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 Conceptual Physics: The Basic Science Cr. 3
Satisfies General Education Requirement: Natural Scientific Inquiry, Physical Sciences, Quantitative Experience Comp
This course will introduce key concepts of classical and modern physics. Students will be able to demonstrate knowledge of physics concepts starting from the foundations of measurements, describing motion, and Newton's Laws. Building on these foundations, they will be able to explore the concepts of conserved quantities, states of matter, temperature and heat, waves and sound, electricity and magnetism, optics, atomic physics, nuclear physics, relativity, elementary particles, and cosmology. About three fourths of the class will be spent in lecture and one-fourth discussing questions and problems at the end of each chapter. Along with PHY 1020, students may take a one-credit laboratory course, PHY 1021. Students will need to do arithmetic and simple algebra roughly at the level of high school that is required by the university for you to graduate. Offered Every Term.

PHY 1021 Conceptual Physics Laboratory Cr. 1
The Conceptual Physics Laboratory is designed as introduction to research methods in physics. Students learn how to design experiments to answer physical questions, learn how to summarize and present their methods, findings and conclusions, and how to present their conclusions both in written and oral form. Students also learn how to discuss their findings and be able to defend their conclusions. Offered Every Term.
Corequisite: PHY 1020
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 Physics for the Life Sciences I Cr. 4
Satisfies General Education Requirement: Natural Scientific Inquiry, Physical Sciences
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.
Corequisite: PHY 2130
Course Material Fees: $25

PHY 2140 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. 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. Offered Every Term.
Corequisite: PHY 2140
Course Material Fees: $25

PHY 2170 University Physics for Scientists I Cr. 4
Satisfies General Education Requirement: Natural Scientific Inquiry, Physical Sciences
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 MAT 2010 with a minimum grade of C- (may be taken concurrently)
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.
Corequisite: PHY 2170
Course Material Fees: $25

PHY 2175 University Physics for Engineers I Cr. 4
Satisfies General Education Requirement: Natural Scientific Inquiry, Physical Sciences
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 2010 with a minimum grade of C (may be taken concurrently)
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-, MAT 2020 with a minimum grade of D- (may be taken concurrently), 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.
Corequisite: PHY 2180
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-), MAT 2010 with a minimum grade of D-, and MAT 2020 with a minimum grade of D- (may be taken concurrently)
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 The Sounds of Music Cr. 4
Satisfies General Education Requirement: Natural Scientific Inquiry, Physical Sciences
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-)), ((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 (PHY 3300 with a minimum grade of C (may be taken concurrently) or PHY 5015 with a minimum grade of C (may be taken concurrently))
Course Material Fees: $25

PHY 3500 Introduction to Thermal and Fluid Physics Cr. 3
Provides an introduction to physics of gases, fluids and other states of matter for majors in physics and other science, technology and mathematics fields. builds on a knowledge of the mechanics in introductory physics courses. Topics covered include: thermodynamic equilibrium; energy, work and heat; Ideal gas and kinetic theory; entropy; free energy; Maxwell relations; chemical equilibria; equilibrium between liquids, solids and gases; heat transport and kinetics; and properties of fluids. Familiarity with mathematics at the level of Calculus 3 is recommended. Offered Yearly.
Prerequisite: PHY 2170 with a minimum grade of C- or PHY 2180 with a minimum grade of C-

PHY 3700 Mathematics for Biomedical Physics Cr. 4
Training in specific applied topics of mathematics for biomedical physics majors. Offered Fall.
Prerequisites: ((PHY 2130 with a minimum grade of C-, PHY 2140 with a minimum grade of C-, PHY 2131 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 2180 with a minimum grade of C-, PHY 2171 with a minimum grade of C-, and PHY 2181 with a minimum grade of C-)) and MAT 2020 with a minimum grade of C- (may be taken concurrently)

