Tulane University

PHYSICS (PHYS)

PHYS 1010 Great Ideas in Science &Tech (4)
For non-scientists. Basic principles of science, applications and their relevance to our world. Typically includes astronomy, universe, Newtonian mechanics, energy and applications, symmetry in nature, order and disorder, electricity and applications, quantum mechanics, atoms and molecules, DNA, computer technology, and ethical issues. Laboratory. Course may be repeated up to unlimited credit hours. Corequisite(s): PHYS 1011.

Corequisite(s): PHYS 1011.
Course Limit: 2

PHYS 1011 Great Ideas in Sci & Tech Lab (0)
Lab section for PHYS 1010. Corequisite(s): PHYS 1010.

Corequisite(s): PHYS 1010.

PHYS 1015 Materials Science & Eng & Lab (3)
This summer session will focus on the field of Materials, which is an interdisciplinary field applying the properties of matter to various areas of science and engineering. This two-week (ten-day) course is intended for high school students who wish to explore and stimulate their interest in the materials sciences and engineering. The course consists of rotations between six materials science research laboratories in the Department of Physics and Engineering Physics. Each rotation combines lectures with hands-on laboratory activities to excite and introduce students to contemporary methods and issues in superconductivity, optics and lasers, biomaterials, nanomaterials, nanotechnology, and energy harvesting materials and technologies. Emphasis is placed on demonstrating basic principles and hands-on student involvement. Laboratory activities will be supervised by Tulane faculty members and graduate students.

PHYS 1025 Optical Images and Illusions (3)
Physics-by-inquiry learning about optics, including how light behaves when it reflects off mirrors or refracts through transparent media. We will learn to explain various phenomena like image creation and optical illusions. For high school students only.

PHYS 1050 Physics for Architects (3)
A non-calculus course in classical physics stressing the fundamental physical laws and their application to architecture. Main topics include Newtonian mechanics with an emphasis on equilibrium applications, elasticity, fluids, and thermal processes. Credit not given for PHYS 1050 and PHYS 1210 or 1310. Does not count towards the B.S. Physics or B.S.E. Engineering Physics degrees.

PHYS 1210 Introductory Physics I (4)
A non-calculus course in classical physics stressing the fundamental physical laws. Newtonian mechanics, oscillations, and classical waves normally are treated in 1210. A weekly laboratory is included; the laboratory includes a review of techniques of problem solving, as well as experiments in classical physics. Not open for credit to students who have completed 1310. Does not count towards the B.S. Physics or B.S.E. Engineering Physics degrees. Corequisite(s): PHYS 1211.

Corequisite(s): PHYS 1211.

PHYS 1211 Introductory Physics I Lab (0)
Lab section for PHYS 1210. Corequisite(s): PHYS 1210.

Corequisite(s): PHYS 1210.

PHYS 1220 Introductory Physics II (4)
A continuation of PHYS 1210. Electricity and magnetism, optics, and thermal phenomena. A weekly laboratory is included. Not open for credit to students who have completed 1320. Does not count towards the B.S. Physics or B.S.E. Engineering Physics degrees. Prerequisite(s): PHYS 1210 or 1310. Corequisite(s): PHYS 1221.

Prerequisite(s): PHYS 1210 or 1310.
Corequisite(s): PHYS 1221.

PHYS 1221 Introductory Physics II Lab (0)
Lab section for PHYS 1220. Corequisite(s): PHYS 1220.

Corequisite(s): PHYS 1220.

PHYS 1310 General Physics I (4)
Prior or concurrent study in calculus is required. A calculus-based course in classical physics designed primarily for physical science and engineering majors. Newtonian mechanics, oscillations, and classical wave motion are studied. Emphasis is on understanding basic principles and solving problems. A weekly laboratory is included. The laboratory includes a review of techniques for problem solving, as well as experiments in classical physics. Prerequisite(s): MATH 1150*, 1210* or 1310*. * May be taken concurrently. Corequisite(s): PHYS 1311.

