

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 (<http://catalogue.uvm.edu/graduate/physics/physicsamp/>)
- Physics M.S. (<http://catalogue.uvm.edu/graduate/physics/physicsms/>)
- Physics Ph.D. (<http://catalogue.uvm.edu/graduate/physics/physicsphd/>)

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 202. Experimental Physics II. 3 Credits.

Experiments in classical and modern physics. Prerequisites: PHYS 128; MATH 121; Junior standing.

PHYS 211. Classical Mechanics. 3 Credits.

Newtonian dynamics of particles and systems of particles, with applications to problems of special importance, such as driven and coupled harmonic oscillators and central field trajectories. Prerequisites: PHYS 152, MATH 121.

PHYS 213. Electricity & Magnetism. 3 Credits.

Fundamental principles of electricity and magnetism; electrostatic fields, and magnetic fields of steady currents. Electric and magnetic properties of matter and electromagnetic energy. Prerequisites: PHYS 152 or PHYS 125 and MATH 121. Credit not given for more than one of PHYS 213 or EE 141.

PHYS 214. Electromagnetism. 3 Credits.

Introduction to time dependent electromagnetic fields. Maxwell's equations in vacuum and in matter. Electromagnetic waves and radiation. Prerequisite: PHYS 213. Credit not given for more than one of PHYS 214 or EE 241.

PHYS 222. Intro Biological Physics. 3 Credits.

General survey course in biological physics. Introduction to biological building blocks (proteins, lipids and nucleic acids) and macromolecular structure, thermostatics of biological systems and two-state models, random walks and polymers, elasticity and mechanics of filaments and membranes, physics of water and molecular solvation, brownian motion and diffusion. Prerequisites: PHYS 012 or PHYS 152, MATH 121.

PHYS 242. Intro to Solid State Physics. 3 Credits.

Introduction to crystal structures, reciprocal lattices, lattice vibrations. Thermal properties of solids and free electron theory of metals and semiconductors. Elementary band theory and introduction to electronic transport theory. Prerequisite: PHYS 128.

PHYS 264. Nuclear & Elem Particle Physic. 3 Credits.

Introduction to theoretical and experimental aspects of nuclear and elementary particle physics. Prerequisite: PHYS 128; Junior standing.

PHYS 265. Thermal & Statistical Physics. 3 Credits.

Thermodynamics, kinetic theory, statistical mechanics. Prerequisites: PHYS 152 or PHYS 125 and MATH 121.

PHYS 273. Quantum Mechanics I. 3 Credits.

Introduction to nonrelativistic quantum mechanics. Schrodinger equation and applications to simple systems. Prerequisite: PHYS 128, PHYS 211.

PHYS 274. Applctns of Quantum Mechanics. 3 Credits.

Applications of Quantum Mechanics including Quantum Statistical Mechanics, Time-Independent and Time- Dependent Perturbation Theory, WKB Approximation, Variational Principle and Scattering. Prerequisite: PHYS 273.

PHYS 301. 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 211, PHYS 214. Alternate years.

PHYS 305. 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 311. 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 211. Alternate years.

PHYS 313. Electromagnetic Theory. 3 Credits.

Development of Maxwell's theory of electromagnetism emphasizing its physical basis and the modes of mathematical description. Prerequisite: PHYS 214. Alternate years.

PHYS 323. Contemporary Physics. 0-6 Credits.

Topics of current interest in physics to be offered as student and faculty interest warrants. May be repeated for credit with department approval. Prerequisite: Instructor permission.

PHYS 333. Biological Physics. 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 152, MATH 121, or Instructor permission.

PHYS 341. 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 214, PHYS 265, PHYS 273 or their equivalents; Instructor permission.

PHYS 356. Computational Physics II. 3 Credits.

Advanced computational physics methods including classical and ab-initio molecular dynamics, classical and quantum Monte Carlo, variational methods, density functional theory, and others. May also include other topics such as high-performance computing and parallelization with MPI/OpenMP and GPUs. Prerequisites: PHYS 256, PHYS 265, PHYS 273.

PHYS 362. 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 273. Alternate years.

PHYS 365. 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. Prerequisites: PHYS 265 or equivalent.

PHYS 391. Master's Thesis Research. 1-12 Credits.**PHYS 491. Doctoral Dissertation Research. 1-18 Credits.**