

# PHY - PHYSICS

## PHY 1001 Perspectives in Physics, Biomedical Physics, and Astronomy Cr. 1

Survey of educational and career paths including specializations in basic research and applied disciplines; recommended for entering students and those considering or beginning a major or minor concentration. Offered Fall.

**Restriction(s):** Enrollment is limited to Undergraduate level students.

## PHY 1020 (PS) Conceptual Physics: The Basic Science Cr. 4

Physical concepts and practical applications to everyday life of the basic principles of motion, forces, energy, matter, heat, sound, electricity, magnetism, and light. Lectures, demonstrations and optional laboratory; laboratory is strongly recommended. Meets General Education Laboratory Requirement when elected for 4 credits. Offered Every Term.

**Course Material Fees:** \$25

## PHY 2020 Science, Technology, and War Cr. 4

Modern weapons, nuclear and otherwise are becoming increasingly available and dangerous; people with grievances seem eager to use them. Science and technology, as well as constraints of bureaucracy and society underpin weapons development and use, as technologies affect prospects and results of war and peace. History of humanity and its tools of war. Offered Yearly.

**Equivalent:** HIS 2510, PCS 2020, PS 2440

## PHY 2130 (PS) Physics for the Life Sciences I Cr. 4

Introduction to physics for students in the life sciences, preparing for medicine, dentistry, pharmacy and health sciences and for general Liberal Arts and Sciences students. Covers motion, forces, energy, diffusion, fluids, thermal physics with many biological examples. Satisfies General Education laboratory requirement only when taken concurrently with PHY 2131. No credit after PHY 2170. Offered Every Term.

**Corequisite:** PHY 2131

## PHY 2131 Physics for the Life Sciences Laboratory Cr. 1

Laboratory experiments in fluid mechanics, diffusion and biophysics. Satisfies General Education laboratory requirement only when taken concurrently with PHY 2130. Offered Every Term.

**Course Material Fees:** \$25

## PHY 2140 (PS) Physics for the Life Sciences II Cr. 4

Second part of introduction to physics for students in the life sciences, students preparing for medicine, dentistry, pharmacy and health sciences and for general Liberal Arts and Sciences students. Covers thermodynamics, electric fields, oscillations, waves and optics. Satisfies General Education laboratory requirement only when taken concurrently with PHY 2141. No credit after PHY 2180. Offered Every Term.

**Prerequisites:** ((PHY 2130 with a minimum grade of C-))

**Corequisite:** PHY 2141

## PHY 2141 Physics for the Life Sciences Laboratory Cr. 1

Laboratory experiments in electric fields, fluids, optics and spectroscopy. Satisfies General Education laboratory requirement only when taken concurrently with PHY 2140. Offered Every Term.

**Course Material Fees:** \$25

## PHY 2170 (PS) University Physics for Scientists I Cr. 4

For students specializing in physics, biology, chemistry, mathematics or engineering. Statics, kinematics, dynamics, energy and linear momentum, rotational kinematics and dynamics, angular momentum, solids and fluids, vibrations and wave motion, thermodynamics. Satisfies General Education Laboratory Requirement only when taken concurrently with PHY 2171. No credit after PHY 2175. Offered Every Term.

**Prerequisites:** ((MAT 1800 with a minimum grade of C-)) AND (May be taken concurrently: [MAT 2010 with a minimum grade of C-])

**Corequisite:** PHY 2171

## PHY 2171 University Physics Laboratory Cr. 1

Laboratory experiments in statics, kinematics, dynamics, energy and linear momentum, rotational kinematics and dynamics, angular momentum, simple harmonic motion, optics, continuum mechanics, thermodynamics. Satisfies General Education laboratory requirement only when taken concurrently with PHY 2170. Offered Every Term.

**Course Material Fees:** \$25

## PHY 2175 (PS) University Physics for Engineers I Cr. 4

For students specializing in engineering. Statics, kinematics, dynamics, energy and linear momentum, rotational kinematics and dynamics, angular momentum, solids and fluids, vibrations and wave motion, thermodynamics. No credit after PHY 2170. Offered Every Term.