Prerequisite(s): MATH 1150*, 1210* or 1310*.
* May be taken concurrently.
Corequisite(s): PHYS 1311.

PHYS 1311 General Physics I Lab (0)
Lab section for PHYS 1310. Corequisite(s): PHYS 1310.

Corequisite(s): PHYS 1310.

PHYS 1320 General Physics II (4)
A continuation of PHYS 1310. Emphasis on electricity and magnetism, with selected topics in optics and modern physics. The laboratory includes a review of techniques for problem solving, as well as experiments in classical physics. Prerequisite(s): PHYS 1310. Corequisite(s): PHYS 1321.

Prerequisite(s): PHYS 1310.
Corequisite(s): PHYS 1321.

PHYS 1321 General Physics II Lab (0)
Lab section for PHYS 1320. Corequisite(s): PHYS 1320.

Corequisite(s): PHYS 1320.

PHYS 1890 Service Learning (0-1)
Students complete a service activity in the community in conjunction with the content of a three-credit co-requisite course. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 1940 Transfer Coursework (0-20)
Transfer Coursework at the 1000 level. Department approval may be required.

Maximum Hours: 99

PHYS 2350 Modern Physics I (3)
Quantitative treatment of important topics of 20th-century physics, focused on special relativity and introductory quantum physics. Planck's and de Broglie's hypotheses, photons, the Bohr model, introduction to wave mechanics, the hydrogen atom, spatial quantization, spin, exclusion principle, multi-electron atoms. Prerequisites: PHYS 1210 and 1220 or 1310 and 1320, MATH 1210 and 1220 or equivalent.

Prerequisite(s): (PHYS 1220 or 1320) and (MATH 1220 or 1310).

PHYS 2360 Modern Physics II (3)
An overview of the major fields in modern physics. Quantum statistics. Diatomic molecules, electrons in metals, band theory of solids, superconductivity, properties of nuclei, radioactivity, nuclear reactions, interaction of particles with matter, elementary particles, the standard model and cosmology. Prerequisites: PHYS 2350.

Prerequisite(s): PHYS 2350.

PHYS 2890 Service Learning (0-1)
Students complete a service activity in the community in conjunction with the content of a three-credit co-requisite course. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 2910 Intro to Physics Pedagogy (1)
Introduction to the theory and practice of teaching physics courses through workshops, observations and assisting teachers at local schools with lectures and/or classroom demonstrations. Prerequisites: PHYS 1210 and 1220 or 1310 and 1320.

Prerequisite(s): (PHYS 1210 or 1310) and (PHYS 1220 or 1320).

PHYS 2940 Transfer Coursework (0-20)
Transfer Coursework at the 2000 level. Department approval may be required.

Maximum Hours: 99

PHYS 3010 Theoretical Physics (3)
An introduction to the methods of theoretical physics emphasizing modern mathematical techniques, numerical methods using computers, and computer algebra. Prerequisites: PHYS 2350 and 11 credits of mathematics, or approval of instructor.

Prerequisite(s): PHYS 2350.

PHYS 3150 Intro To Neutron Science (3)
An introduction to the theory and applications of neutron scattering, neutron optics, neutron interferometry and neutron beta decay. This course explores the many uses of thermal and cold neutron beams to study condensed matter, nuclear, molecular and biological systems; test fundamental principles of quantum mechanics and advance the frontier of particle physics. Prerequisites: MATH 2210, MATH 2240 or equivalent; PHYS 2350, PHYS 2360 or equivalent.

Prerequisite(s): MATH 2210, 2240, PHYS 2350 and 2360.

PHYS 3170 Computnl Physics & Engr (3)
An introduction to the use of computational methods in physics and engineering. Writing computer code and using data visualization techniques to help solve experimental and theoretical problems. Data analysis and modeling, Monte Carlo simulations, numerical differentiation and integration, ordinary and partial differential equations, electrostatics nonlinear dynamics and chaos, fast Fourier transform, noisy signal processing, quantum spectra, thermodynamics. Prerequisites: PHYS 2350 and MATH 2210 or 2240.

