COURSES OF INSTRUCTION

The following courses, numbered 5000-9999, are offered for graduate credit. Courses numbered 5000-6999 which are also offered for undergraduate credit may be found in the undergraduate bulletin, along with all other undergraduate courses (numbered 0900-4999). Courses in the following list numbered 5000-6999 may be taken for undergraduate credit unless specifically restricted to graduate students as indicated by individual course limitations.

All courses with a laboratory have a non-refundable materials fee and are so indicated in the Schedule of Classes.

ASTRONOMY (AST)

5010  (AST 5010) Astrophysics and Stellar Astronomy. (PHY 5010)  Cr. 3
Prereq: PHY 2140 or PHY 2180, MAT 2010, or consent of instructor. 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. (B:W)

6180  (PHY 6180) Astronomy and Planetary Geology for Secondary-School Educators.  Cr. 3-4
Open only to middle- or high school teachers. Prereq: PHY 2130, 2140. Material fee applies when taken for four credits (optional laboratory). Quantitative description of constituents of solar system. Required math: algebra and trigonometry. Material Fee As Indicated In The Schedule of Classes (B:F)

PHYSICS (PHY)

5010  (AST 5010) Astrophysics and Stellar Astronomy.  Cr. 3
Prereq: PHY 2140 or 2180, MAT 2010 or consent of instructor. 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. (B:W)

5030  Plasma Physics.  Cr. 3
Prereq: PHY 6600, or 2180 and consent of instructor and MAT 2020. Introduction to plasma physics for students in science and engineering. Motion of charged particles in electromagnetic fields; magnetoionic theory including electron conductivity and mobility; wave propagation in a plasma; plasma kinetic theory with emphasis on Boltzmann, Vlasov and Fokker-Planck equations; plasma sheaths. (B:W)

5100  Methods of Theoretical Physics I.  Cr. 3
Prereq: PHY 2180, MAT 2030. Introduction to mathematical tools used in advanced courses in physics. (F)

5200  (WI) Classical Mechanics I.  Cr. 3
Prereq: PHY 2180, PHY 5100. 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. (F)
5210  Classical Mechanics II.  Cr. 3  
Prereq: PHY 5200 and MAT 2350.  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.  (W)

5340  Optics.  Cr. 3  
Prereq: PHY 2140 or PHY 2180, MAT 2030; coreq. for PHY majors: PHY 5341. Electromagnetic radiation; geometrical, physical, and modern optics.  (F)

5341  Optics Laboratory.  Cr. 2  
Prereq. or coreq: PHY 5340 or ECE 5760. Experiments involving geometrical, physical, and quantum optics. Material Fee As Indicated In The Schedule of Classes  (F)

5500  Thermal Physics.  Cr. 4  
Prereq: PHY 3300, PHY 5100.  Notions of temperature, equation of state, internal energy, the three Laws of Thermodynamics, Carnot's theory, entropy, thermodynamic potentials, kinetic theory, partition function, heat capacity of solids, thermodynamics of radiation, Fermi-Dirac gases.  (F)

5620  Electronics and Electrical Measurements.  Cr. 5  
Prereq: PHY 2180 or 2140 or consent of instructor.  Amplifier circuits, operational amplifiers, oscillators, digital electronics, analog and digital measurements. Material Fee As Indicated In The Schedule of Classes  (W)

5990  Directed Study.  Cr. 1-3  
Prereq: junior standing and consent of adviser and instructor.  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.  (T)

6050  Special Topics in Physics for Secondary-School Educators.  Cr. 3  
Prereq: introductory physics courses in mechanics, and in electricity and magnetism; or consent of instructor. Open only to pre-college or community college teachers. Special topics in physics designed for secondary teachers.  Topics offered as needed; may include: astronomy and cosmology, meteorology, relativity, quantum theory, atomic and nuclear physics, optics.  (Y)

6100  Classical Physics for Secondary School Educators.  Cr. 3  
Open only to middle- or high school teachers.  Prereq: PHY 2130, 2140. Mechanics, electricity, magnetism: fundamentals.  Applications to problem solving.  Selected special topics. Required math: algebra and trigonometry.  (B:F)

6120  Energy Generation and Consumption for Secondary-School Educators.  Cr. 3-4  
Open only to middle- or high school teachers.  Prereq: PHY 2130, 2140.  Material fee applies when elected for four credits  (optional laboratory). Different sources of energy and how their use impacts the environment.  Required math: algebra and trigonometry. Material Fee As Indicated In The Schedule of Classes  (B:W)

6160  Meteorology for Secondary-School Educators.  Cr. 3-4  
Open only to middle- or high school teachers.  Prereq: PHY 2130, 2140.  Material fee applies when elected for four credits (optional laboratory). Earth's atmosphere and various weather processes. Required math: algebra and trigonometry. Material Fee As Indicated In The Schedule of Classes  (S)
6180  Astronomy and Planetary Geology for Secondary-School Educators.  Cr. 3-4
Open only to middle- or high school teachers. Prereq: PHY 2130, 2140. Material fee applies when
taken for four credits (optional laboratory). Quantitative description of constituents of solar system.
Required math: algebra and trigonometry. Material Fee As Indicated In The Schedule of Classes  (B:F)