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- 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 MAT 2020 with a minimum grade of C- (may be taken concurrently)
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-)), 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 Every Other 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. 4
Introduction to fundamental ideas: Newton's laws, notions of momentum, angular momentum, kinetic and potential energy, mechanical energy, conservation laws, friction and retardation forces, oscillations, resonances, gravitation, and introduction to the Lagrangian formalism. Offered Fall.
Prerequisites: PHY 2180 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: (PHY 2140 with a minimum grade of C- and MAT 2030 with a minimum grade of C-), (PHY 2180 with a minimum grade of C- and PHY 3700 with a minimum grade of C-), (PHY 2140 with a minimum grade of C- and PHY 3700 with a minimum grade of C-), or (PHY 2180 with a minimum grade of C- and MAT 2030 with a minimum grade of C-)

PHY 5341 Optics Laboratory Cr. 2
Experiments involving geometrical, physical, and quantum optics. Offered Winter.
Prerequisites: ECE 5760 with a minimum grade of C (may be taken concurrently) and PHY 5340 with a minimum grade of C (may be taken concurrently)
Course Material Fees: $25

PHY 5460 Lasers for Medical Applications Cr. 3
Summarizes the wealth of recent research on the principles, technologies and application of lasers in diagnostics, therapy and surgery. Includes an overview of optics, optical components used in a typical laser, key principles of lasers and radiation interactions with tissue. The respective types of the laser (solid state, gas, dye, and semiconductor) are reviewed to provide an understanding of the wide diversity, and therefore, the large possible choice of these devices for a specific diagnosis, treatment, or surgery. Offered Winter.
Equivalent: ME 5465

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 PHY 5621 with a minimum grade of C- (may be taken concurrently)
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 6080 Survey of Astrophysics Cr. 3
This course provides an introduction to high-energy astrophysics with a focus on X-ray astronomy. We will cover the physics of X-ray emission and absorption in an astrophysical context, as well as discussing observational techniques used to detect X-rays. Bright X-ray emitting objects are some of the most extreme in the universe, and we will discuss objects including neutron stars, black holes, cataclysmic variables, supernovae and supernovae remnants, and galaxy clusters. Offered Every Other Year.
Prerequisites: PHY 6080 with a minimum grade of C-
Equivalent: AST 6080

PHY 6250 Survey of Condensed Matter Physics Cr. 3
This course introduces upper-level undergraduate majors in physics and other science, technology and mathematics fields to the discoveries and research methods of condensed matter physics. Modern condensed matter physics research is experiencing rapid growth in various areas such as superconductivity, magnetism, and topological matter. Important advances critically depend on a good understanding of the basic concepts. This course is prepared to help you start by introducing the basic properties of solids and other condensed matter. Methods of electromagnetic and quantum theory are applied to study the electronic and topological properties, magnetism, the Hall effect, superconductivity, and the optical properties of solids and condensed matter. The course builds on a knowledge of electromagnetic theory as studied in courses like PHY 6600. Offered Every Other Winter.
Prerequisites: PHY 6600 with a minimum grade of C-

PHY 6260 Survey of Elementary Particle Physics Cr. 3
Introduces students to the discoveries and research methods of elementary particle physics. Topics covered can include elementary particle dynamics; relativistic kinematics; symmetries, introduction to quantum field theory; Feynman calculus; gauge theories; the standard model and proposed modifications; experimental evidence; survey of experimental methods, detector, accelerators and colliders. Methods of quantum mechanics are introduced, including scattering theory; spin; symmetry groups; bound states; time dependent and time independent perturbation theory. Builds on a knowledge of quantum physics studied in courses like PHY 6400. Offered Every Other Fall.
Prerequisite: PHY 6400 with a minimum grade of C
Restriction(s): Enrollment is limited to Undergraduate level students.

PHY 6270 Survey of Nuclear Physics Cr. 3
Introduces upper-level undergraduate majors in physics and other science, technology and mathematics fields to the discoveries and research methods of nuclear physics. Nuclear physics topics covered can include nuclear collisions; nuclear structure: liquid drop model, shell model; nucleon-nucleon interaction; quarks and the strong interaction; quark-gluon plasma; alpha, beta and gamma decay; and nuclear fusion. Nuclear astrophysics topics can include compact objects; stellar nucleosynthesis; nucleosynthesis in supernovae, neutron star collisions, and the big bang. Methods of quantum mechanics are introduced, including scattering theory; Born approximation; eikonal approximation; Glauber Model; WKB theory; time dependent and time independent perturbation theory. Builds on a knowledge of quantum physics studied in PHY 6400 and is in-part a sequel to that course. Offered Every Other Fall.
Prerequisite: PHY 6400 with a minimum grade of C
Restriction(s): Enrollment is limited to Undergraduate level students.

