

## PHY

## Physics

**Note:** It is assumed that all prerequisites include, in addition to any specific course listed, the phrase “or equivalent,” or “consent of instructor.”

### **PHY 120 HOW THINGS WORK. (3)**

The close relationship between physical science, technology and our everyday lives will be illuminated by examination of the technology we purchase and use and by observations of natural phenomena we can make using only the informed mind and eye.

### **PHY 130 SCIENCE AND TECHNOLOGY FOR THE FUTURE. (3)**

This course will explore the energy issues of today and tomorrow, including where the energy of the future will come from, energy independence, global warming, nuclear power, the potential of renewable energy sources, and the future of coal, showing how these are affected by history, geography, politics, technology, and the laws of physics and economics.

### **PHY 140 QUANTUM THEORY FOR EVERYONE. (3)**

A lecture course to explore the surprising nature of the nano-world. Wave properties of matter, probabilistic interpretation, duality, causality, uncertainty principle and quantum entanglement. Technologies and discoveries which exploit quantum effects will be selectively covered.

### **PHY 151 INTRODUCTION TO PHYSICS. (3)**

A lecture demonstration course covering the mechanics of solids, liquids, gases, heat, and sound. Credit is not given to students who already have credit for PHY 201, 211 or 231. Prereq: Two years of high school algebra, and an ACT math score of 19 or above, or SAT math score of 515 or above or SAT2016 math score of 510 or above, or MA 108R or higher.

### **PHY 152 INTRODUCTION TO PHYSICS. (3)**

A lecture demonstration course covering electricity, magnetism, optics, atomic and nuclear physics. Credit is not given to students who already have credit for PHY 203, 213 or 232. Prereq: Two years of high school algebra or MA 108R.

### **PHY 160 PHYSICS AND ASTRONOMY FOR TEACHERS. (3)**

The basics of electric circuits, magnetism, object motion, naked-eye astronomy and light behavior. The course is designed in conjunction with GLY 160 to provide basic concepts of earth science, astronomy and physics appropriate for elementary and middle school teachers. Both courses are taught with an emphasis on inquiry-based, laboratory activities. Lecture, one hour; laboratory, five hours per week.

### **PHY 170 BLACK HOLES AND TIME TRAVEL. (3)**

The course will discuss basic concepts in physics prior to the 20th century and the backdrop to the emergence of the Special Theory of Relativity. Elements of Special and General Relativity will be discussed at a non-technical level. These concepts will be used to explain how very massive stars inevitably collapse to form black holes. Their observational signatures will be discussed. The work of Hawking leading to the prediction that black holes emit faint radiation will be explained. Finally, the possibility of existence of wormholes leading to time travel will be explored.

### **PHY 210 SPECIAL LABORATORY FOR GENERAL PHYSICS PHY 201. (1)**

Special laboratory for students who have completed PHY 201 and later determine that they need an accompanying laboratory. Laboratory, two hours per week. Prereq: PHY 201.

### **PHY 211 GENERAL PHYSICS. (5)**

First part of a two-semester survey of classical and modern physics, focusing on the motion of solids and fluids as governed by Newton's Laws and by the conservation laws of energy, momentum, and angular momentum. Lecture, two hours; recitation, two hours; laboratory, two hours. Credit is not given to students who already have credit for PHY 231 and 241. Prereq: A working knowledge of algebra as obtainable in MA 109 or MA 110 or MA 112, or an ACT math score of 25 or above, or an SAT math score of 590 or above, or an SAT2016 math score of 610 or above.

### **PHY 212 SPECIAL LABORATORY FOR GENERAL PHYSICS PHY 203. (1)**

Special laboratory for students who have completed PHY 203 and later determine that they need an accompanying laboratory. Laboratory, two hours per week. Prereq: PHY 203.