6350  Applied Modern Optics.  Cr. 3
Prereq: PHY 5340. Coherent radiation, laser physics and optical devices, optical techniques in
experimental science, topics in modern optics.  (B:W)

6400  Quantum Physics I.  Cr. 3
Prereq: PHY 3300, PHY 5100, MAT 2150. Operators and their eigenfunctions, quantization rules,
solution of Schroedinger equation in 1- and 3-D, the hydrogen atom, angular momentum, spin,
bozon, fermions, Time-independent perturbation theory.  (W)

6410  Quantum Physics II.  Cr. 3
Prereq: PHY 6400 or consent of instructor. 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.  (F)

6450  Introduction to Material and Device Characterizations.  Cr. 4
Coreq: PHY 7050 or ECE 5500 or ECE 5550 or equiv. 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.  (W)

6570 (ECE 6570) Smart Sensor Technology I: Design. (BME 6470)  Cr. 4
Prereq: B.S. degree in engineering or science. Introduction to various types of sensors and the
design of basic analog VLSI circuit building blocks.  (F)

6600  Electromagnetic Fields I.  Cr. 3
Prereq: PHY 5100, PHY 5200, MAT 2150, or consent of instructor. Topics include electrostatics,
solution of Laplace equation, dielectric media, electric current, magnetic field of steady currents,
magnetic properties of matter, electromagnetic induction.  (W)

6610  Electromagnetic Fields II.  Cr. 3
Prereq: PHY 6600 or consent of instructor. Continuation of PHY 6600: Maxwell equations,
electromagnetism and relativity, optics, wave guides and transmission lines, radiation of EM
waves.  (W)

6850 (WI) Modern Physics Laboratory.  Cr. 2
Prereq: PHY 3300 or consent of instructor. Techniques and experiments in physics of atoms,
atomic nuclei, molecules, the solid state and other areas that have advanced our modern
understanding of physics. Material Fee As Indicated In The Schedule of Classes  (W)

6860  Computational Physics.  Cr. 3
Introduction to computational languages and local computational environment; description of
techniques in numerical analysis including linear algebra, integration, algebraic and differential
equations, data analysis and symbolic algebra; optimization and parallel computing.  (B:W)
6991 Special Topics. Cr. 1-4 (Max. 4)
Prereq: consent of instructor. Offered for S and U grades only. Topics and prerequisites for each section to be announced in Schedule of Classes. More than one section may be elected in a semester. (Y)

6992 Physics Graduate Teaching Assistant Training. Cr. 1
Prereq: graduate standing or consent of instructor. Offered for S and U grades only. 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. (F)

7010 (PHY 5015) Modern Physics for Secondary-School Educators. Cr. 3-4
Open only to middle- or high school teachers. Prereq: PHY 2130, 2140. Material fee applies when elected for four credits (optional laboratory). Development of relativity and quantum mechanics. Emphasis on nuclear physics and elementary particles. Required math: algebra and trigonometry. Material Fee As Indicated In The Schedule of Classes (F,S)

7050 Elementary Solid State Physics. Cr. 3
Prereq: PHY 6400 or equiv. Contemporary solid state physics dealing primarily with experiments in this area and with modern descriptive models of solids. (F)

7060 Survey of Elementary Particle Physics. Cr. 3
Prereq: PHY 6400 or equiv. 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. (W)

7070 Survey of Nuclear Physics. Cr. 3
Prereq: PHY 6400 or equiv. Survey of nuclear decay, nuclear structures, nuclear interactions and reactions, nuclear models, conservative laws and subnuclear particles. (F)

7075 Methods of Theoretical Physics II. Cr. 3
Prereq: PHY 5100 or equiv. Continuation of PHY 5100. (W)

7200 Advanced Mechanics. Cr. 4
Prereq: PHY 5210 or consent of instructor. Variational principles, central forces, transformation theory, Hamilton-Jacobi theory. (W)

7215 (PSL 7215) Nanobioscience. (CHE 7215) (CHM 7215) Cr. 3
Prereq: first year calculus, general chemistry. Introduction to interdisciplinary research field of nanobioscience, at the interphase of biology, chemistry, and physics; specific properties of nanoscale objects. (F)

7400 Quantum Mechanics I. Cr. 3
Prereq: PHY 7200 or consent of instructor; coreq: PHY 5100 or equiv. Schrodinger wave equation, its meaning and solutions as applied to simple physical and chemical problems. Perturbation theory. Theory of atomic collisions, matrix mechanics, transformation theory, angular momentum and spin, theory of measurement. (F)

7410 Quantum Mechanics II. Cr. 3
Prereq: PHY 7400. Continuation of PHY 7400. (W)
7500 **Statistical Mechanics. Cr. 4**  
Prereq: PHY 5500, 7400 or consent of instructor. Classical and quantum statistical mechanics and applications.  