Prerequisite(s): PHYS 2350 and (MATH 2210 or 2240).

PHYS 3210 Molec Biophysics & Polymer Phy (3)
An introduction to the physics of polymers and the physical bases underlying the biofunctionality of macromolecules in living systems. Themes of molecular self-organization, conformation, complementarity, and information content are emphasized and related to protein, lipid, and nucleic acid structure and processes. Introduction to scattering and other spectroscopic techniques. Prerequisites: PHYS 2350 or equivalent, CHEM 1070 or equivalent, and MATH 1220 or equivalent.

Prerequisite(s): MATH 1220 or 1310.

PHYS 3230 Quantum Information Sci & Eng (3)
This survey course introduces students to the new world of quantum information, quantum communication, and quantum computing. The course is intended for advanced undergraduates and beginning graduate students in physics, engineering, and mathematics. Topics include: Quantum states, operators, and linear algebra; Bits and qubits; Ensembles and density operators; Unitary transformations; Gates and circuits; Information and entropy; POVM measurement; Multipartite systems; Bell inequality, Bell states, and non-locality; Measures of entanglement; Quantum communication and cryptography; Teleportation; Superdense coding; Quantum noise and error correction; Classical and quantum computational complexity; Quantum algorithms; Deutsch-Jozsa, Grover, Shor; DiVincenzo criteria; Physical realizations of quantum computers: trapped ions, solid state qubits; Quantum optics and quantum internet; Topological quantum computation; Quantum biology. Prerequisite(s): PHYS 2350 and (MATH 2210 or 2240).

Prerequisite(s): PHYS 2350 and (MATH 2210 or 2240).

PHYS 3290 Computation Material Sci & Eng (3)
Computational Materials Science and Engineering: This course will cover theories, implementations, and applications of common quantum mechanical software for computational study of materials. State-of-the-art computational methods will be introduced for materials research with emphasis on the atomic and nano scales and hands-on modeling on PCs and supercomputers. The class is aimed at beginning graduate students and upper level undergraduate students, and will introduce a variety of computational methods used in different fields of materials science. The main focus is quantum mechanical methods with a short overview of atomistic methods for modeling materials. These methods will be applied to the properties of real materials, such as electronic structure, mechanical behavior, diffusion and phase transformations. Computational design of materials using materials database via high-throughput and machine learning methods will also be covered. Prerequisite(s): PHYS 2350 and 2360.

Prerequisite(s): PHYS 2350 and 2360.

PHYS 3310 Quantum Optics (3)
Quantum optics is an emerging field of physics that involves the study of semi-classical and quantum-mechanical models of the electromagnetic field, as well as its interaction with atoms and molecules. These nonclassical and quantum features of light have been shown to break the barriers imposed by classical physics in a variety of fields, such as communication, interferometry, computation, and imaging. The main emphasis of this course will be to introduce these nonclassical features, quantize the electromagnetic field, introduce fundamental tests of quantum mechanics by use of optics, and explore the applications of nonclassical concepts such as entanglement. Prerequisite(s): PHYS 1320*. * May be taken concurrently.

Prerequisite(s): PHYS 1320*.
* May be taken concurrently.

PHYS 3350 Kinetics of Material Systems (3)
This course covers all aspects of kinetics in material systems. Topics include thermodynamics, steady state and time dependent diffusion, phase transformations, statistical mechanics, structure evolution, boundaries and interfaces, solidification, and precipitation effects. Prerequisite(s): ENGP 3120.

Prerequisite(s): ENGP 3120.

PHYS 3360 Structure of Materials (3)
The properties of matter depend on which of the about 100 different kinds of atoms they are made of and how they are bonded together in different crystal structures; specifically, the atomic structure primarily affects the chemical, physical, thermal, electrical, magnetic, and optical properties of materials. Metals behave differently than ceramics, and ceramics behave differently than polymers. Students will learn the different states of condensed matter and develop a set of tools for describing the crystalline structure of all of them. They will gain a better understanding of the principles of structure common to all materials. Key concepts, such as symmetry theory will be introduced and applied to provide a common viewpoint for describing structures of ceramic, metallic, and polymeric materials and the latter includes optical microscopy, electron optics, x-ray diffraction and some surface analytical techniques. Structure-sensitive properties of real materials will also be introduced.

