PHYSICS (PHY)

Master of Science, Doctor of Philosophy

Overview
Opportunities for study are those usually associated with large research universities, while the atmosphere of a small liberal arts university with an ideal faculty/student ratio is maintained.

For admission to the program, students should have knowledge of senior level undergraduate mechanics, electricity and magnetism, thermodynamics, and quantum physics. The course of study for each student is planned in conference with the graduate advisor after an evaluation of academic background and experience. Deficiencies may be removed during the first year of study by taking remedial courses.

The research interests of the graduate faculty are in experimental and computational biophysics, nanotechnology, optics, experimental and theoretical condensed matter physics, particle physics, and gravitation. All research laboratories are well-equipped with state-of-the-art instrumentation, such as subpicosecond pulsed lasers; EPR; time-resolved, UV-vis spectrophotometers; optical tweezers; atomic force microscopes; single molecule manipulators; high-sensitivity optical and confocal microscopes; numerous, standard biochemical research apparatuses; and others. The Center of Nanotechnology and Molecular Materials (www.wfu.edu/nanotech), which houses state-of-the-art electron microscopes, sample analysis and preparation instruments and a clean room, is part of the physics department. Computational and theoretical research is supported by the DEAC Linux Cluster (deac.wfu.edu (https://deac.wfu.edu/services/high-performance-computing/)) with several thousand computational processing cores.

For more details on the PhD program, visit www.wfu.edu/physics or write to the program director.

Programs

- Physics, MS (https://bulletin.wfu.edu/graduate/programs/degree-programs/physics/physics-ms/)
- Physics, PhD (https://bulletin.wfu.edu/graduate/programs/degree-programs/physics/physics-phd/)
- MD/PhD (https://bulletin.wfu.edu/graduate/programs/dual-degrees/md-phd/)
- PhD/MBA (https://bulletin.wfu.edu/graduate/programs/dual-degrees/phd-mba/)
- Structural and Computational Biophysics (SCB), Certificate (https://bulletin.wfu.edu/graduate/programs/certificates/structural-computational-biophysics-scb-certificate/)

Courses

PHY 601. Physics Seminar. (0.5 h)
Discussion of contemporary research, usually with visiting scientists. S/U only.

PHY 607. Biophysics. (3 h)
Introduction to the structure, dynamic behavior, and function of DNA and proteins, and a survey of membrane biophysics. The physical principles of structure determination by X-ray, NMR, and optical methods are emphasized.

PHY 610. Extragalactic Astronomy and Cosmology. (3 h)
Topics covered include galactic structure, models for galaxies and galaxy formation, the large-scale structure of the universe, the Big Bang model of the universe, physical processes such as nucleosynthesis in the early universe, and observational cosmology.

PHY 620. Physics of Macromolecules. (3 h)
The physics of large biologically important molecules, especially proteins and nucleic acids. Topics covered include the physical basis of biomolecular structure, the energetics and statistical mechanics of biomolecular dynamics, and the electrostatics and solvation of biomolecules. Designed for students with biochemistry, chemistry, or physics backgrounds.

PHY 623. Computational Biophysics Laboratory. (1 h)
Application of techniques in molecular modeling, including energy minimization, molecular dynamics simulation, and conformational analysis. C-PHY 620 or POI.

PHY 625. Biophysical Methods Lab. (1.5 h)
Experiments using various biophysical techniques such as electron paramagnetic resonance, atomic force microscopy, stopped-flow absorption spectroscopy, X-ray diffraction, and gel electrophoresis. C-PHY 607.

PHY 635. Computational Physics. (3 h)
An introduction to finding numerical solutions to scientific problems. Topics include understanding computational errors, differentiation, integration interpolation, root finding, random numbers, linear systems, Fourier methods, and the solution of ODEs and PDEs. There is no computer programming prerequisite. Credit will not be given for both PHY 635 and CSC/MST 655.

PHY 637. Analytical Mechanics. (1.5 h)
The Lagrangian and Hamiltonian formulations of mechanics with applications. Taught in the first half of the fall semester.

