

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 High Magnetic Field Lab.

We offer students the opportunity to follow customized curricula organized in 3 tracks (Electronic Materials, Biomaterials and Mechanics of Materials) that prepares 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
Furis, Madalina Ioana; Adjunct Professor, Department of Physics; PHD, University of Buffalo

Headrick, Randall L.; Professor, Department of Physics; PHD, University of Pennsylvania

Kotov, Valeri N.; Professor, Department of Physics; PHD, Clarkson University

Landry, Christopher C.; Professor, Department of Chemistry; PHD, Harvard University

Li, Jianing; Adjunct Associate Professor, Department of Chemistry; PHD, Columbia University

Li, Wei; Assistant Professor, Department of Mechanical Engineering, PHD, Michigan State University

Ma, Jihong; Assistant Professor, Department of Mechanical Engineering, PHD, University of Minnesota, Twin Cities

Punihaole, David; Assistant Professor, Department of Chemistry, PHD, University of Pittsburgh

Ruggiero, Michael; Assistant Professor, Department of Chemistry; PHD, Syracuse University

Sansoz, Frederic P.; Professor, Department of Mechanical Engineering; PHD, Ecole Des Mines de Paris

Schadler, Linda S.; Dean, College of Engineering and Mathematical Sciences; Professor, Department of Mechanical Engineering; PHD, University of Pennsylvania

Schneebeli, Severin; Adjunct Associate Professor, Department of Chemistry; PHD, Columbia University

Vanegas, Juan; Assistant Professor, Department of Physics, PHD; University of California Davis

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. 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. 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. 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. Prerequisites: MATH 2248 or equivalent; Graduate student.

CHEM 5990. Special Topics. 1-3 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 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 6560. Physical Organic Chemistry. 3 Credits.

Experimental and computational techniques for determining and interpreting structure, properties, and reactivity of organic molecules, with an emphasis on the mechanisms of organic reactions. Prerequisites: 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 6590. Polymer Chemistry. 3 Credits.

Polymer synthesis and characterization. Kinetic models for polymerization and copolymerization. Physical properties, characterization of polymers in the solid state and in solution. Prerequisites: 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 6610. Solid State Chemistry. 3 Credits.

Explores the rich field of solid-state chemistry. Solid-state materials represent some of the most promising advanced materials in development, with applications ranging from pharmaceuticals to flexible electronics. Introduces the chemical physics surrounding solids. Topics include (but are not limited to) crystals and their properties, nanomaterials, semiconductors, and characterization methods. Prerequisite: Chemistry Graduate student.

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. Electric Energy Systems Analys. 3 Credits.**

Transmission line, generator, transformer modeling and control, per-unit conversion, power flow calculations and software, symmetric components and fault analysis, protection/relaying, stability analysis, smart grid. Prerequisite: EE 3315. Co-requisite: MATH 2522 (preferred) or MATH 2544.

EE 5320. Smart Grid. 3 Credits.

Smart Grid: Using information/communication technology to modernize electric power/energy systems, including generation, transmission, distribution and consumption. Electricity physics/economics/policy; renewable energy; energy storage; demand response; energy efficiency; distributed generation; advanced metering infrastructure; distribution automation; microgrids; synchrophasors; HVDC and FACTS systems. Prerequisite: Electrical Engineering Graduate student or Instructor permission. Co-requisite: EE 5310 is helpful.

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.

EE 5420. Analog VLSI Circuit Design. 0 or 3 Credits.

The design and analysis of active and passive radio frequency and microwave circuits. The design, layout, and simulation of VLSI analog circuits. Emphasis on small signal models and circuits used in operational amplifiers as well as a focus on learning the basics of RF circuit design and analysis. Prerequisite: Electrical Engineering Graduate student or Instructor permission.

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. 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. Prerequisite: Electrical Engineering Graduate student or Instructor permission.

EE 5530. Modern Control Systems. 3 Credits.

Feedback control theory with application to mechanical and electrical systems. Includes elements of classical control theory such as stability analysis and PID control. A series of labs implemented on an electric motor and rotary inverted pendulum will reinforce the concepts. Emphasis on both theory and design. Prerequisite: Electrical Engineering Graduate student or Instructor permission. Cross-listed with: ME 3320.

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.

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.

EE 5620. Wireless Communication. 3 Credits.

Modern wireless systems, including cellular design, propagation modeling, multiple access and equalization techniques. Prerequisite: Graduate student or Instructor permission.

EE 5810. Digital Computer Design I. 3 Credits.

Hardware organization and realization, hard-wired and microprogrammed control units, interrupt and I/O systems. Hardware design language introduced and used for computer design. Prerequisites: EE 2810; EE 3815 or CS 2210.

EE 5990. Special Topics. 1-18 Credits.

See Schedule of Courses for specific titles.

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: EE 3150 or ME 2120; STAT 2510 or STAT 2430.

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: MATH 3230.

MATH 5360. Foundations of Geometry. 3 Credits.

Complex numbers as tool to solve problems in Euclidean geometry. Two models of hyperbolic (non-Euclidean) geometry: Poincare and upper-half plane. Invariants and Moebius transformations. Prerequisites: MATH 2055 or CS 1640; MATH 2248, MATH 2522, or MATH 2544; or Instructor permission.