PHY 6290 Survey of Biophysics Cr. 3
Introduction to modern biophysics with emphasis on a physical understanding of biological structure and function; biological activity; biology and light; energy, thermodynamics and statistical mechanics in biology; and techniques of experimental biophysics. Offered Yearly.
Prerequisite: PHY 3300 with a minimum grade of C- and (MAT 2030 with a minimum grade of C- or PHY 3700 with a minimum grade of C-) and (PHY 4700 with a minimum grade of C- or PHY 3500 with a minimum grade of C-)
Restriction(s): Enrollment is limited to Undergraduate level students.

PHY 6400 Quantum Physics I Cr. 4
This course introduces upper-level undergraduate majors in physics and other science, technology and mathematics fields to the methods of quantum mechanics. Topics covered will include operators and their eigenfunctions; quantization rules; solution of Schrödinger equation in 1- and 3-dimensions; angular momentum; spin; bosons and fermions; and time-independent perturbation theory. The course builds on a knowledge of modern physics as studied in introductory courses such as PHY 3300. Mathematical methods will be introduced for application to specific quantum mechanics problems. These include: Linear algebra; boundary value problems in ordinary differential equations; separation of variables in partial differential equations; Fourier transforms; orthogonal functions; Laplacian in spherical and cartesian coordinates; Legendre Functions and Spherical Harmonics; operators in Hilbert space. Offered Winter.
Prerequisites: PHY 3300 with a minimum grade of C- and MAT 2150 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.
Prerequisites: PHY 7050 with a minimum grade of C (may be taken concurrently), ECE 5500 with a minimum grade of C (may be taken concurrently), or ECE 5550 with a minimum grade of C (may be taken concurrently)
Restriction(s): Enrollment is limited to Graduate level students.
Course Material Fees: $60

PHY 6480 Introduction to Quantum Computing Cr. 3
Serves as an introduction to quantum computing and brings together students with different backgrounds in mathematics, physics, chemistry, and computer science to foster interdisciplinary connections in the areas of quantum computing and quantum information. A strong background in linear algebra over the complex numbers as well as differential and integral calculus is required. Familiarity with quantum physics and complexity theory will be helpful, but it is not required. Offered Fall.
Equivalent: MAT 6480

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 5100 with a minimum grade of C- and PHY 3300 with a minimum grade of C-

PHY 6570 Smart Sensor Technology I: Design Cr. 3
Introduction to various types of sensors and the design of basic analog VLSI circuit building blocks. Offered Winter.
Prerequisites: PHY 2185 with a minimum grade of C- or PHY 2180 with a minimum grade of C-
Equivalent: BME 6470, ECE 6570

PHY 6600 Electromagnetic Fields I Cr. 4
This course introduces upper-level undergraduate majors in physics and other science, technology and mathematics fields to the methods of electricity and magnetism. Topics covered will include electrostatics; solution of the Laplace equation; electric current; magnetic field of steady currents; electromagnetic induction; Maxwell Equations; and electromagnetic waves. The course builds on a knowledge of electromagnetic phenomena as studied in introductory courses such as PHY 2180. Mathematical methods will be introduced for application to specific electromagnetism problems, including spherical and cylindrical coordinates; vector calculus in 2 and 3 dimensions; Stokes and divergence integral theorems; solution of Laplace and Wave equations by separation of variables; uniqueness of solutions for linear PDE of Elliptic and Hyperbolic type; boundary and initial value problems; scalar and vector potentials. Offered Fall.
Prerequisites: 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 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 Research Methods in Biomedical Physics Cr. 3
Satisfies General Education Requirement: Writing Intensive Competency
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 Modern Physics Laboratory Cr. 2
Satisfies General Education Requirement: Writing Intensive Competency
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 6995 Professional Development Seminar in Physics Cr. 2
Introduction to the conduct, skills and ethics of a professional physicist or astronomer. Topics include: critical reading of scientific literature; research ethics and professional conduct; introduction to modern research topics in physics and research in the department of physics and astronomy; careers in physics and astronomy; scientific and proposal writing; and teamwork. Offered Yearly.
Repeatable for 4 Credits

