

Physics

College of Arts & Sciences

The Department of Physics and Astronomy offers courses and research opportunities leading to the M.S. and Ph.D. degrees in the areas of astronomy and astrophysics, atomic and molecular physics, low and intermediate energy nuclear physics, condensed matter physics, and particle physics. More detailed descriptions of each of these options is available at <https://pa.as.uky.edu/pa-faculty-research>. Opportunities exist for experimental, theoretical, and computational, and observational research. Excellent laboratory facilities and library materials are available. Major facilities located within the Department are the six-million volt Van de Graaff accelerator and the Center for Advanced Materials. Computational resources include the Lipscomb HPC cluster and access to XSEDE, NERSC, TACC, JLab and BNL. The Department is active in research at many national laboratories, including Jefferson Lab (Virginia), Oak Ridge National Lab (Tennessee), Los Alamos National Lab (New Mexico), Argonne National Lab (Illinois), Brookhaven National Lab (New York), Triangle Universities Nuclear Lab (North Carolina), National High Magnetic Field Facility (Florida), and Lawrence Berkeley Lab (California) as well as international laboratories including Paul Scherrer Institute (Switzerland), TRIUMF (Vancouver), and MAX-lab (Sweden). In astronomy our students conduct research at facilities including the National Radio Astronomy Observatory (West Virginia), Arecibo Observatory (Puerto Rico), Kitt Peak National Observatory (Arizona), McDonald Observatory (Texas), and the Hubble Space Telescope, and participate in collaborations including Sloan Digital Sky Survey-IV (SDSS-IV) and the Large Synoptic Survey Telescope (LSST). Such activities expose our graduate students to state-of-the-art instrumentation and world-class researchers.

Admission Requirements

In addition to the admissions requirements of the Graduate School, the Department of Physics & Astronomy requires graduate applicants to have a sound foundation in undergraduate physics. This foundation will normally include advanced courses in classical mechanics, electromagnetism and quantum mechanics. Applicants are encouraged to take the GRE physics subject exam. Applicants wishing to apply for financial aid in the form of a teaching assistantship, research assistantship or fellowship must supply letters of recommendation from three individuals familiar with their academic capabilities. Such applicants must also submit a written statement of their interests and background in physics.

Admissions requirements are the same for the M.S. and the Ph.D. programs except that applicants for the Ph.D. must possess an interest in carrying out original research at the advanced level.

Degree Requirements

The M.S. program can include an emphasis on basic or applied physics or physics education, and students are encouraged to take courses in related programs that satisfy the appropriate academic objectives. Before taking the M.S. oral exam, the M.S. student must have completed (with a B average) 16 (plan A with a thesis) or 20 (plan B without a thesis) credit hours in approved graduate courses.

The Ph.D. degree is a research degree granted on the basis of broad knowledge of physics and in-depth research in a specific area leading to a dissertation (and generally publications in appropriate refereed journals). Students may perform this research at the University of Kentucky or appropriate collaborating institutions. Before taking the Ph.D. qualifying exam, the student must pass the Physics GRE at the 50th percentile or higher and satisfactorily pass core courses in graduate classical mechanics, electromagnetism, quantum mechanics, and statistical mechanics, as well as electives in topical areas of modern physics.

Course Descriptions

PHY 504 ADVANCED MECHANICS. (3)

A continuation and extension of PHY 404G. Includes dynamics of a particle, rigid bodies, Lagrange's equations, constrained motions, and oscillations. Prereq: PHY 404G, MA 214.

PHY 506 METHODS OF THEORETICAL PHYSICS I. (3)

The course and its sequel (MA/PHY 507) are designed to develop, for first-year graduate students, familiarity with the mathematical tools useful in physics. Topics include curvilinear coordinates, infinite series, integrating and solving differential equations of physics, and methods of complex variables. Work with Green's functions, eigenvalues, matrices and the calculus of variations are included as a part of MA/PHY 506 and 507. Prereq: PHY 404G or equivalent. (Same as MA 506.)

PHY 507 METHODS OF THEORETICAL PHYSICS II.

Continuation of MA/PHY 506. Fourier and Laplace Transforms, the special functions (Bessel, Elliptic, Gamma, etc.) are described. Work with Green's functions, eigenvalues, matrices and the calculus of variations are included as a part of MA/PHY 506 and 507. Prereq: MA/PHY 506. (Same as MA 507.)

PHY 508 COMPUTATIONAL PHYSICS. (3)

A laboratory and lecture course using computational and numerical methods to investigate different phenomena in selected topics of physics. Lecture 2 hours; laboratory, 2 hours per week. Prereq: PHY 361.

PHY 520 INTRODUCTION TO QUANTUM MECHANICS I. (3)

A lecture and problem course providing an introduction to the concepts and formalism of quantum mechanics. Primary emphasis is on the time-independent Schrodinger equation and its applications to simple systems such as the harmonic oscillator, the square-well potential, and the hydrogen atom without spin. Prereq: PHY 361, MA 214.

