PHYS - PHYSICS

PHYS 601 Analytical Mechanics

Credits 3. 3 Lecture Hours. Hamilton approaches to dynamics; canonical transformation and variational techniques; central force and rigid body motions; the mechanics of small oscillations and continuous systems. **Prerequisites:** PHYS 302 or equivalent; MATH 311 and MATH 412 or equivalents; concurrent registration in PHYS 615.

PHYS 603 Electromagnetic Theory

Credits 3. 3 Lecture Hours. Boundary-value problems in electrostatics; basic magnetostatics; multipoles; elementary treatment of ponderable media; Maxwell's equations for time-varying fields; energy and momentum of electromagnetic field; Poynting's theorem; gauge transformations. **Prerequisites:** PHYS 304 or equivalents; PHYS 615.

PHYS 606 Quantum Mechanics

Credits 3. 3 Lecture Hours. Schrodinger wave equation, bound states of simple systems, collision theory, representation and expansion theory, matrix formulation, perturbation theory. **Prerequisites:** PHYS 412 or equivalent; MATH 311 and MATH 412 or equivalents; concurrent registration in PHYS 615.

PHYS 607 Statistical Mechanics

Credits 3. 3 Lecture Hours. Classical statistical mechanics, Maxwell-Boltzmann distribution, and equipartition theorem; quantum statistical mechanics, Bose-Einstein distribution and Fermi-Dirac distribution; applications such as polyatomic gases, blackbody radiation, free electron model for metals, Debye model of vibrations in solids, ideal quantum mechanical gases and Bose-Einstein condensation; if time permits, phase transitions and nonequilibrium statistical mechanics. **Prerequisites:** PHYS 408 and PHYS 412 or equivalents; PHYS 615.

PHYS 610 Scientific Writing for Physics

Credit 1. 1 Lecture Hour. Range of techniques designed to increase writing productivity in physics. **Prerequisites:** PHYS 309 or equivalent or approval of instructor.

PHYS 611 Electromagnetic Theory

Credits 3. 3 Lecture Hours. Continuation of PHYS 603. Propagation, reflection and refraction of electromagnetic waves; wave guides and cavities; interference and diffraction; simple radiating systems; dynamics of relativistic particles and fields; radiation by moving charges. **Prerequisite:** PHYS 603.

PHYS 615 Methods of Theoretical Physics I

Credits 3. 3 Lecture Hours. Orthogonal eigenfunctions with operator and matrix methods applied to solutions of the differential and integral equations of mathematical physics; contour integration, asymptotic expansions of Fourier transforms, the method of stationary phase and generalized functions applied to problems in quantum mechanics. **Prerequisites:** MATH 311, MATH 407 and MATH 412 or equivalents.

PHYS 616 Methods of Theoretical Physics II

Credits 3. 3 Lecture Hours. Group theory and its implementation in physical systems; finite groups, Lie groups and Lie algebras; representation theory, symmetries of regular objects, global aspects of Lie groups and classification of Lie algebras. **Prerequisites:** PHYS 615 or approval of instructor.

PHYS 617 Physics of the Solid State

Credits 3. 3 Lecture Hours. Crystalline structure and symmetry operations; electronic properties in the free electron model with band effects included; lattice vibrations and phonons; thermal properties; additional topics selected by the instructor from: scattering of X-rays, electrons, and neutrons, electrical and thermal transport, magnetism, superconductivity, defects, semiconductor devices, dielectrics, optical properties. **Prerequisites:** PHYS 606 and PHYS 607.

PHYS 619 Modern Computational Physics

Credits 3. 3 Lecture Hours. Modern computational methods with emphasis on simulation such as molecular dynamics and Monte Carlo; applications to condensed matter and nuclear many-body physics and to lattice gauge theories. **Prerequisites:** PHYS 408 and PHYS 412 or equivalents; knowledge of any programming language.

PHYS 624 Quantum Mechanics

Credits 3. 3 Lecture Hours. Continuation of PHYS 606. Scattering theory, second quantization, angular momentum theory, approximation methods, application to atomic and nuclear systems, semi-classical radiation theory. **Prerequisite:** PHYS 606.

PHYS 625 Nuclear Physics

Credits 3. 3 Lecture Hours. Nuclear models, nuclear spectroscopy, nuclear reactions, electromagnetic properties of nuclei; topics of current interest. **Prerequisite:** PHYS 606.

PHYS 626 Theoretical Nuclear Physics

Credits 3. 3 Lecture Hours. Theoretical foundations of modern nuclear physics; quantum chromodynamics and properties; confinement; chiral symmetry and breaking; quark model and hadron structure; nuclear forces; many-body theory and effective field theory; fundamental symmetries; nuclear reactions and nuclear astrophysics; nuclear collisions and nuclear matter at high temperatures and densities; spectral functions and transport phenomena. **Prerequisite:** PHYS 606, 615, and 625, or equivalent.