**Prerequisites:** ((MAT 1800 with a minimum grade of D-)) AND (May be taken concurrently: [MAT 2010 with a minimum grade of C])

**Restriction(s):** Enrollment limited to students in the College of Engineering.

## PHY 2180 University Physics for Scientists II Cr. 4

Electric forces and electric fields, electrical energy, capacitance, current, resistance, direct current circuits, magnetism, induced voltage and inductance, AC circuits, electromagnetic waves, geometric and wave optics. No credit after PHY 2185. Offered Every Term.

**Prerequisites:** ((MAT 2010 with a minimum grade of D-)) AND (May be taken concurrently: [MAT 2020 with a minimum grade of D-]) AND ((PHY 2170 with a minimum grade of C-))

**Corequisite:** PHY 2181

## PHY 2181 University Physics Laboratory II Cr. 1

Laboratory experiments in electrostatics, currents and circuit elements, magnetic fields, magnetic induction, AC circuits, electromagnetic waves, interference of waves. Offered Every Term.

**Course Material Fees:** \$25

## PHY 2185 University Physics for Engineers II Cr. 4

Electric forces and electric fields, electrical energy, capacitance, current, resistance, direct current circuits, magnetism, induced voltage and inductance, AC circuits, electromagnetic waves, geometric and wave optics. No credit after PHY 2180. Offered Every Term.

**Prerequisites:** ((PHY 2170 with a minimum grade of C-)) OR (PHY 2175 with a minimum grade of C-)) AND ((MAT 2010 with a minimum grade of D-)) AND (May be taken concurrently: [MAT 2020 with a minimum grade of D-])

**Restriction(s):** Enrollment limited to students in the College of Engineering.

## PHY 2210 General Physics Laboratory Cr. 1

Consult departmental undergraduate academic advisor prior to registering for this course. No credit after PHY 1020 if taken for four credits. Offered Every Term.

**Prerequisite:** PHY 1020 with a minimum grade of D-

**Course Material Fees:** \$15

**PHY 3100 (PS) The Sounds of Music Cr. 4**

For music majors and other students interested in the physical foundations of the production, perception, and reproduction of musical sounds. Makes only limited use of simple mathematics. Includes topics such as wave properties, loudness levels and the human ear, hearing loss, tone quality, frequency and pitch, musical intervals and tuning, room acoustics, the production of sound by various musical instruments, and electronic reproduction of music. Meets General Education Laboratory Requirement. Offered Fall.

**Course Material Fees:** \$25

**PHY 3300 Introductory Modern Physics Cr. 3**

For physics, chemistry, engineering, mathematics majors and other interested students. Introduction to relativity, quantum phenomena, atomic structure, quantum mechanics, condensed matter physics, quantum optics, nuclear physics, elementary particles, and anti-particles. Offered Fall, Winter.

**Prerequisites:** ([PHY 2130 with a minimum grade of C- and PHY 2131 with a minimum grade of C-] OR [PHY 2170 with a minimum grade of C- and PHY 2171 with a minimum grade of C-]) AND ([PHY 2140 with a minimum grade of C- and PHY 2141 with a minimum grade of C-] OR [PHY 2180 with a minimum grade of C- and PHY 2181 with a minimum grade of C-]) AND ([MAT 2020 with a minimum grade of C-])

**Corequisite:** PHY 3310

**PHY 3310 Introductory Modern Physics Laboratory Cr. 2**

Laboratory course to accompany PHY 3300. Hands-on experience in logical and rigorous analysis of phenomena of modern physics. Offered Fall, Winter.