PHY 639. Electricity and Magnetism. (1.5 h)
Electrostatics, magnetostatics, dielectric and magnetic materials, Maxwell’s equations and applications to radiation, relativistic formulation. The first half course is taught in the second half of the fall semester, following PHY 637. The other course is taught in the spring semester. These should be taken in sequence.

PHY 640. Electricity and Magnetism. (3 h)
Electrostatics, magnetostatics, dielectric and magnetic materials, Maxwell’s equations and applications to radiation, relativistic formulation. PHY 640 is taught in the spring semester after PHY 639. These should be taken in sequence. P-PHY 639.

PHY 641. Thermodynamics and Statistical Mechanics. (3 h)
Introduction to classical and statistical thermodynamics and distribution functions.

PHY 643. Quantum Physics. (3 h)
Basic quantum theory and applications including the time-independent Schrodinger equation, formalism and Dirac notation, the hydrogen atom, spin, identical particles, and approximation models.

PHY 644. Quantum Physics. (3 h)
Basic quantum theory and applications including the time-independent Schrodinger equation, formalism and Dirac notation, the hydrogen atom, spin, identical particles, and approximation methods.

PHY 645. Introduction to Quantum Computing. (3 h)
Introduction to the physics of quantum information sciences and quantum computing.
PHY 652. Physical Optics and Optical Design. (4 h)
Interaction of light with materials; diffraction and coherent optics; ray
trace methods of optical design. C- PHY 652L.

PHY 652L. Physical Optics Lab. (0 h)

PHY 654. Introduction to Solid State Physics. (3 h)
Survey of the structure, composition, physical properties, and
technological applications of condensed matter. P-PHY 643.

PHY 655. Exotic Materials. (1.5 h)
This course explores materials systems that express exotic properties
derived from some aspect of dimensionality or topology. Thermal,
electrical, optical and magnetic properties of these quantum materials
will be addressed with emphasis on applications in quantum information
sciences. From superconducting SSH polymers, to topological insulators,
simple models are used throughout the course to develop insight into the
physics of low-dimensional structures.

PHY 656. Electronic Imaging Sciences. (1.5 h)
This course introduces the theory and application of the electron imaging
systems: transmission electron microscopy (TEM) and scanning electron
microscopy (SEM). It focuses on basic materials science though some
biological materials will be covered. It is taught as a series of lectures
followed by laboratories.

PHY 657. Scanning Probes. (1.5 h)
This course examines the theory and application of scanning tunneling
microscopy and atomic force microscopy (STM/AFM). It introduces how
each type of imaging works, how to model spectroscopic data, and how
to use each microscope. Students will image using the STM and AFM as
well as take and reduce spectroscopy data using models built in Maple or
Mathematica.

PHY 658. Kinetics of Materials. (1.5 h)
This course offers a study of driving forces for atomic and ionic motion
within solids leading to a range of materials properties from work
hardening to phase transformations and formation. Atomic-level models
for diffusion will be introduced as well as techniques and examples of
the solution to the diffusion equation. It complements the traditional
thermodynamics course.

PHY 661. Biophysics Seminar. (1 h)
Seminal and current publications in biophysics are studied. Each week a
member of the class makes an oral presentation on a chosen publication
and leads the ensuing discussion. Students may also be required to make
a second oral presentation relevant to their own research. Does not fulfill
course requirements for Master’s or PhD degrees. May be repeated for
credit. S/U only.

PHY 663. Condensed Matter Seminar. (1 h)
Seminal and current publications in condensed matter physics are
studied. Each week a member of the class makes an oral presentation on
a chosen publication and leads the ensuing discussion. Does not fulfill
course requirements for Master’s or PhD degrees. May be repeated for
credit. S/U only.

PHY 685. Bioinformatics. (3 h)
Introduction to computational approaches essential to modern biological
inquiry. Approaches may include large biological dataset analyses,
sequence similarity and motif searches, and analysis of high-throughput
genomic technologies. Emphasizes interdisciplinary interaction and
communication. Also listed as CSC 685 and BIO 685.