PHYS 3370 Processing of Biomaterials (3)
Processing of biomaterials gives an overview of the most advanced techniques to process biomaterials into structures that satisfy next generation applications. All materials classes will be covered including polymers, ceramics, metals, composites and cells and tissues. In each case, the material-specific processing and the properties and potential applications will be covered.

PHYS 3380 Materials for Energy (3)
The course begins with a history of our understanding and utilization of different sources of energy and a review of thermodynamics. In all cases, the most effective materials used are discussed as well as the relevant fundamental equations used and approaches for improving the figure-of-merit. The 5 different forms of energy are introduced - mechanical, electromagnetic, thermal, chemical, and nuclear - and discussed. Materials and techniques used for energy applications are discussed including thermoelectrics, fossil fuels, nanoparticles, different approaches for energy storage, fuel cells, nuclear energy (fission and fusion), energy biological systems - from cellular scale and ATP and catabolism/anabolism to biomass conversion, and magnetohydrodynamics. Techniques for energy conversion, biomimetics, energy and the environment and material issues for energy transformation are discussed. The sun is also discussed as a source of energy for photosynthesis, photovoltaics, and photothermal power generation. Prerequisite(s): ENGP 3120.

Prerequisite(s): ENGP 3120.

PHYS 3390 Synthesis of Nanomaterials (3)
This course focuses on the fundamentals of nanomaterials synthesis mechanisms and characterization. The course gives an introduction for nanomaterials classes and their importance for today's world, followed by basics of physical chemistry of solid surfaces. Then, top-down and bottom-up synthesis approaches for nanomaterials systems including gas, liquid and solid phase processes are covered. Characterization techniques of special importance for nanomaterials are taught. During the semester students will study and review scientific articles focused on nanomaterials synthesis and characterization.

Prerequisite(s): ENGP 3120.

PHYS 3450 Elem Particle Physics (3)
An introduction to modern elementary particle physics, with an emphasis on the Standard Model, its phenomenology, and dynamics. The Standard Model explains, in principle and with remarkable success, virtually all phenomena that are observed in nature except gravity. The course begins with a qualitative examination of the electromagnetic, strong, and weak interactions and an introduction to the elementary particles through the use of Feynman diagrams. This is followed by relativistic kinematics, the quantum theory of angular momentum and spin, discrete symmetries, and bound states of leptons and quarks, with a focus on the hadrons. Finally the Dirac equation, the Feynman calculus, and the mathematical tools needed to calculate basic decay lifetimes and cross sections involving the electromagnetic and weak interactions are developed and applied. Prerequisite(s): (PHYS 1310) and PHYS 1320, 2350 and 2360 and (MATH 2210).

Prerequisite(s): (PHYS 1310) and PHYS 1320, 2350 and 2360 and (MATH 2210).

PHYS 3530 Advanced Laboratory (3)
Advanced experiments in modern physics, particularly nuclear physics, emphasizing research techniques and analysis of data using computers. Prerequisites: PHYS 2350 or approval of instructor.

Prerequisite(s): PHYS 2350.

PHYS 3560 Photonic Materials & Devices (3)
This course will cover the theory, design, fabrication, characterization, and application of photonic materials and devices. The course will start with a review of the fundamentals of photonics, including ray optics, wave optics, and nanophotonics/quantum optics. The course will then focus on light-matter interactions and photonic materials, including dielectrics, semiconductors, metals, metamaterials, and photonic crystals. Using these principles and materials, we will explore a number of device architectures, including LEDs, lasers, photodetectors, photovoltaics, etc. We will then discuss fabrication methods for making these materials and devices and common optoelectronic characterization techniques. The course will conclude with exploration of cutting edge topics in photonics research. Prerequisites: PHYS 2350 and PHYS 2360 (or equivalent) or instructor approval.