**Prerequisites:** ([PHY 2140 with a minimum grade of D- and PHY 2141 with a minimum grade of D-] OR [PHY 2180 with a minimum grade of D- and PHY 2181 with a minimum grade of D-]) AND (May be taken concurrently: [PHY 3300 with a minimum grade of D-] OR [PHY 5015 with a minimum grade of D-])

**Course Material Fees:** \$25

**PHY 3700 Mathematics for Biomedical Physics Cr. 4**

Training in specific applied topics of mathematics for biomedical physics majors. Offered Fall.

**PHY 3750 Introduction to Computational Methods Cr. 1**

Introduction to the principles of computer programming with MATLAB or similar software. In addition to learning applications of the software, there will be opportunities for independent or group projects of interest to students. Offered Fall.

**Prerequisites:** ([PHY 2130 with a minimum grade of C-, PHY 2131 with a minimum grade of C-, PHY 2140 with a minimum grade of C-, and PHY 2141 with a minimum grade of C-] OR [PHY 2170 with a minimum grade of C-, PHY 2171 with a minimum grade of C-, PHY 2180 with a minimum grade of C-, and PHY 2181 with a minimum grade of C-]) AND (May be taken concurrently: [MAT 2020 with a minimum grade of C-])

**Restriction(s):** Enrollment is limited to students with a major in Biomedical Physics.

**PHY 3990 Directed Study Cr. 1-4**

Primarily for students who wish to continue in a field beyond material covered in regular courses, or who wish to study material not covered in regular courses, including certain research participation. Offered Every Term.

**Repeatable for 4 Credits**

**PHY 4700 Introduction to Biomedical Physics Cr. 4**

Basic and applied physical concepts used in biology, human anatomy, and physiology, as well as in medical diagnosis and treatment. Offered Winter.

**Prerequisites:** ([PHY 2130 with a minimum grade of C- and PHY 2140 with a minimum grade of C-] OR [PHY 2170 with a minimum grade of C- and PHY 2180 with a minimum grade of C-]) AND ([PHY 3700 with a minimum grade of C-] AND ([MAT 2020 with a minimum grade of D-])

**PHY 5010 Astrophysics and Stellar Astronomy Cr. 3**

Electromagnetic radiation and matter; solar characteristics; stellar distances; magnitudes; spectral classification; celestial mechanics; binary stars; stellar motions, structure and evolution; compact and variable stars; Milky Way Galaxy and interstellar medium; galaxies and clusters of galaxies; quasars; Hubble's Law; cosmology. Offered Biannually (Winter).

**Prerequisites:** ([PHY 3300 with a minimum grade of C-])

**Equivalent:** AST 5010

**PHY 5015 Non-classical Physics for Educators Cr. 3**

Development of relativity and quantum mechanics. Emphasis on nuclear physics and elementary particles. Required math: algebra and trigonometry. Offered for undergraduate credit only. Offered Winter.

**Prerequisites:** ([PHY 2130 with a minimum grade of D-] AND ([PHY 2140 with a minimum grade of D-])

**PHY 5100 Methods of Theoretical Physics I Cr. 3**

Introduction to mathematical tools used in advanced courses in physics. Offered Fall.

**Prerequisites:** ([MAT 2030 with a minimum grade of C-] AND ([PHY 2180 with a minimum grade of C-])

**PHY 5200 Classical Mechanics I Cr. 3**

Introduction to fundamental ideas: Newton's laws, notions of momentum, angular momentum, kinetic and potential energy, mechanical energy, conservation laws, motion in 1- and 3-D, friction and retardation forces, oscillations, resonances, and gravitation. Offered Fall.

**Prerequisites:** ([PHY 2180 with a minimum grade of C-] AND (May be taken concurrently: [PHY 5100 with a minimum grade of C-])

**PHY 5210 Classical Mechanics II Cr. 3**

Accelerated reference frames, centrifugal and Coriolis forces, rigid body dynamics, motion of tops and gyroscopes, Lagrange's equations, constraints, Lagrange multipliers, general central force problem, stability of orbits, relativistic mechanics. Offered Winter.