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: MATH 2055.

MATH 5737. Gr Intro to Numerical Anlyl. 3 Credits.

Error analysis, root-finding, interpolation, least squares, quadrature, linear equations, numerical solution of ordinary differential equations. Prerequisite: Graduate student or Instructor permission. Cross-listed with: CS 5737.

MATH 5766. Gr Chaos,Fractals&Dynamcl Systm. 3 Credits.

Discrete and continuous dynamical systems, Julia sets, the Mandelbrot set, period doubling, renormalization, Henon map, phase plane analysis and Lorenz equations. Prerequisites: Graduate student or Instructor permission. Cross-listed with: CSYS 5766.

MATH 5775. Mathematical Models&Anlysis. 3 Credits.

Techniques of calculus and linear algebra are applied for mathematical analysis of models of natural and human-created phenomena. Students are coached to give presentations. Prerequisites: MATH 2248; MATH 2522, MATH 2544, MATH 3230, or MATH 3201.

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: MATH 2522 or MATH 2544; MATH 3230 or MATH 3201; or Instructor permission.

MATH 5990. Special Topics. 1-18 Credits.

See Schedule of Courses for specific titles.

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: MATH 3230.

MATH 6249. Nonlinear Partial Diff Eqs. 3 Credits.

This course covers modern mathematical theories and numerical methods for nonlinear partial differential equations. Topics include: inverse scattering transform; solitons; bilinear method; Darboux transformation; solitary waves; Vakhitov-Kolokolov stability criterion; transverse instability; virial theorem; wave collapse; pseudo-spectral method; split-step method. Prerequisite: MATH 5230 (or equivalent) or Instructor permission.

MATH 6344. Algebraic Topology. 3 Credits.

Homotopy, Seifert-van Kampen Theorem; simplicial, singular, and Cech homology. Prerequisite: MATH 3468 or MATH 4344.

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: MATH 3472.

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: MATH 3472.

MATH 6551. Abstract Algebra III. 3 Credits.

Advanced group theory and field theory. Prerequisite: MATH 3555 or Graduate student.

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. Prerequisite: MATH 3551 or MATH 5678.

MATH 6701. Principles of Complex Systems. 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. Complex Networks. 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: MATH 2248; MATH 2522 or MATH 2544; MATH 3230, MATH 3201, or MATH 3737 recommended.

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 5110. Mechanical Behavior Materials. 3 Credits.

Isotropic and anisotropic elasticity; theory of plasticity; deformation mechanisms in crystalline solids; dislocation theory; creep behavior; advanced fatigue and fracture mechanisms. Prerequisites: ME 2110; 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: ME 2240 or equivalent; 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 5410. Adv Bioengineering Systems. 3 Credits.

Advanced bioengineering design and analysis for current biomedical problems spanning molecular, cell, tissue, organ, and whole body systems including their interactions and emergent behaviors.

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. Prerequisite: ME 2231, ME 2111, or BME 3600. 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. Prerequisites: MATH 3201; MATH 2522 or MATH 2544. Cross-listed with: CEE 5980.

ME 5990. Special Topics. 1-18 Credits.

See Schedule of Courses for specific titles.

ME 6040. Adv Engineering Analysis II. 3 Credits.

Advanced analytical techniques for problems in engineering mechanics and physics, including: integral transform methods Green's functions, perturbation methods, and variational calculus. Prerequisite: ME 5040 or equivalent.

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 6250. Advanced Gas Dynamics. 3 Credits.

Transonic flows; hypersonic flows and shock relations; boundary layer interactions; high-temperature gases and aerothermodynamics; rarefied flows; computational methods. Prerequisite: ME 3250 or equivalent.

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: ME 2230.

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: PHYS 2200, PHYS 4300.

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: PHYS 2200.

PHYS 5300. Electromagnetic Theory. 3 Credits.

Development of Maxwell's theory of electromagnetism emphasizing its physical basis and the modes of mathematical description. Prerequisite: PHYS 4300.

PHYS 5400. Statistical Mechanics. 3 Credits.

Following a review of thermodynamics, we study 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: PHYS 3400 or equivalent.

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: PHYS 3500.

PHYS 5990. Special Topics. 1-18 Credits.

See Schedule of Courses for specific titles. Prerequisites: PHYS 2500; Department permission.

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. 1-12 Credits.

Research for the Master's Thesis.

PHYS 6600. Advanced Solid State Physics. 3 Credits.

Introduction to crystal symmetry and the reciprocal lattice. Crystal binding and lattice vibrations. Thermal, electrical, and magnetic properties of solids, free electron theory of metals, and band theory. Prerequisites: PHYS 4300, PHYS 3400, PHYS 3500 or their equivalents; Instructor permission.

PHYS 6700. Biological Physics II. 3 Credits.

Physical principles of biological systems including advanced techniques in macromolecular structure (experimental and computational), molecular solvation and hydration models, thermostatics, two-state models and cooperativity, elasticity and mechanics of soft tissues, chemical equilibria and reaction kinetics including enzymes. Prerequisites: PHYS 1650, MATH 2248, or Instructor permission.

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.