Prerequisite(s): PHYS 2350 and 2360.

PHYS 3570 Semiconductor Devices (3)
An introduction to the physics and technology underlying semiconductor electronic and optoelectronic devices, including electrons and holes in semiconductors, energy-band diagrams, carrier transport, metal-semiconductor contacts, p-n junctions, and heterostructures. Device examples include bipolar transistors, MOSFETs, LEDs, and solar cells. Prerequisite(s): PHYS 2360 or equivalent.

Prerequisite(s): PHYS 2360.

PHYS 3600 Nanoscience & Technology (3)
Nanoscience and technology is often branded the science of the 21st century. It has been promised that nanotechnology will have similar stimulating effects on the world's economy and society as the industrial-and microelectronics- revolution. Nanoscience is an interdisciplinary effort with the aim to manipulate and control matter at length scales down to single molecules and atoms and thus to create materials and devices with novel properties. With diminishing dimensions material properties are being governed by quantum mechanics. The description and exploitation of quantum phenomena in novel devices is the quintessence of nanophysics. Consequently, the main emphasis of this course is to give an overview of the physics of low dimensional solid state systems. This course is supplementary to courses in solid state physics and surface science but can be taken independently. Prerequisites: PHYS 2350.

Prerequisite(s): PHYS 2350.

PHYS 3620 MicroFab and Nanotech (3)
Nano/micro-electromechanical devices (N/MEMS) require knowledge of a broad range of disciplines, from the fundamental physics of mechanics and electromagnetism to practical nano/microfabrication processes and techniques. This course is opened for the introduction of this interdisciplinary engineering field, using examples and design projects drawn from real-word N/MEMS applications. Lectures will cover nano/micro-fabrication technologies, material properties at different scaling, physical principle and behaviors of nano/microstructural behavior, piezoresistive and capacitive sensing, electrostatic actuation, fluid damping, noise, and feedback systems. Prerequisite(s): PHYS 2360.

Prerequisite(s): PHYS 2360.

PHYS 3630 Electromagnetic Theory (3)
Electrostatic fields in a vacuum, dielectric materials, solutions to Laplace's and Poisson's equations, currents, magnetic fields, vector potentials, electromagnetic induction, relation to Special Relativity, Maxwell's equations, and the properties of classical electromagnetic waves. Prerequisites: PHYS 1310, PHYS 1320, and Mathematics 2210 or equivalent.

Prerequisite(s): PHYS 1310, 1320 and MATH 2210.

PHYS 3660 Special Topics (1-3)
Special Topics.

PHYS 3700 Electrnc Prop of Materls (3)
Quantum physics, electronics and energy bands in crystals, electronic transport in materials, photoconductivity, Hall effect, quantum Hall effect, superconductors and their applications, magnetic properties of material and their applications, thermal properties of materials and dielectric properties of materials. Prerequisites: PHYS 2350/2360 or instructor approval.

Prerequisite(s): PHYS 2350 and 2360.

PHYS 3720 Mechanic Behavior of Materials (3)
he course covers the general foundations of elasticity and plasticity theory, dislocation theory, and strengthening mechanisms. Basics of materials forming processes are studied. An overview for non-destructive testing of materials is taught. The course emphasis is on destructive mechanical testing of materials including; tension, torsion, hardness, fatigue and creep tests, in addition to fracture mechanics and failure analysis. Prerequisite(s): ENGP 3120, 2430 and MATH 2210.

Prerequisite(s): ENGP 3120, 2430 and MATH 2210.

PHYS 3740 Classical Mechanics (3)
Newtonian mechanics, oscillations, central force motion, special theory of relativity, dynamics of rigid bodies, and the Lagrangian formulation of classical mechanics. Prerequisites: PHYS 1310, 1320, and MATH 2210.

Prerequisite(s): PHYS 1320 and MATH 2210.

PHYS 3760 Thermodynamics of Materials (3)
The course covers the general foundation of both statistical thermodynamics and classical thermodynamics, including thermodynamics laws, auxiliary functions, and behavior of gases and solutions. In addition, special attention is dedicated to equilibria of reactions and phase diagrams of materials. Computer-based programs will be used to solve thermodynamics problems for complicated materials.