PHY 691. Special Topics in Physics. (1-4 h)
Courses in selected topics in physics. May be repeated if course content
differs.
PHY 771. Radiological Physics. (3 h)
The nature and fundamental concepts of ionizing radiation including: ionizing radiation, radiation quantities, attenuation and stopping power, charged particle and radiation equilibria radioactive decay, photon interactions, charged and uncharged particle interactions, x-ray production and quality, dosimetry concepts, ionization cavity theory, and calibration of ionizing radiation beams. Also listed as BMES 771 and MPH 771.

PHY 773. Radiation Therapy Physics. (3 h)
The physics of radiation treatment including: radiation producing equipment, character of photon and electron radiation beams, radiation dose functions, computerized radiation treatment planning, brachytherapy, special radiation treatment procedures, quality assurance, and radiation shielding for high energy facilities. Also listed as BMES 773 and MPH 773.

PHY 774. Physics of Medical Imaging. (3 h)
The physical principles, mathematical algorithms and devices used in diagnostic medical imaging, covering the following imaging modalities: x-ray digital imaging, digital image receptors, computerized tomography and reconstruction algorithms, ultrasound imaging, magnetic resonance imaging and nuclear medicine imaging. Also listed as BMES 774 and MPH 774.

PHY 776. Medical Health Physics. (3 h)
Physical and biological aspects for the use of ionizing radiation in medical environments, biological consequences of human radiation exposure, principles of ionizing radiation protection, operational dosimetry, radiation exposure recommendations and regulations, physical principles of radiation shielding design, personnel monitoring, medical health physics instrumentation, and waste disposal. Also listed as BMES 776 and MPH 776.

PHY 780. Theory of General Relativity. (3 h)
Study of the covariant formulation of physical laws in mechanics and electromagnetism.

PHY 785. Topics in Theoretical Physics. (1-3 h)
Selected topics of current interest in theoretical physics not included in other courses. May be repeated for credit.

PHY 787. Advanced Topics in Physics. (1-3 h)
Lectures on advanced topics in physics that depend on the subspecialty of the instructor. Topics range from medical physics to special topics in biophysics, condensed matter physics, or quantum optics. May be repeated for credit.

PHY 789. Survival Skills for Scientists. (1 h)
Students will learn skills that are essential to a successful career in the sciences. The following topics will be covered: Mentoring; How to Read, Write, and Review a Research Paper; Grant & Fellowship Basics; Choosing a Career Path & Creating a Winning Job Application; and Networking & Giving Effective Talks.

PHY 791. Thesis Research I. (1-9 h)
May be repeated for credit. Satisfactory/Unsatisfactory.

PHY 792. Thesis Research II. (1-9 h)
May be repeated for credit. Satisfactory/Unsatisfactory.

PHY 795. Physics for Education Research. (3 h)
Fulfills the requirement for a graduate course in physics for students in the Masters in Education program seeking certification to teach physics.

PHY 891. Dissertation Research I. (1-9 h)
May be repeated for credit. Satisfactory/Unsatisfactory.

PHY 892. Dissertation Research II. (1-9 h)
May be repeated for credit. Satisfactory/Unsatisfactory.

Faculty
Program Director and Professor Freddie Salsbury
Department Chair/Professor/Harbert Family Distinguished Chair Daniel B. Kim-Shapiro
Professor and Wright Family Endowed Chair in Physics Timo Thonhauser
Baker Family Professor of Physics Oana Jurchescu
Professor/Associate Chair/Kykenych Family Fellow Martin Guthold
Professor and Associate Provost for Research and Scholarly Activities Keith Bonin
Professor and MacDonough Family Fellow Paul R. Anderson
Professors David L. Carroll, Natalie A. W. Holzwarth, Jed Macosko
Associate Professors Eric D. Carlson, Samuel S. Cho, Gregory B. Cook
Teaching Professor Jack A. Dostal
Assistant Professors Ajay Ram Srimath Kandada, Stephen M. Winter
Adjunct Professors J. Daniel Bourland, Michael Munley, Peter Santiago
Adjunct Associate Professor Adam R. Hall
Affiliate Assistant Professors Erin Henslee, Lauren Lowman