PHY 7050 Survey of Condensed Matter Physics Cr. 3
This course introduces graduate students to the discoveries and research methods of condensed matter physics. Modern condensed matter physics research is experiencing rapid growth in various areas such as superconductivity, magnetism, and topological matter. Important advances critically depend on a good understanding of the basic concepts. This course is prepared to help you start by introducing the basic properties of solids and other condensed matter. Methods of electromagnetic and quantum theory are applied to study the electronic and topological properties, magnetism, the Hall effect, superconductivity, and the optical properties of solids and condensed matter. The course builds on a knowledge of electromagnetic theory as studied in courses like PHY 6600. Offered Winter.
Prerequisite: PHY 6600 with a minimum grade of C
Restriction(s): Enrollment is limited to Graduate level students.

PHY 7060 Survey of Elementary Particle Physics Cr. 3
This course introduces graduate students to the discoveries and research methods of elementary particle physics. Topics covered can include elementary particle dynamics; relativistic kinematics; symmetries, introduction to quantum field theory; Feynman calculus; gauge theories; the standard model and proposed modifications; experimental evidence; survey of experimental methods, detector, accelerators and colliders. Methods of quantum mechanics are introduced, including scattering theory; spin; symmetry groups; bound states; time dependent and time independent perturbation theory. The course builds on a knowledge of quantum physics studied in courses like PHY 6400. Offered Every Other Fall.
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
This course introduces graduate students to the discoveries and research methods of nuclear physics. Nuclear physics topics covered can include nuclear collisions; nuclear structure: liquid drop model, shell model; nucleon-nucleon interaction; quarks and the strong interaction; quark-gluon plasma; alpha, beta and gamma decay; and nuclear fusion. Nuclear astrophysics topics can include compact objects; stellar nucleosynthesis; nucleosynthesis in supernovae, neutron star collisions, and the big bang. Methods of quantum mechanics are introduced, including scattering theory; Born approximation; eikonal approximation; Glauber Model; WKB theory; time dependent and time independent perturbation theory. The course builds on a knowledge of quantum physics studied in courses like PHY 6400. Offered Every Other Fall.
Prerequisite: PHY 6400 with a minimum grade of C
Restriction(s): Enrollment is limited to Graduate level students.

PHY 7080 Survey of Astrophysics Cr. 3
This course provides an introduction to high-energy astrophysics with a focus on X-ray astronomy. We will cover the physics of X-ray emission and absorption in an astrophysical context, as well as discussing observational techniques used to detect X-rays. Bright X-ray emitting objects are some of the most extreme in the universe, and we will discuss objects including neutron stars, black holes, cataclysmic variables, supernovae and supernovae remnants, and galaxy clusters. Offered Every Other Year.
Prerequisites: PHY 3300 with a minimum grade of C-
Restriction(s): Enrollment is limited to Graduate level students.

PHY 7090 Survey of Biophysics Cr. 3
Introduction to modern biophysics with emphasis on a physical understanding of biological structure and function; biological activity; biology and light; energy, thermodynamics and statistical mechanics in biology; and techniques of experimental biophysics. Offered Yearly.
Prerequisites: 3 of (MAT 2030 or PHY 3700), PHY 3300, and (PHY 4700 or PHY 3500)
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 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.
Prerequisites: PHY 6410 with a minimum grade of C and PHY 7110 with a minimum grade of C (may be taken concurrently)
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 Every Other 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 Every Other 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 Spring/Summer.
Prerequisite: PHY 6570 with a minimum grade of B- or ECE 6570 with a minimum grade of B- or BME 6470 with a minimum grade of B-
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 7850 Data Analysis Techniques Cr. 3
Foundations in probability and statistics used in physics, biophysics and astronomy, an extensive discussion of the notions of statistical and systematic uncertainties, data correction techniques, and basic Monte Carlo techniques. Offered Yearly.
Prerequisite: MAT 2030 with a minimum grade of C or PHY 6850 with a minimum grade of C or PHY 6750 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 Every Other 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 Every Other 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 Every Other 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 Every Other 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: $416.08
Repeatable for 0 Credits