PHYS 3800 Physics Colloquium (1)
A series of undergraduate and faculty seminars emphasizing topics and points of view not covered in the standard curriculum, but which are nonetheless important to the education of a physicist. Notes: Required of all majors. Prerequisites: Junior standing or departmental approval.

PHYS 3880 Writing Practicum (1)
Writing Practicum. Notes: Does not count toward Physics courses or electives for the Physics major. Prerequisites: Successful completion of the First-Year Writing Requirement. Corequisites: Three-credit departmental course.

PHYS 3890 Service Learning (0-1)
Students complete a service activity in the community in conjunction with the content of a three-credit co-requisite course. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 3940 Transfer Coursework (0-20)
Transfer Coursework at the 3000 level. Department approval may be required.

Maximum Hours: 99

PHYS 4230 Thermal Physics (3)
A study of the physical properties of matter where temperature is an important variable. The laws of thermodynamics, equations of state, thermodynamic potentials. Kinetic theory of gases. Elementary statistical postulates. Ensembles, the partition function. Entropy, phase transitions. Prerequisites: PHYS 1210 and 1220, or 1310 and 1320.

Prerequisite(s): (PHYS 1210) and (PHYS 1220) or (PHYS 1310) and (PHYS 1320).

PHYS 4470 Intro Quantum Mechanics (3)
The postulates of quantum mechanics, Schroedinger equation, operator methods, angular momentum, fermion and boson systems, and Heisenberg formulations, applications to simple physical systems. Prerequisites: PHYS 2350 and MATH 2210.

Prerequisite(s): PHYS 2350 and MATH 2210.

PHYS 4650 Optics (3)
Geometrical, physical and quantum optics, with an emphasis on the classical electromagnetic aspects of optics pertaining to scattering, reflection, refraction, dispersion, polarization and interference. Applications to optical instruments, spectroscopy, interferometry, and Fourier optics. Prerequisite(s): PHYS 1320 and MATH 2210. PHYS 3630 recommended but not required.

Prerequisite(s): PHYS 1320 and MATH 2210.

PHYS 4660 Special Topics (1-3)
Special Topics. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 4910 Independent Studies (1-3)
Independent Studies. Prerequisites: Approval of instructor and chair of department. Course may be repeated up to 6 credit hours.

Maximum Hours: 6

PHYS 4920 Independent Studies (1-3)
Independent Studies. Prerequisites: Approval of instructor and chair of department. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 4940 Transfer Coursework (0-20)
Transfer coursework at the 4000 level. Departmental approval required.

Maximum Hours: 99

PHYS 4990 Honors Thesis (3)
Honors thesis research, first semester. Register in department.

PHYS 5000 Honors Thesis (4)
Honors thesis research, second semester. Register in department.

PHYS 5380 Study Abroad (1-20)
Courses taught abroad by non-Tulane faculty. Does not count toward Tulane GPA. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 5390 Study Abroad (1-20)
Courses taught abroad by non-Tulane faculty. Does not count toward Tulane GPA. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 6010 Techniques Theor Phys I (3)
Mathematical techniques used in theoretical physics. Topics include partial differential equations, orthogonal coordinate systems, separation of variables, introduction to ordinary differential equations, series solutions and convergence; Sturm Liouville theory, eigensystems and orthogonal functions; complex variables, Taylor and Laurent series, contour integration, integration by steepest descents, and conformal mappings.

PHYS 6020 Techniques Theor Phys II (3)
A continuation of PHYS 6010. Calculus of variations, Rayleigh Ritz technique, Bessel and Legendre functions, Fourier series, Fourier and Laplace transforms, Green functions. An introduction to group theory and symmetry. Prerequisite(s): PHYS 6010.

Prerequisite(s): PHYS 6010.