PHYS 627 Elementary Particle Physics

Credits 3. 3 Lecture Hours. Fundamentals of elementary particle physics; particle classification, symmetry principles, relativistic kinematics and quark models; basics of strong, electromagnetic and weak interactions. **Prerequisite:** PHYS 606.

PHYS 631 Quantum Theory of Solids

Credits 3. 3 Lecture Hours. Second quantization, and topics such as plasmons; many-body effects for electrons; electron-phonon interaction; magnetism and magnons; other elementary excitations in solids; BCS theory of superconductivity; interactions of radiation with matter; transport theory in solids. **Prerequisites:** PHYS 617 and PHYS 624.

PHYS 632 Condensed Matter Theory

Credits 3. 3 Lecture Hours. Continuation of PHYS 631. Recent topics in condensed matter theory. Peierl's Instability, Metal-Insulator transition in one-dimensional conductors, solitons, fractionally charged excitations, topological excitations, Normal and Anomalous Quantum Hall Effect, Fractional Statistics, Anyons, Theory of High Temperature Superconductors, Deterministic Chaos. **Prerequisites:** PHYS 601, PHYS 617 and PHYS 624.

PHYS 634 Relativistic Quantum Field Theory

Credits 3. 3 Lecture Hours. Classical scalar, vector and Dirac fields; second quantization; scattering matrix and perturbation theory; dispersion relations; renormalization. **Prerequisite:** PHYS 624.

PHYS 638 Quantum Field Theory II

Credits 3. 3 Lecture Hours. Functional integrals; divergences, regularization and renormalization; non-abelian gauge theories; other topics of current interest. **Prerequisite:** PHYS 634.

PHYS 639 Methods of Experimental Particle Physics

Credits 3. 2 Lecture Hours. 2 Lab Hours. Methods of particle detection and data analysis techniques in experimental particle physics; computational and statistical methods in modern research; next challenges in experimental particle physics; use of statistical and computational techniques, Monte Carlo simulation methods, presenting and documenting scientific findings using LaTex. **Prerequisites:** PHYS 305 and PHYS 412; working knowledge of C or C++; or approval of instructor.

PHYS 641/ASTR 601 Extragalactic Astronomy

Credits 3. 3 Lecture Hours. Overview of observations of galaxies and large-scale structures in the Universe to understand their formation and evolution from theoretical and observational perspectives; galaxy luminosity functions; evolution of stellar populations and chemical enrichment; clusters and AGN. **Prerequisites:** PHYS 601; or ASTR 314 and PHYS 302; or approval of instructor. **Cross Listing:** ASTR 601/PHYS 641.

PHYS 642/ASTR 602 Astronomical Observing Techniques and Instrumentation

Credits 3. 3 Lecture Hours. Theory and practice of obtaining and analyzing astrometric, photometric, spectroscopic, and interferometric measurements of astronomical sources across the electromagnetic spectrum; principles of design, fabrication, assembly, test, deployment, and use of astronomical instruments. **Prerequisites:** PHYS 615 or equivalent; or approval of instructor. **Cross Listing:** ASTR 602/PHYS 642.

PHYS 643/ASTR 603 Stellar Astrophysics

Credits 3. 3 Lecture Hours. Theoretical and observational aspects of stellar astrophysics; thermodynamic properties of stellar interiors; energy sources; nuclear processes and burning stages; convective and radiative energy transport; evolutionary models; atmospheres; stability and pulsations; chemical enrichment processes; population synthesis. **Prerequisites:** PHYS 606 and PHYS 607 or equivalents; or approval of instructor. **Cross Listing:** ASTR 603/PHYS 643.

PHYS 644/ASTR 604 Cosmology

Credits 3. 3 Lecture Hours. Basic principles of modern cosmology and particle physics; general relativity; cosmic inflation; Big Bang nucleosynthesis; expansion of the universe; cosmic microwave background; large-scale structure of the Universe; properties of particles; dark matter; dark energy. **Prerequisites:** PHYS 615 or equivalent; or approval of instructor. **Cross Listing:** ASTR 604/PHYS 644.

PHYS 645/ASTR 605 Galactic Astronomy

Credits 3. 3 Lecture Hours. Basic nature and structure of constituents of Milky Way galaxy; distribution and motions of stars and gas; origin evolution and distribution of large-scale chemical abundances and kinematic patterns across populations; models of galaxy formation and implications of modern observations. **Prerequisites:** PHYS 601 and PHYS 607 or equivalents; or approval of instructor. **Cross Listing:** ASTR 605/PHYS 645.