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- PHY 213 GENERAL PHYSICS.** (5)  
Continuation of PHY 211, covering electrostatics, de circuits, magnetism, Maxwell's Equations, electromagnetic radiation, light and some modern physics. Lecture, two hours; recitation, two hours; laboratory, two hours. Credit is not given to students who already have credit for PHY 232 and 242. Prereq: PHY 211 or equivalent.
- PHY 228 OPTICS, RELATIVITY AND THERMAL PHYSICS.** (3)  
A lecture and problems course covering the principles of geometrical optics, special relativity, and thermal physics. Prereq or concur: MA 114.
- PHY 231 GENERAL UNIVERSITY PHYSICS.** (4)  
First part of a two-semester survey of classical physics. Consequences of the principles of mechanics are developed conceptually, analytically and quantitatively. Lecture, three hours; recitation, one hour per week. Prereq or concur: MA 113.
- PHY 232 GENERAL UNIVERSITY PHYSICS.** (4)  
A general course covering electricity, magnetism, electromagnetic waves and physical optics. Lecture, three hours; recitation, one hour per week. Prereq: PHY 231; concur: MA 213.
- PHY 241 GENERAL UNIVERSITY PHYSICS LABORATORY.** (1)  
A laboratory course offering experiments in mechanics and heat, framed in a small group environment that requires coordination and team work in the development of a well-written lab report. Prereq or concur: PHY 231.
- PHY 242 GENERAL UNIVERSITY PHYSICS LABORATORY.** (1)  
A laboratory course offering experiments in electricity, magnetism, and light, framed in a small group environment that requires coordination and team work in the development of a well written lab report. Prereq: PHY 241; concur: PHY 232.
- PHY 306 THEORETICAL METHODS OF PHYSICS.** (3)  
A lecture and problems course on the applications in physics of vector calculus, Fourier series and transforms, special functions and asymptotic forms. Prereq or concur: MA 214.
- PHY 335 DATA ANALYSIS FOR PHYSICISTS.** (2)  
A computational methods course in the theory and techniques of data analysis and error propagation, with emphasis on applications common to the physical sciences: the treatment of statistical errors, the maximum-likelihood method, the chi-square distribution, and curve fitting. Students will learn computer programming, and they will prepare a set of analysis programs for use in subsequent lab courses. Concur: MA 213, PHY 242. (Same as STA 335.)
- PHY 361 PRINCIPLES OF MODERN PHYSICS.** (3)  
An introduction to the foundations of quantum mechanics and selected topics in atomic, nuclear, particle, solid state, and statistical physics. Prereq: MA 213; PHY 232 or, with consent of instructor, PHY 213.
- PHY 395 INDEPENDENT WORK IN PHYSICS.** (1-3)  
Students may select an approved topic for study under the direction of a faculty member. May be repeated to a maximum of 12 credits. Prereq: Major and a standing of 3.0 in the department.
- PHY 401G SPECIAL TOPICS IN PHYSICS AND ASTRONOMY FOR ELEMENTARY, MIDDLE SCHOOL AND HIGH SCHOOL TEACHERS.** (1-4)  
Selected topics in physics and astronomy of special interest to teachers will be discussed. When the course is offered, a specific title with specific credits, the number of hours in lecture-discussion and laboratory will be announced. Lecture/discussion, two-four hours; laboratory, zero-four hours. May be repeated to a maximum of eight credits. Prereq: Open only to elementary, middle school and high school teachers.
- PHY 402G ELECTRONIC INSTRUMENTATION AND MEASUREMENTS.** (3)  
Elementary treatment of electronic circuits emphasizing laboratory work. Topics include AC circuits, filters, theory and operation of transistors and other semiconductor devices and a simple treatment of operational amplifiers. Lecture, two hours per week; laboratory, three hours per week. Prereq: PHY 242 or EE 305 or consent of instructor. (Same as EE 402G.)