PHYS 6070 Astrophysics (3)
Fundamentals of stellar atmospheres and interiors: nuclear astrophysics, energy generation in stars, stellar evolution, nucleo-synthesis, and theories of supernovae. Gravitational collapse and properties of superdense stars. Galactic structure and evolution, elements of cosmology.

PHYS 6150 Intro To Neutron Science (3)
An introduction to the theory and applications of neutron scattering, neutron optics, neutron interferometry and neutron beta decay. This course explores the many uses of thermal and cold neutron beams to study condensed matter, nuclear, molecular and biological systems; test fundamental principles of quantum mechanics and advance the frontier of particle physics.

PHYS 6170 Computnl Physics & Engr (3)
An introduction to the use of computational methods in physics and engineering. Writing computer code and using data visualization techniques to help solve experimental and theoretical problems. Data analysis and modeling, Monte Carlo simulations, numerical differentiation and integration, ordinary and partial differential equations, electrostatic nonlinear dynamics and chaos, fast Fourier transform, noisy signal processing, quantum spectra, thermodynamics.

PHYS 6210 Molec Biophysics & Polymer Phy (3)
An introduction to the physics of polymers and the physical bases underlying the biofunctionality of macromolecules in living systems. Themes of molecular self-organization, conformation, complementarity, and information content are emphasized and related to protein, lipid, and nucleic acid structure and processes. Introduction to scattering and other spectroscopic techniques.

PHYS 6230 Quantum Information Sci & Eng (3)
This survey course introduces students to the new world of quantum information, quantum communication, and quantum computing. The course is intended for advanced undergraduates and beginning graduate students in physics, engineering, and mathematics. Topics include: Quantum states, operators, and linear algebra; Bits and qubits; Ensembles and density operators; Unitary transformations, Gates and circuits; Information and entropy; POVM measurement; Multipartite systems; Bell inequality; Bell states and non-locality; Measures of entanglement: Quantum communication and cryptography; Teleportation, Superdense coding; Quantum noise and error correction; Classical and quantum computational complexity; Quantum algorithms; Deutsch-Jozsa, Grover, Shor; DiVincenzo criteria; Physical realizations of quantum computers; trapped ions, solid state qubits; Quantum optics and quantum internet; Topological quantum computation; Quantum biology.

PHYS 6300 General Relativity (3)
Review of special relativity. Tensor analysis. Differential forms and manifolds. Geodesics and curvature two-forms. The metric tensor. The stress-energy tensor and the Einstein equations. The initial data problem. The Schwarzschild and Kerr solutions: classical black holes. Elementary relativistic cosmology. Generation and detection of gravitational waves. Experimental tests of general relativity: the PPN formalism. Global techniques and the Hawking-Penrose singularity theorems. Hawking radiation and the Bekenstein bound.

PHYS 6310 Quantum Optics (3)
Quantum optics is an emerging field of physics that involves the study of semi-classical and quantum-mechanical models of the electromagnetic field, as well as its interaction with atoms and molecules. These nonclassical and quantum features of light have been shown to break the barriers imposed by classical physics in a variety of fields, such as communication, interferometry, computation, and imaging. The main emphasis of this course will be to introduce these nonclassical features, quantize the electromagnetic field, introduce fundamental tests of quantum mechanics by use of optics, and explore the applications of nonclassical concepts such as entanglement.

PHYS 6450 Elem Particle Physics (3)
An introduction to modern elementary particle physics, with an emphasis on the Standard Model, its phenomenology, and dynamics. The Standard Model explains, in principle and with remarkable success, virtually all phenomena that are observed in nature except gravity. The course begins with a qualitative examination of the electromagnetic, strong, and weak interactions and an introduction to the elementary particles through the use of Feynman diagrams. This is followed by relativistic kinematics, the quantum theory of angular momentum and spin, discrete symmetries, and bound states of leptons and quarks, with a focus on the hadrons. Finally the Dirac equation, the Feynman calculus, and the mathematical tools needed to calculate basic decay lifetimes and cross sections involving the electromagnetic and weak interactions are developed and applied.