**Prerequisite:** PHY 5200 with a minimum grade of C- and MAT 2150 with a minimum grade of C-

**PHY 5340 Optics Cr. 3**

Electromagnetic radiation; geometrical, physical, and modern optics. Offered Winter.

**Prerequisites:** ([MAT 2030 with a minimum grade of C- and PHY 2140 with a minimum grade of C-] OR [PHY 2180 with a minimum grade of C- and PHY 3700 with a minimum grade of C-] OR [PHY 2140 with a minimum grade of C- and PHY 3700 with a minimum grade of C-] OR [MAT 2030 with a minimum grade of C- and PHY 2180 with a minimum grade of C-])

**PHY 5341 Optics Laboratory Cr. 2**

Experiments involving geometrical, physical, and quantum optics. Offered Winter.

**Prerequisites:** (May be taken concurrently: [ECE 5760 with a minimum grade of C]) AND (May be taken concurrently: [PHY 5340 with a minimum grade of C])

**Course Material Fees:** \$25

**PHY 5620 Electronics and Electrical Measurements Cr. 3**

Theory of amplifier circuits, operational amplifiers, oscillators, digital electronics, analog and digital measurements. Offered Fall.

**Prerequisites:** ([PHY 2180 with a minimum grade of C- and PHY 2181 with a minimum grade of C-] OR [PHY 2140 with a minimum grade of C- and PHY 2141 with a minimum grade of C-]) AND (May be taken concurrently: [PHY 5621 with a minimum grade of C-])

**Corequisite:** PHY 5621

**PHY 5621 Electronics and Electrical Measurements Laboratory Cr. 2**

Laboratory measurements related to amplifier circuits, operational amplifiers, oscillators, and digital electronics. The lab will also cover analog and digital measurements and will require a final project. Offered Fall.

**Corequisite:** PHY 5620

**Course Material Fees:** \$25

**PHY 5750 Biological Physics Cr. 4**

Introduction to applications of physics to molecular biology. Offered Fall.

**Prerequisites:** ([PHY 3700 with a minimum grade of C-]) AND ([PHY 4700 with a minimum grade of C-])

**PHY 5990 Directed Study Cr. 1-3**

Primarily for students who wish to continue in a field beyond material covered in regular courses, or who wish to study material not covered in regular courses, including certain research participation. Offered Every Term.

**Repeatable for 6 Credits**

**PHY 6160 Meteorology: 2ndy Sch Cr. 3-4**

Offered Spring/Summer.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Course Material Fees:** \$25

**PHY 6400 Quantum Physics I Cr. 3**

Operators and their eigenfunctions, quantization rules, solution of Schrodinger equation in 1- and 3-D, the hydrogen atom, angular momentum, spin, boson, fermions, Time-independent perturbation theory. Offered Winter.

**Prerequisites:** ([MAT 2150 with a minimum grade of C-, PHY 3300 with a minimum grade of C-, and PHY 5100 with a minimum grade of C-])

**PHY 6410 Quantum Physics II Cr. 3**

Applications of quantum mechanics: atoms in electric and magnetic fields, multielectron atoms, molecules, quantum statistics, solids (band structure, magnetic properties), nuclei, fundamental forces and standard model. Offered Fall.

**Prerequisites:** ([PHY 6400 with a minimum grade of C-])

**PHY 6450 Introduction to Material and Device Characterizations Cr. 4**

Lecture/laboratory; introduction to analytic and measurement techniques for characterizing and evaluating materials, especially for potential applicability in sensor and integrated devices. Techniques include diffraction and microscopy methods, electron spectroscopies, and electrical, optical and magnetic measurements. Offered for graduate credit only. Offered Winter.

**Prerequisite:** (PHY 7050 (may be taken concurrently) or ECE 5500 (may be taken concurrently) or ECE 5550 (may be taken concurrently))

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 6500 Thermodynamics and Statistical Physics Cr. 4**

Laws of thermodynamics, thermodynamic equilibrium, applications of kinetic theory of gases, basic introduction to classical and quantum statistical description of physical systems with large numbers of particles. Offered Fall.