PHY 521 INTRODUCTION TO QUANTUM MECHANICS II. (3)

A continuation of PHY 520, introducing the quantum description of systems with spin, and approximation methods. Principles of quantum mechanics will be illustrated by their application to model systems selected from the fields of atomic, solid state, nuclear and particle physics. Prereq: PHY 520.

PHY 522 THERMODYNAMICS AND STATISTICAL PHYSICS. (3)

Temperature, heat, and entropy, and the Laws of Thermodynamics, as applied to simple systems. Introduction to statistical mechanics and the description of thermodynamic quantities in terms of ensemble averages. Prereq: PHY 361 and MA 214.

PHY 524 SOLID STATE PHYSICS. (3)

Introductory solid state physics with emphasis on the properties of electrons in crystals; crystal structure, crystal diffraction, reciprocal lattice, lattice vibrations and phonons, free electron theory, energy bands in solids, semiconductors. Prereq: PHY 520, or consent of instructor. Engineering standing required for EE 524. (Same as EE 524.)

PHY 525 CONDENSED MATTER PHYSICS. (3)

Optical, magnetic, and transport properties of metals, semiconductors, superconductors, and dielectrics; cooperative phenomena and phase transitions. Prereq: PHY 524 or consent of instructor.

PHY 535 ADVANCED PHYSICS LABORATORY. (3)

An advanced laboratory course emphasizing quantum phenomena in atomic, solid state and nuclear systems. Laboratory techniques include optical spectroscopy, gamma-ray and particle detection, optical

pumping, atomic and nuclear collisions, and interferometer. Prereq: PHY 335, PHY 361. This course is a Graduation Composition and Communication Requirement (GCCR) course in certain programs, and hence is not likely to be eligible for automatic transfer credit to UK.

PHY 545 RADIATION HAZARDS AND PROTECTION. (3)

An analysis of common radiation hazards encountered in medicine, research, industry, and the environment. Regulations and procedures for the safe use of ionizing and nonionizing radiations. Lecture, two hours; laboratory, two and one-half hours. Prereq: PHY/RM 472G or consent of instructor. (Same as RM/RAS 545.)

PHY 546 GENERAL MEDICAL RADIOLOGICAL PHYSICS. (3)

The uses and dosimetric aspects of radiation in medicine will be analyzed, including many basic applications in the fields of diagnostic radiology physics, therapy physics, and nuclear medical physics. Prereq or concur: RM/PHY 472G or consent of instructor. (Same as RM/RAS 546.)

PHY 554 FUNDAMENTALS OF ATOMIC PHYSICS. (3)

A continuation of introductory quantum mechanics with application to atomic systems. Topics include angular momentum, perturbation theory, variational principles, interaction of radiation with matter, atomic spectra and the Zeeman and Stark effects. Prereq: PHY 520.

PHY 555 FUNDAMENTAL NUCLEAR PHYSICS. (3)

Topics covered include nuclear systematics, the nucleon-nucleon-interaction, nuclear models, radioactivity, nuclear reactions, fission and fusion. Prereq: PHY 520.

PHY 556 FUNDAMENTAL PARTICLE PHYSICS.

Introduction to elementary particle physics. Topics include: particle interactions and families, the quark model, symmetries and conservation laws, particle reactions and decays, quark dynamics, and elements of quantum chromodynamics and electroweak interactions. Prereq: PHY 520.

PHY 567 INTRODUCTION TO LASERS AND MASERS. (3)

Basic principles of laser action, atomic transitions; population inversion; two- and three-level systems; optical resonators; pumping methods; applications. Prereq: EE 360, EE 468G, or PHY 417G, or consent of instructor. (Same as EE 567.)

PHY 570 SEMINAR ON TEACHING PHYSICS. (1)

A seminar course for teaching assistants focused on developing the art and science of teaching physics. Journal articles, books and other texts will be studied to serve as sources of discussion about the teaching and learning activities in the Department of Physics and Astronomy. Prereq: Consent of instructor.

PHY 571 SEMINAR ON TEACHING PHYSICS LABORATORIES. (1)

A seminar course for teaching assistants focused on developing the art and science of teaching physics laboratories. Journal articles, books and other texts will be studied to serve as sources of discussion about the teaching and learning activities in the laboratory classes in the Department of Physics and Astronomy. Prereq: Consent of instructor.

PHY 591 ASTROPHYSICS I – STARS. (3)

The physics of stars from star formation to stellar death. Topics include stellar structure and evolution, energy generation and transport, the later stages of stellar evolution and stellar remnants. Prereq: PHY 361, PHY 416G, PHY 417G or consent of instructor. (Same as AST 591.)