7550 **Solid State Physics I. Cr. 3**  
Prereq: PHY 7400 or consent of instructor. Crystal structure, elastic constants, introduction to band theory, semiconductors, magnetic properties of materials, optical properties of solids.  

7560 **Solid State Physics II. Cr. 3**  
Prereq: PHY 7550. Continuation of PHY 7550.  

7580 *(ECE 7570) Smart Sensor Technology II: Characterization and Fabrication. (BME 7470) Cr.*  
Prereq: PHY 6570 or ECE 6570. The fabrication process; characterization of sensors; design of associated analog VLSI circuit.  

7600 **Electromagnetic Theory I. Cr. 3**  
Prereq: PHY 6610 or consent of instructor. Microscopic and macroscopic Maxwell's equations, special relativity, Lagrangian and Hamiltonian formulation of EM theory, energy-momentum tensor, conservation laws, radiation, scattering, applications.  

7610 **Electromagnetic Theory II. Cr. 3**  
Prereq: PHY 7600. Continuation of PHY 7600.  

7990 **Directed Study. Cr. 1-3 (Max. 6)**  
Prereq: consent of adviser, instructor, chairperson of graduate studies committee and graduate officer must be obtained prior to registration. Application forms available in department office. Primarily for graduate students in physics who wish to study material not covered in regular courses.  

7996 **Research in Physics. Cr. 1-4 (Max. 12)**  
Prereq: consent of adviser and chairperson of graduate studies committee.  

7999 **Master's Essay Direction. Cr. 1-3 (3 req.)**  
Prereq: consent of adviser.  

8570 *(ECE 8570) Smart Sensor Technology Seminar. (BME 8470) Cr.*  
Prereq: ECE 6570, 7570. Technological advances. Interaction of research experience in smart sensors and integrated devices.  

8800 **Nuclear Physics. Cr. 3**  
Prereq: PHY 7070, 7110, and 7410. Research topics in nuclear physics such as: relativistic heavy ion physics, nuclear/nucleon models, and many body theory. Covers both theory and experimental methods.  

8810 **Particle Physics. Cr. 3**  
Prereq: PHY 7060, 7110, and 7410. 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.
8850 Quantum Theory of Fields I. Cr. 3
Prereq: PHY 7110, 7410. Introduction to quantum field theory with quantum electrodynamics. Renormalization, regularization, Feynman diagrams, applications to scattering processes and bound states. Suitable for both students of theory and experiment in the fields of nuclear, particle, and solid state physics. (B:F)

8860 Quantum Theory of Fields II. Cr. 3
Prereq: PHY 8850. Continuation of quantum field theory. Advanced topics; development of strong, electroweak, and gravitational interactions; other topics. Appropriate for students in fields of nuclear, particle, or solid state physics. (B:W)

8991 Special Topics. Cr. 1-3 (Max. 12)
Prereq: consent of instructor, adviser and chairperson of graduate studies committee. Offered for S and U grades only. Topics and prerequisites for each section to be announced in Schedule of Classes. More than one topic may be elected in a semester. (F,W)

8995 Colloquium. Cr. 1
Offered for S and U grades only. Must be elected every semester by all graduate physics students. Lectures given by visitors, graduate staff and advanced graduate students. (F,W)

8999 Master's Thesis Research and Direction. Cr. 1-8 (8 req.)
Prereq: consent of adviser. (T)

9990 Pre-Doctoral Candidacy Research. Cr. 1-8 (Max. 10)
Prereq: consent of department. For Ph.D. program applicants. Offered for S and U grades only. Research in preparation for doctoral dissertation. (T)

9991 Doctoral Candidate Status I: Dissertation Research and Direction. Cr. 7.5
Prereq: consent of dissertation adviser; Ph.D. candidate in department. Required in academic-year semester following advancement to Ph.D. candidacy. Offered for S and U grades only. (T)

9992 Doctoral Candidate Status II: Dissertation Research and Direction. Cr. 7.5
Prereq: consent of dissertation adviser; PHY 9991. Required in academic-year semester following 9991. Offered for S and U grades only. (T)

9993 Doctoral Candidate Status III: Dissertation Research and Direction. Cr. 7.5
Prereq: consent of dissertation adviser; PHY 9992. Required in academic-year semester following 9992. Offered for S and U grades only. (T)

9994 Doctoral Candidate Status IV: Dissertation Research and Direction. Cr. 7.5
Prereq: consent of dissertation adviser; PHY 9993. Required in academic-year semester following 9993. Offered for S and U grades only. (T)

9995 Candidate Maintenance Status: Doctoral Dissertation Research and Direction. Cr. 0
Prereq: consent of dissertation adviser; completion of 30 credits in PHY 9999, or 9991-9994. Offered for S and U grades only. (T)

9999 Doctoral Dissertation Research and Direction. Cr. 1-16
Prereq: consent of doctoral adviser. Offered for S and U grades only. (T)