PHYS 6600 Nanoscience & Technology (3)
Nanoscience and technology is often branded the science of the 21st century. It has been promised that nanotechnology will have similar stimulating effects on the world's economy and society as the industrial-and microelectronics- revolution. Nanoscience is an interdisciplinary effort with the aim to manipulate and control matter at length scales down to single molecules and atoms and thus to create materials and devices with novel properties. With diminishing dimensions material properties are being governed by quantum mechanics. The description and exploitation of quantum phenomena in novel devices is the quintessence of nanophysics. Consequently, the main emphasis of this course is to give an overview of the physics of low dimensional solid state systems. This course is supplementary to courses in solid state physics and surface science but can be taken independently.

PHYS 6660 Special Topics (1-3)
Special Topics. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 6700 Electrnc Prop of Materls (3)
Quantum physics, electronics and energy bands in crystals, electronic transport in materials, photoconductivity, Hall effect, quantum Hall effect, superconductors and their applications, magnetic properties of material and their applications, thermal properties of materials and dielectric properties of materials.

PHYS 6750 Modern Cosmology (3)
The Friedmann cosmological models: open, flat, and closed; matter and radiation dominated. The cosmological constant. Three degree blackbody radiation and its theoretical implications. Experimental tests in cosmology. Nucleosynthesis and galaxy formation. Anisotropic and inhomogeneous cosmologies: the Bianchi models, primarily Kasner and Type IX. GUTs in the very early universe: baryogenesis and phase transitions. Dark matter. Cosmic strings and magnetic monopoles. Inflationary models. Chaotic inflation. Future history and final state of the universe.

PHYS 6940 Transfer Coursework (0-20)
Transfer coursework at the 6000 level. Departmental approval required.

Maximum Hours: 99

PHYS 7060 Theoretical Mechanics (3)
Advanced studies of theoretical mechanics. Lagrangian and Hamiltonian methods. Integrable and non-integrable problems.

PHYS 7100 Statistical Mechanics (3)
Advanced studies of statistical mechanics. Probability theory, random walks, statistical ensembles, entropy, quantum statistical mechanics and applications.

PHYS 7130 Solid State Physics (3)
Advanced studies of solid state physics. Properties of the solid state, semiconductors, novel systems, applications.

PHYS 7160 Atomic/Molecular Physics (3)
Advanced studies of atomic and molecular physics. The hydrogen, helium and many electron atoms. Diatomic and polyatomic molecules.

PHYS 7170 Quantum Mechanics I (3)
Advanced studies of quantum mechanics. Quantization, probability, quantum wave functions, quantum entanglement. Two, three and multi-level quantum systems and applications.

PHYS 7180 Quantum Mechanics II (3)
Continuation of PHYS 7170. Prerequisite(s): PHYS 7170.

Prerequisite(s): PHYS 7170.

PHYS 7230 Electromagnetic Theory I (3)
Advanced studies of electromagnetic theory. Maxwell's equations and applications. Electric and magnetic fields and their properties. Applications.

PHYS 7240 Electro-Magnetic Thry II (3)
Continuation of PHYS 7230.

PHYS 7310 Advanced Spec Problems (3)
Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 7311 Advanced Special Problems (3)

PHYS 7312 Advanced Special Problems (3)

PHYS 7320 Adv Special Problems II (1-9)

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PHYS 7810 Seminar (3)

PHYS 7820 Seminar (1)

PHYS 7910 Research I (3)
Individual research supervised by faculty.

PHYS 7920 Research II (3)
Individual research supervised by faculty.

PHYS 7930 Research III (3)
Individual research supervised by faculty.

PHYS 7940 Research IV (3)
Individual research supervised by faculty. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 7951 Advanced Research I (3)

PHYS 7952 Advanced Research II (3)

PHYS 7990 Research (1-9)
Individual research supervised by faculty.

PHYS 9980 Masters Research (3)
Research toward completion of a masters degree. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99

PHYS 9990 Dissertation Research (3)
Research toward completion of a doctoral degree. Course may be repeated up to unlimited credit hours.

Maximum Hours: 99