of relevant surface processes. Available is an ultra-high vacuum thin-
studies of surface phenomena, combined with computer simulation
projects involve real-time X-ray or electron diffraction structural
semiconductors and magnetic materials. Many of the research
with interesting and useful physical properties such as organic
of thin film growth and surface processing, applied to materials
inclusion of fullerenes-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/
physicssamp/)
- Physics M.S. (http://catalogue.uvm.edu/graduate/physics/
physicssms/)
- Physics Ph.D. (http://catalogue.uvm.edu/graduate/physics/
physicsphd/)
PHYS 012. Molecular Solvation, Brownian Motion, and Diffusion. Prerequisites: Mechanics of Filaments and Membranes, Physics of Water, and Two-State Models; Random Walks and Polymers, Elasticity, and Macromolecular Structure; Thermostatistics of Biological Systems; Biological Building Blocks (Proteins, Lipids, and Nucleic Acids). General Survey Course in Biological Physics. Introduction to PHYS 222. Intro Biological Physics. 3 Credits.

PHYS 211. Classical Mechanics. 3 Credits. Development of Newtonian dynamics of particles and systems of particles, with applications to problems of special importance, such as driven systems. Credit not given for more than one of PHYS 213 or EE 241.

PHYS 213. 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 214. Electromagnetism. 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 215. 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 217. Mathematics for Theoretical Physics 1. 3 Credits. Introduction to mathematical methods of theoretical physics; vector and tensor analysis, partial differential equations, orthogonal functions, complex variables, and variational techniques. Prerequisite: Undergraduate degree in Physics; Instructor permission.

PHYS 218. Mathematical Methods of Physics. 3 Credits. Prerequisite: PHYS 217. 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 222. Intro Biological Physics. 3 Credits. General survey course in biological physics. Introduction to biological building blocks (proteins, lipids, nucleic acids) and macromolecular structure, thermostatistics 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 224. 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 & Elementary Particle Physics. 3 Credits. Introduction to theoretical and experimental aspects of nuclear and elementary particle physics. Prerequisite: PHYS 128; Junior standing.

PHYS 266. 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. Applications 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 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.