**Prerequisites:** ([PHY 3300 with a minimum grade of C- and PHY 5100 with a minimum grade of C-])

**PHY 6570 Smart Sensor Technology I: Design Cr. 4**

Introduction to various types of sensors and the design of basic analog VLSI circuit building blocks. Offered for graduate credit only. Offered Fall.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Equivalent:** BME 6470, ECE 6570

**PHY 6600 Electromagnetic Fields I Cr. 3**

Topics include electrostatics, solution of Laplace equation, dielectric media, electric current, magnetic field of steady currents, magnetic properties of matter, electromagnetic induction. Offered Fall.

**Prerequisite:** PHY 5100 with a minimum grade of C- and PHY 5200 with a minimum grade of C- and MAT 2150 with a minimum grade of C-

**PHY 6610 Electromagnetic Fields II Cr. 3**

Continuation of PHY 6600: Maxwell equations, electromagnetism and relativity, optics, wave guides and transmission lines, radiation of EM waves. Offered Winter.

**Prerequisite:** PHY 6600 with a minimum grade of C-

**PHY 6710 Physics in Medicine Cr. 3**

Applications of physics in medicine including radioactivity; interaction of radiation in matter; x-ray, CT, MRI, ultrasound, and PET imaging; nuclear medicine; radiation oncology; nerve electrophysiology, electrocardiogram, pacemakers, and defibrillators. Offered Winter.

**Restriction(s):** Enrollment is limited to students with a major in Biomedical Physics.

**PHY 6750 Applied Computational Methods Cr. 2**

Development of concepts learned in PHY 3750 or PHY 3310 for computer applications in physics research, including applications in theoretical physics, data fitting, image analysis, and integration with experimental equipment. There will be opportunities for independent as well as group projects. Offered Fall.

**Prerequisite:** PHY 3750 with a minimum grade of C- or PHY 3310 with a minimum grade of C-

**PHY 6780 (WI) Research Methods in Biomedical Physics Cr. 3**

Introduction to laboratory experience in biomedical physics research. Capstone course for biomedical physics majors. Offered Winter.

**Prerequisites:** ([PHY 3700 with a minimum grade of C- and PHY 4700 with a minimum grade of C-])

**PHY 6850 (WI) Modern Physics Laboratory Cr. 2**

Techniques and experiments in physics of atoms, atomic nuclei, molecules, the solid state and other areas that have advanced our modern understanding of physics. Offered Winter.

**Prerequisites:** ([PHY 3300 with a minimum grade of C-])

**Course Material Fees:** \$25

**PHY 6860 Computational Physics Cr. 3**

Introduction to use of computers to model physical systems; description of techniques in numerical analysis including linear algebra, integration, algebraic and differential equations, data analysis and symbolic algebra. Offered Fall.

**Prerequisites:** ([PHY 3310 with a minimum grade of C-] OR [PHY 5100 with a minimum grade of C-])

**PHY 6991 Special Topics Cr. 1-4**

Topics and prerequisites for each section to be announced in Schedule of Classes. More than one section may be elected in a semester. Offered for graduate credit only. Offered Yearly.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 4 Credits**

**PHY 6992 Physics Graduate Teaching Assistant Training Cr. 1**

Students solve and discuss problems from calculus-based general physics courses in front of their peers and instructor, enhancing their ability to analyze, interpret and present the material in a clear, informative way. Offered for graduate credit only. Offered Fall.

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7010 Modern Physics for Secondary School Educators Cr. 3**

Development of relativity and quantum mechanics. Emphasis on nuclear physics and elementary particles. Required math: algebra and trigonometry. Offered Fall, Spring/Summer.

**Prerequisite:** PHY 2130 with a minimum grade of C- and PHY 2140 with a minimum grade of C-

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7050 Survey of Condensed Matter Physics Cr. 3**

Contemporary solid state physics dealing primarily with experiments in this area and with modern descriptive models of solids. Offered Winter.

