social phenomena, complex networks. Students from all disciplines welcomed. Pre/co-requisites: Calculus and statistics required; linear algebra, differential equations, and computer programming recommended but not required. Cross-listed with: CSYS 6701.

MATH 6713. Principles of Complex Systms 2. 3 Credits.
Detailed exploration of distribution, transportation, small-world, scale-free, social, biological, organizational networks; generative mechanisms; measurement and statistics of network properties; network dynamics; contagion processes. Students from all disciplines welcomed. Pre/co-requisites: MATH 6701, CSYS 6701, calculus, and statistics required. Cross-listed with: CSYS 6713.

MATH 6737. Numerical Diff Equations. 3 Credits.
Numerical solution and analysis of differential equations: initial-value and boundary-value problems; finite difference and finite element methods. Prerequisites: Calculus and linear algebra required in addition to differential equations or numerical analysis.

MATH 6990. Special Topics. 1-18 Credits.
Subject will vary from year to year. May be repeated for credit.

MATH 6991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

MATH 6993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

MATH 6995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

MATH 7491. Doctoral Dissertation Research. 1-18 Credits.
Research for the Doctoral Dissertation.

MATH 7990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

MATH 7991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

MATH 7995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

Mechanical Engineering Courses

ME 5040. Adv Engineering Analysis I. 3 Credits.
Analytical methods for the solution of partial differential equations in engineering mechanics and physics, including: eigenfunction expansions; Fourier series; Sturm-Liouville theory and special functions. Prerequisite: Graduate student in engineering, mathematics, or physical sciences or Instructor permission.

ME 5120. Adv Engineering Materials. 3 Credits.
Advanced material processing; physical and mechanical principles of high-temperature alloys, light-weight materials, thin films, nanomaterials, and biomedical materials; elements of computational materials design. Prerequisite: Senior/Graduate student or Instructor permission.

ME 5160. Continuum Mechanics. 3 Credits.
Tensors, conservation laws, field equations for solids and fluids.

ME 5220. Adv Engr Thermodynamics I. 3 Credits.
Foundations of statistical mechanics. Gases and crystals. Chemical equilibrium. Irreversible processes. Prerequisite: Senior/Graduate student or permission.

ME 5230. Vortex Flows. 3 Credits.
General theorems of vorticity transport in fluids; methods for solution of vortex flows; application to wake vortices, turbulent wall-layer vortices, wing-tip vortices, intake vortices, vortex-structure interaction, vortex reconnection, vortex breakdown, tornadoes and hurricanes. Prerequisites: Content knowledge in fluid mechanics (such as ME 2230) is assumed.

ME 5240. Advanced Heat Transfer I. 3 Credits.
Analytical methods for multidimensional steady and transient heat conduction; phase change and moving boundaries. Thermal radiation exchange in enclosures; view factors; emitting/absorbing gases. Prerequisite:Successful completion of undergraduate Heat Transfer course or similar is assumed; Graduate Standing or Instructor permission.

ME 5370. Micro and Nano Systems. 3 Credits.
Operating principles, fabrication and design of engineered systems with submillimeter dimensions. Prerequisite: Senior/Graduate student in engineering or physical sciences.

ME 5440. Biothermodynamics. 3 Credits.
Inter-disciplinary; guides the student through the thermodynamics of living organisms, comprised of the study of energy transformation in the life sciences. Designed for students from the STEM disciplines. Covers Gibbs free energy, statistical thermodynamics, binding equilibria, and reaction kinetics. Prerequisites: Successful completion of Materials and Mechanics Lab such as ME 2111, Thermo-Fluid Labs such as ME 2321, or Biomedical design such as BME 3600 is assumed; Graduate student or Instructor permission. Cross-listed with: BME 5440.

ME 5520. Computational Solid Mechanics. 3 Credits.
Project-based. Computational methods using the finite element analysis (FEA) applied to linear elastic and non-linear problems in the mechanics of deformable solids and structures, contact mechanics, and fracture mechanics. Hands-on computational experience using a commercial FEA software. Prerequisites: ME 1140, MATH 2544, and MATH 3201, or equivalent.