PHY 592 ASTROPHYSICS II – GALAXIES AND INTERSTELLAR MATERIAL. (3)

The physics of galaxies and of the interstellar medium. Topics include galaxy formation, evolution and interaction, phases of the interstellar medium, and physical processes in the interstellar medium. Prereq: PHY 361, PHY 416G, PHY 417G or consent of instructor.
(Same as AST 592.)

PHY 600 SELECTED TOPICS IN ADVANCED PHYSICS. (2-3)

An advanced seminar course on topics related to departmental research programs. Topics may include astrophysics, atomic physics, condensed matter physics, nuclear physics and particle physics. May be repeated to a maximum of nine hours. Prereq: Consent of instructor.

PHY 605 GRAVITY. (3)

An introduction to the general theory of relativity, covering tensor analysis, Einstein's equations, experimental tests, black holes, and cosmology. Prereq: PHY 504 and PHY 417G, or permission of instructor.

PHY 611 ELECTROMAGNETIC THEORY I. (3)

A lecture and problem course treating electrostatics, boundary conditions, potential problems, energy in electric and magnetic fields, magnetic materials and Maxwell's equations. Prereq: PHY 416G; MA 214.

PHY 613 ELECTROMAGNETIC THEORY II. (3)

Continuation and extension of PHY 611. Includes theory of electromagnetic waves and applications to optical phenomena and radiation. Special theory of relativity and the covariant treatment of Maxwell's equations will be discussed. Prereq: PHY 611.

PHY 614 QUANTUM MECHANICS I. (3)

A lecture and problem course dealing with the description of quantum systems in the forms of wave mechanics, matrix mechanics and state vectors. Also includes angular momentum and its addition, and approximation methods for bound states. Prereq: PHY 520.

PHY 615 QUANTUM MECHANICS II. (3)

Continuation of PHY 614 covering time dependent perturbation theory, symmetry and invariance principles, and elementary scattering theory including the method of partial waves. Prereq: PHY 614.

PHY 616 QUANTUM FIELD THEORY I.

An introduction to field theory and many-body theory. Topics include path integral quantization, second quantization, relativistic field theory of bosons and fermions, Green's function and perturbation theory, field theories on the lattice, renormalization of scalar fields and applications to critical phenomena. Prereq: PHY 615, PHY 632.

PHY 624 CONDENSED MATTER THEORY. (3)

Electron band theory, lattice dynamics, electron-phonon and electron-electron interactions, superconductivity and superfluidity, Fermi liquid theory. Prereq: PHY 524, 614, 632.

PHY 630 TOPICS IN NUCLEAR AND INTERMEDIATE ENERGY PHYSICS (Subtitle required). (3)

A course in nuclear physics, hadron physics and particle physics. Emphasis is placed on topics related to departmental research activities at Jefferson laboratory and elsewhere. Such topics include study of the structure and interactions of hadrons in terms of quarks and gluons. They also include low energy tests of Standard Model predictions. (PHY 630 may be repeated to a maximum of six hours when taken under different subtitles.) Prereq: PHY 629.

PHY 632 STATISTICAL MECHANICS. (3)

A lecture and problem course dealing with the thermal properties of matter from the standpoint of statistical mechanics. Topics include thermodynamic properties, perfect gases, and Fermi-Dirac statistics. Prereq: PHY 504, 520, 522.

PHY 639 PHYSICAL PROCESSES IN ASTROPHYSICS. (3)

A lecture and problem course covering the physical processes encountered in astrophysics. The topics covered will include microphysical processes in stellar atmospheres and the interstellar medium, high-energy astrophysics, and basic hydrodynamics and shock waves. Prereq: PHY/AST 592 or consent of instructor. (Same as AST 639.)

PHY 716 QUANTUM FIELD THEORY II. (3)

A continuation of PHY 616. Topics include approximation methods in many body theory and applications to condensed matter and nuclear systems, quantum electrodynamics, radiative corrections, Higgs mechanism and applications to particle physics and superconductivity, introduction to non-Abelian gauge fields and the standard model. Prereq: PHY 616.

PHY 748 MASTER'S THESIS RESEARCH. (0)

Half-time to full-time work on thesis. May be repeated to a maximum of six semesters. Prereq: All course work toward the degree must be completed.

PHY 749 DISSERTATION RESEARCH. (0)

Half-time to full-time work on dissertation. May be repeated to a maximum of six semesters. Prereq: Registration for two full-time semesters of 769 residence credit following the successful completion of the qualifying exams.

PHY 767 DISSERTATION RESIDENCY CREDIT. (2)

Residency credit for dissertation research after the qualifying examination. Students may register for this course in the semester of the qualifying examination. A minimum of two semesters are required as well as continuous enrollment (Fall and Spring) until the dissertation is completed and defended. A weekly meeting of the staff and advanced students for the discussion of recent developments in physics and of work in progress in the department. Credit is given to those who satisfactorily present papers. May be repeated to a maximum of eight credi