**Prerequisite:** PHY 6400 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7060 Survey of Elementary Particle Physics Cr. 3**

Fundamental interactions and the basic particles; introduction to quantum mechanical treatment of decay, scattering, spin, internal symmetries; introduction to quantum field theory; gauge theories; the standard model and proposed modifications; experimental evidence; survey of experimental methods, detector, accelerators and colliders. Offered Winter.

**Prerequisite:** PHY 6400 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7070 Survey of Nuclear Physics Cr. 3**

Survey of nuclear decay, nuclear structures, nuclear interactions and reactions, nuclear models, conservative laws and subnuclear particles. Offered Winter.

**Prerequisite:** PHY 6400 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7110 Methods of Theoretical Physics II Cr. 3**

Complex variables and their applications. Homogeneous and inhomogeneous differential equations. Special functions such as gamma functions, Bessel functions, Legendre functions, Hermite functions and Laguerre functions. Fourier series. Offered Fall.

**Prerequisite:** PHY 5100 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7200 Advanced Mechanics Cr. 3-4**

Variational principles, central forces, transformation theory, Hamilton-Jacobi theory. Offered Winter.

**Prerequisite:** PHY 5210 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7215 Nanobioscience Cr. 3**

Introduction to interdisciplinary research field of nanobioscience, at the interphase of biology, chemistry, and physics; specific properties of nanoscale objects. Offered Fall.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Equivalent:** PSL 7215

**PHY 7400 Quantum Mechanics I Cr. 3**

Physical and mathematical principles of quantum mechanics. Schrodinger equation and its applications. Spin and angular momentum in quantum mechanics. The WKB approximation. Perturbation theory for time-independent and time-dependent cases. Offered Fall.

**Prerequisite:** PHY 6410 with a minimum grade of C and PHY 7110 (may be taken concurrently) with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7410 Quantum Mechanics II Cr. 3**

Scattering theory. Partial wave expansion and perturbation theory. Bound states. Symmetry principles and conservation laws. The path integral formalism. Entanglement. Quantum computation. Charged particles in electromagnetic fields. Quantum theory of radiation. Relativistic one-particle equations Offered Winter.

**Prerequisite:** PHY 7400 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7500 Statistical Mechanics Cr. 4**

Classical and quantum statistical mechanics and applications. Offered Fall.

**Prerequisite:** PHY 6500 with a minimum grade of C and PHY 7400 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7550 Advanced Condensed Matter Physics: Solid State Cr. 3**

Current topics in condensed matter physics, including electronic band structure, magnetism, superconductivity, nanophysics, and the optical properties of solids. Offered Biannually (Fall).

**Prerequisite:** PHY 7050 with a minimum grade of C and PHY 7110 with a minimum grade of C and PHY 7400 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7560 Advanced Condensed Matter Physics: Soft Matter Cr. 3**

Current topics in condensed matter physics, including the building blocks, structures, physical properties, and phase transitions in a variety of complex fluid systems such as simple liquids and liquid mixtures, colloids, polymers, liquid crystals, amphiphiles, and soft matter in living organisms. Offered Biannually (Winter).

**Prerequisite:** PHY 7050 with a minimum grade of C and PHY 7110 with a minimum grade of C and PHY 7400 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7580 Smart Sensor Technology II: Characterization and Fabrication Cr. 4**

Integration of ongoing research in integrated technology of smart sensors. Design of smart sensor devices using computer simulation. Fabrication of smart sensor. Offered Winter.

**Prerequisite:** PHY 6570 with a minimum grade of C or ECE 6570 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**Course Material Fees:** \$50

**Equivalent:** BME 7470, ECE 7570

**PHY 7600 Electromagnetic Theory I Cr. 3**

Microscopic and macroscopic Maxwell's equations, special relativity, Lagrangian and Hamiltonian formulation of EM theory, energy-momentum tensor, conservation laws, radiation, scattering, applications. Offered Winter.