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**PHY 404G MECHANICS. (3)**

A lecture and problem course covering the fundamental laws of mechanics. Topics include Newton's Laws, Kepler's Laws, oscillatory motion and an introduction to Lagrangian methods. Prereq: PHY 232, or with permission of Director of Undergraduate Studies, PHY 213; concur: MA 214.

**PHY 416G ELECTRICITY AND MAGNETISM. (3)**

First of two lecture and problem courses covering: the theory of electrostatic fields in the presence of conductors and dielectric materials, magnetic fields due to steady currents in the presence of magnetic materials, electromagnetic induction, and electromagnetic fields due to time-varying currents. Prereq: PHY 306; MA 214 with a grade of C or better.

**PHY 417G ELECTRICITY AND MAGNETISM. (3)**

Second of two lecture and problem courses covering: the theory of electrostatic fields in the presence of conductors and dielectric materials, magnetic fields due to steady currents in the presence of magnetic materials, electromagnetic induction, and electromagnetic fields due to time-varying currents. Prereq: PHY 416G.

**PHY 422 COMPUTATIONAL PHYSICS LABORATORY (3)**

An introductory laboratory and lecture course covering the application of numerical methods to the solution of problems encountered in classical mechanics and electrostatics. Students will be expected to write computer programs, but no previous programming experience is required. Lecture, one hour; laboratory, four hours per week. Prereq: MA 214, PHY 404G.

**PHY 435 INTERMEDIATE PHYSICS LABORATORY. (3)**

An intermediate-level laboratory course emphasizing quantum phenomena in atomic, solid state and nuclear systems. Laboratory techniques include optical spectroscopy, gamma-ray and particle detection, atomic and nuclear collisions, and interferometry. This course satisfies the Graduation Writing Requirement. 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 460G HANDS-ON PHYSICS FOR MIDDLE SCHOOL AND HIGH SCHOOL TEACHERS. (2)**

An exploration of classical and modern physics, in a laboratory setting. This course may be taken twice for credit. Prereq: PHY 228 and PHY 361.

**PHY 472G INTERACTION OF RADIATION WITH MATTER. (3)**

Basic aspects of the interaction of ionizing radiation with matter. Bohr atom, atomic spectra, radioactivity, energetics of decay. Sources of radiation, penetration of charged particles, electromagnetic radiation, and neutrons through matter; excitation and ionization processes; selected nuclear reactions; basic radiation detection and dosimetry. Prereq: PHY 213 or 232; MA 114 (may be taken concurrently); or equivalent. (Same as RAS/RM 472G.)

**PHY 495 SENIOR THESIS. (3)**

With mentoring from faculty member(s), advanced undergraduate students propose and execute an independent research project. A final report will be written and a presentation will be made in a forum such as a professional meeting, a student group such as a regional or national Society of Physics Students meeting, or a small group of faculty. May be repeated to a maximum of six credits. Prereq: Advanced standing.

**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.)

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**PHY 507 METHODS OF THEORETICAL PHYSICS II. (3)**

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.

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- PHY 556 FUNDAMENTAL PARTICLE PHYSICS. (3)**  
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.

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- PHY 616 QUANTUM FIELD THEORY I. (3)**  
 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 micro-physical 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.
- PHY 768 RESIDENCE CREDIT FOR THE MASTER'S DEGREE. (1-6)**  
 May be repeated to a maximum of 12 hours.
- PHY 769 RESIDENCE CREDIT FOR THE DOCTOR'S DEGREE. (0-12)**  
 May be repeated indefinitely.
- PHY 770 COLLOQUIUM. (1)**  
 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 credits.

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**PHY 781 INDEPENDENT WORK IN PHYSICS. (1-9)**

May be repeated to a maximum of 18 credits. Prereq: Graduate standing in Physics.

**PHY 790 RESEARCH IN PHYSICS. (3)**

May be repeated to a maximum of six credits.

**PHY 791 RESEARCH IN PHYSICS. (5)**

May be repeated to a maximum of 10 credits.