

PHYSICS

<http://www.uvm.edu/~physics/>

OVERVIEW

The Department of Physics offers research opportunities in theoretical and experimental condensed matter physics, astronomy and astrophysics, and soft condensed matter physics and biophysics.

Research in theoretical condensed matter physics focuses on the dynamics of quantum systems with application to electronic, magnetic, optical, structural, and thermal properties of nanomaterials including fullerene-derived solids (buckyballs) and carbon nanotubes. Basic research also includes the investigation of low energy scattering of atoms and molecules from surfaces and systems with many internal degrees of freedom, and the development of new methods for studying quantum many-body systems, such as new extensions of density functional theory to van der Waals systems. In addition, high performance computational techniques including quantum Monte Carlo and exact diagonalization are used to study strongly-interacting quantum systems with a focus on the types of emergent phenomena that are ubiquitous in complex systems. This includes investigations of entanglement in quantum fluids and gases in the presence of confinement, disorder, and dissipation.

The physics of recently discovered Graphene and its derivatives is another major direction of theoretical research. These materials exhibit unconventional electronic, magnetic, mechanical, and transport properties, and efforts are under way to understand the role of quantum many-body effects both from fundamental standpoint and in relation to nanodevice applications.

Additional theoretical studies include strongly-correlated electron systems, such as complex oxides and cuprates and high-temperature superconductors. Of particular interest are frustrated quantum magnets with novel ground states, as well as conducting cuprates which exhibit complex interplay of charge and spin phenomena. Such systems also tend to undergo quantum phase transitions, and the study of quantum critical phenomena is a major research direction.

Theoretical studies of the optical properties of materials include the electronic structure of defect complexes in ionic crystals, the application of subtracted dispersion relations to optical data analysis, and the separation of inter- and intra-band effects in the infrared spectra of metals. Related studies are concerned with theories of X-ray scattering, of X-ray optical properties, and of X-ray optical elements.

Research in materials physics includes studies of the kinetics of thin film growth and surface processing, applied to materials with interesting and useful physical properties such as organic semiconductors and magnetic materials. Many of the research projects involve real-time X-ray or electron diffraction structural studies of surface phenomena, combined with computer simulation of relevant surface processes. Available is an ultra-high vacuum thin-

film deposition laboratory dedicated to these studies, and regular use is made of synchrotron X-ray facilities in the U.S.

Additional research in materials physics includes studies of fundamental magnetic and spin-dependent electronic properties of semiconductor nanostructures that employ high magnetic field optical spectroscopy imaging techniques. The physics department hosts 1 of the few laboratories in New England where time-resolved, spin-dependent spectroscopy imaging at magnetic fields as high as 5 Tesla may be carried out.

Astrophysical research centers on experimental radio astronomy, with particular emphasis on pulsars and the interstellar medium. Observations are carried out using major instruments of the U.S. National Observatories and generally involve computer analysis and interpretation.

Research in biophysical ultrasound is directed toward an understanding of the physical principles involved when ultrasound interacts with living systems. This often involves collaboration with the College of Medicine. Acoustical and optical tweezers permit manipulating single cells without touching them. New forms of ultrasonic transducers and biosensors are being developed in collaboration with the Department of Electrical Engineering, as part of the Materials Science program. Biophysical research includes studies on the development and employment of novel uses of in situ atomic force microscopy for biological applications, specifically high-resolution structural studies of membrane proteins, investigation of the packing of genetic materials on bilayer membranes, and studies on how DNA-bilayer interactions affect the use of cationic lipids as gene-delivery means. Other research in biological physics and protein dynamics involves combining the detail of atomic-resolution X-ray crystallography with the sensitivity of optical and IR spectroscopy. The department has access to a state-of-the-art protein crystallography diffractometer and organizes regular trips to synchrotrons in the U.S. and Europe.

Opportunities for collaborative research with other university departments and groups include those with Chemistry, the Materials Science program, Molecular Physiology and Biophysics, the Cellular, Molecular and Biomedical Sciences program, Computer Science, Electrical Engineering, Civil and Environmental Engineering, Mechanical Engineering, Medical Radiology, and Geology.

The department participates in a doctoral program in Materials Science.

DEGREES

Physics AMP

Physics M.S.

Physics Ph.D.

FACULTY

Clougherty, Dennis Paul; Professor, Department of Physics; PHD, Massachusetts Institute of Technology

Del Maestro, Adrian G.; Adjunct Professor, Department of Physics; PHD, Harvard University

Furis, Madalina Ioana; Associate Professor, Department of Physics; PHD, University of Buffalo

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

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

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

White, Matthew S.; Assistant Professor, Department of Physics; PHD; University of Colorado Boulder

Wu, Junru; Professor Emeritus, Department of Physics; PHD, University of California Los Angeles

Yang, Jie; Associate Professor, Department of Physics; PHD, Princeton University

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.