ME 5980. Numerical Methods for Engineer. 3 Credits.
Foundational concepts of numerical integration, numerical differentiation, and numerical approximation and solution of differential and partial differential equations of the type encountered in the analysis of engineering problems and data processing. Prerequisite: Graduate student or Instructor permission; content knowledge of calculus through differential equations (such as MATH 3201) and linear algebra (such as MATH 2522 or MATH 2544) assumed. Cross-listed with: CEE 5980.

ME 5990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

ME 5993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

ME 6110. Mechanical Behavior of Solids. 3 Credits.
Intended to provide advanced concepts in elasticity, plasticity, creep, fracture, and fatigue of natural and engineered materials. Special emphasis is placed on the mathematics and physics of deformation in crystalline solids. Topics include: isotropic and anisotropic elasticity, deformation mechanisms at atomic scale, dislocation theory, strengthening mechanisms, theory of plasticity and yield criteria, creep and fracture. Pre/Co-requisites: Graduate student standing in engineering or physical sciences; knowledge of linear algebra, matrix analysis, introductory materials science, and mechanics, such as ME 5160 Continuum Mechanics is assumed.

ME 6120. Advanced Dynamics. 3 Credits.
Application of Lagrange's equation, Hamilton's principle to mechanical systems. Systems with constraints. Matrix formulation of problems in kinematics, dynamics. Stability of linear, nonlinear systems.

ME 6230. Advanced Fluid Dynamics. 3 Credits.
Stress in continuum; kinematics, dynamics; potential fields; Wing theory; Navier-Stokes equation; hydrodynamic stability; turbulence; laminar, turbulent boundary layer theory; transient flows; free laminar, turbulent flows; mixing.

ME 6270. Turbulence. 3 Credits.
Description of turbulent flows; statistical and modeling of turbulent flows; Navier Stokes as a dynamical system; experimental and numerical approaches. Prerequisite: Graduate student or Instructor permission; successful completion of undergraduate Mechanical Engineering Fluid Mechanics or similar required.

ME 6391. Master's Thesis Research. 1-18 Credits.
Research for the Master's Thesis.

ME 6550. Multiscale Modeling. 3 Credits.
Computational modeling of the physics and dynamical behavior of matter composed of diverse length and time scales. Molecular simulation. Coarse-graining. Coupled atomistic/continuum methods.

ME 6990. Special Topics. 1-18 Credits.
Advanced topics in recently developed technical areas. Prerequisite: Three hours with Instructor permission.

ME 6991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

ME 6993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

ME 6995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

ME 7491. Doctoral Dissertation Research. 1-18 Credits.
Research for the Doctoral Dissertation.

ME 7990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

ME 7991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

ME 7995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

Physics Courses

PHYS 5125. Mathematical Physics. 3 Credits.
Introduction to basic mathematical methods of theoretical physics; vector and tensor analysis, partial differential equations, orthogonal functions, complex variables and variational techniques. Prerequisites: Graduate student or undergraduate student with Instructor permission; knowledge of PHYS 2200 and PHYS 4300 topics strongly recommended.

PHYS 5165. Microelec. Circuit Fabrication. 0 or 4 Credits.
Provides a firm knowledge base in modern semiconductor fabrication technology. This technology lies at the heart of all modern computer and communication systems. Analyze and evaluate the unit processes involved in creating semiconductor chips such as photolithography, plasma etch, ion implant and metallization. Explore the current state-of-the-art and demonstrate how these building blocks affect the electrical behavior of semiconductor devices. Prerequisites: Electrical Engineering, Materials Science, Mechanical Engineering, or Physics Graduate student; or Instructor permission. Cross-listed with: EE 5460.