**Prerequisite:** PHY 6610 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7610 Electromagnetic Theory II Cr. 3**

Continuation of PHY 7600. Offered Fall.

**Prerequisite:** PHY 7600 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 7990 Directed Study Cr. 1-3**

Application forms available in department office. Primarily for graduate students in physics who wish to study material not covered in regular courses. Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 6 Credits**

**PHY 7996 Research in Physics Cr. 1-4**

Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 12 Credits**

**PHY 7999 Master's Essay Direction Cr. 1-3**

Offered Every Term.

**Restriction(s):** Enrollment limited to students with a class of Candidate Masters; enrollment is limited to Graduate level students.

**PHY 8800 Advanced Nuclear Physics Cr. 3**

Research topics in nuclear physics such as: relativistic heavy ion physics, nuclear/nucleon models, and many body theory. Covers both theory and experimental methods. Offered Biannually (Winter).

**Prerequisite:** PHY 7070 with a minimum grade of C and PHY 7110 with a minimum grade of C and PHY 7410 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 8810 Advanced Particle Physics Cr. 3**

Advanced elementary particle physics including weak, electromagnetic, and strong interactions. Rudiments of experimental devices and techniques at level appropriate to both experimentally- and theoretically-oriented students. Offered Biannually (Fall).

**Prerequisite:** PHY 7060 with a minimum grade of C and PHY 7110 with a minimum grade of C and PHY 7410 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 8850 Quantum Theory of Fields I Cr. 3**

Introduction to quantum field theory, classical and path integral quantization of scalar, spinor, and vector fields, gauge theories, interactions and Feynman rules, modal field theories, Hubbard model, introduction to renormalization Suitable for both students of theory and experiment in the fields of nuclear, particle, and condensed matter physics and astrophysics. Offered Biannually (Fall).

**Prerequisite:** PHY 7110 with a minimum grade of C and PHY 7410 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 8860 Quantum Theory of Fields II Cr. 3**

Symmetry and symmetry breaking. Goldstone theorem and Higgs effect, renormalization group, collective phenomena, superfluids and superconductivity, the Standard Model of electroweak interactions, effective field theories. Appropriate for students in fields of nuclear, particle, condensed matter physics and astrophysics. Offered Biannually (Winter).

**Prerequisite:** PHY 8850 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 8991 Special Topics Cr. 1-3**

Topics and prerequisites for each section to be announced in Schedule of Classes . More than one topic may be elected in a semester. Offered Fall, Winter.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 12 Credits**

**PHY 8995 Colloquium Cr. 1**

Must be elected every semester by all graduate physics students. Lectures given by external visitors and graduate faculty. Offered Fall, Winter.

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 8999 Master's Thesis Research and Direction Cr. 1-8**

Offered Every Term.

**Restriction(s):** Enrollment limited to students with a class of Candidate Masters; enrollment is limited to Graduate level students.

**Repeatable for 8 Credits**

**PHY 9990 Pre-Doctoral Candidacy Research Cr. 1-8**

Research in preparation for doctoral dissertation. Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 12 Credits**

**PHY 9991 Doctoral Candidate Status I: Dissertation Research and Direction Cr. 7.5**

Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 9992 Doctoral Candidate Status II: Dissertation Research and Direction Cr. 7.5**

Offered Every Term.

**Prerequisite:** PHY 9991 with a minimum grade of S

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 9993 Doctoral Candidate Status III: Dissertation Research and Direction Cr. 7.5**

Offered Every Term.

**Prerequisite:** PHY 9992 with a minimum grade of S

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 9994 Doctoral Candidate Status IV: Dissertation Research and Direction Cr. 7.5**

Offered Every Term.

**Prerequisite:** PHY 9993 with a minimum grade of S

**Restriction(s):** Enrollment is limited to Graduate level students.

**PHY 9995 Candidate Maintenance Status: Doctoral Dissertation Research and Direction Cr. 0**

Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Course Material Fees:** \$348.67

**Repeatable for 0 Credits**