PHYS 5185. Nano-analysis of Materials. 1 Credit.
Explores the theory and practical operation of advanced techniques to analyze the structure, composition, and surfaces of micro and nano-scale materials. Students will be trained as users of a Field Emission Scanning Electron Microscope (FESEM) including x-ray elemental analysis. Credit not awarded for both PHYS 3175 and PHYS 5185. Prerequisite: Graduate student in Physics, Materials Science, or related program, or Instructor permission. Cross-listed with: MATS 5185.

PHYS 5200. Advanced Dynamics. 3 Credits.
Classical mechanics presented as the basis of the concepts and methods of modern physics. Variational, Lagrangian, and Hamiltonian formulations, canonical transformations, continuous systems. Prerequisite: Graduate student or undergraduate student with Instructor permission; knowledge PHYS 2200 topics strongly recommended.

PHYS 5300. Electromagnetic Theory. 3 Credits.
Development of Maxwell's theory of electromagnetism emphasizing its physical basis and the modes of mathematical description. Prerequisite: Graduate student or undergraduate student with Instructor permission; knowledge of PHYS 4300 topics strongly recommended.

PHYS 5400. Statistical Mechanics. 3 Credits.
Following a review of thermodynamics, covers the fundamentals of classical and quantum statistical mechanics including ensembles, identical particles, Bose and Fermi statistics, phase-transitions and critical phenomena, renormalization group, irreversible processes and fluctuations. Prerequisite: Graduate student or undergraduate student with Instructor permission; knowledge of PHYS 3400 topics strongly recommended.

PHYS 5500. Quantum Mechanics II. 3 Credits.
Mathematical and physical foundations of nonrelativistic quantum mechanics from the unifying point of view of Dirac. Symmetry operations and the algebraic structure of quantum mechanics are emphasized. Prerequisite: Graduate student or undergraduate student with Instructor permission; knowledge of PHYS 3400 topics strongly recommended.

PHYS 5625. Structure&Bonding of Materials. 3 Credits.
Study of atomic and molecular bonding, the structure of materials, and their associated properties. Explores how structures and bonding types influence the electrical, thermal, mechanical, and optical properties of materials. Covers topics such as primary and secondary bonding mechanisms, crystallography, diffraction techniques, and the properties of metals, ceramics, polymers, and biological materials. Prerequisites: Graduate student in Physics, Materials Science, or related program, or Instructor permission. Cross-listed with: MATS 5625.

PHYS 5675. Gr Semiconductor Materials/Dev. 0 or 4 Credits.
Covers Energy band theory, effective mass, band structure and electronic properties of semiconductors. Transport of electrons and holes in bulk materials and across interfaces. MOSFETs, BJTs, pn junctions, and Schottky barriers. Experimental portion of course will have a laboratory component for electronic measurements of semiconductor devices. Credit not awarded for both PHYS 5675 and PHYS 3675. Prerequisite: Graduate student or Instructor permission. Cross-listed with: EE 5440.

PHYS 5990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles. Prerequisites: Department permission, Graduate student.

PHYS 6000. Teaching of College Physics. 1 Credit.
Instructional strategies and techniques with application to the teaching of laboratories and recitations. Prerequisites: Undergraduate degree in Physics; Instructor permission.

PHYS 6391. Master's Thesis Research. 1-18 Credits.
Research for the Master's Thesis.

PHYS 6990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

PHYS 6991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

PHYS 6993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

PHYS 6994. Teaching Assistantship. 1-3 Credits.
Student service as a teaching assistant, usually in an introductory level course in the discipline, for which credit is awarded. Offered at department discretion.

PHYS 6995. Graduate Independent Research. 1-18 Credits.
Graduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

PHYS 7491. Doctoral Dissertation Research. 1-18 Credits.
Research for the Doctoral Dissertation.

PHYS 7990. Special Topics. 1-18 Credits.
See Schedule of Courses for specific titles.

PHYS 7991. Internship. 1-18 Credits.
On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

PHYS 7993. Independent Study. 1-18 Credits.
A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.