PHYS 646/ASTR 606 Radiative Transfer

Credits 3. 3 Lecture Hours. Fundamental radiative processes in stellar and planetary atmospheres; radiative fields; Stokes parameters; Mueller matrix formalism; radiation from moving charges; Compton scattering; plasma effects; atomic structure and radiative transitions; molecular structure and spectra; multiple scattering. **Prerequisites:** PHYS 302, PHYS 304, PHYS 408, and PHYS 412 or equivalents; or approval of instructor. **Cross Listing:** ASTR 606/PHYS 646.

PHYS 647 Gravitational Physics

Credits 3. 3 Lecture Hours. Special relativity; equivalence principle; theory of gravitation; Einstein's theory of general relativity; classic tests of general relativity; simple black hole and cosmological solutions; global aspects; penrose diagrams; stationary black holes; Hawking radiation. **Prerequisites:** PHYS 611 and PHYS 615.

PHYS 648 Quantum Optics and Laser Physics

Credits 3. 3 Lecture Hours. Line widths of spectral lines; laser spectroscopy; optical cooling; trapping of atoms and ions; coherence; pico- and femto-second spectroscopy; spectroscopic instrumentation. **Prerequisite:** Approval of instructor.

PHYS 649 Physics of Optoelectronic Devices

Credits 3. 3 Lecture Hours. Overview of basic concepts: laser physics, optics of semiconductors, heterostructures with quantum confinement and their interaction with light; physical principles of state of the art optoelectronic devices; emerging concepts and technologies: integrated photonics, nanophotonics, plasmonics, metamaterials, terahertz optoelectronics, quantum information processing, etc. **Prerequisites:** Quantum mechanics (PHYS 412 and PHYS 414 or PHYS 606 or equivalent).

PHYS 651 Superstring Theory I

Credits 3. 3 Lecture Hours. Basics of string theory, including bosonic string, conformal field theory, strings with worldsheet and space-time supersymmetry, as well as the higher dimensional extended objects called D-branes. **Prerequisites:** PHYS 634 and PHYS 653; PHYS 647 recommended.

PHYS 652 Superstring Theory II

Credits 3. 3 Lecture Hours. M-theory unification of superstring theories into a single eleven-dimensional theory; duality symmetries relating string theories; string geometry; Calabi-Yau manifolds and exceptional holonomy manifolds; flux compactifcations; black holes in string theory; AdS/CFT correspondence; string and M-theory cosmology. **Prerequisites:** PHYS 651; PHYS 647 recommended.

PHYS 653 Introduction to Supersymmetry and Supergravity

Credits 3. 3 Lecture Hours. Core material on supersymmetric field theories and their coupling to supergravity theories. **Prerequisite:** PHYS 634.

PHYS 654 The Standard Model and Beyond

Credits 3. 3 Lecture Hours. The standard model of particle physics in detail; general principles of gauge theories, including spontaneous breaking and applications to Electro-Weak Interactions and Quantum Chromodynamics; extension of the standard model involving Grand Unified Theories (GUT), Supersymmetry (SUSY) and Supergravity (SUGRA). **Prerequisites:** PHYS 624 and PHYS 634.

PHYS 655 String Phenomenology

Credits 3. 3 Lecture Hours. Physical applications of string theory; rudiments of string theory; compactification of extreme dimensions in string theory; free-fermionic formulation; dualities, M-theory, intersection D-Branes, and D-Brane phenomenology; model building. **Prerequisites:** PHYS 634 and PHYS 651.

PHYS 661 Superfluidity and Superconductivity

Credits 3. 3 Lecture Hours. Basic properties of superconductors, superfluid 4He and superfluid 3He; Bose Einstein condensation, BCS theory and Ginzburg-Landau theory; methods of achieving low temperatures, with lab tours. Special topics include broken symmetry, neutron stars, ultra-cold atomic gases and tunneling in superconductors. **Prerequisite:** PHYS 408, PHYS 412, and PHYS 414, or equivalents.

PHYS 666 Scientific Instrument Making

Credits 3. 2 Lecture Hours. 2 Lab Hours. Theory and techniques for designing and constructing advanced scientific instruments such as spectrometers, cryostats, vacuum systems, etc.; mechanical and electronic shop procedures utilizing the lathe and mill; welding and soldering; drafting and print reading; circuit design. **Prerequisite:** Approval of instructor.

PHYS 671 Ultrafast Laser Physics

Credits 3. 3 Lecture Hours. Ultrafast optics; nonlinear optics; laser physics; active and passive mode-locking; pulse characterization and shaping; applications in industry and research such as time-resolved spectroscopy, coherent control, terahertz spectroscopy, and high-order harmonic generation. **Prerequisites:** PHYS 304, PHYS 305, PHYS 221 and PHYS 412, or equivalents.

PHYS 672 Nonlinear Optics

Credits 3. 3 Lecture Hours. Foundation for evolving areas of science and industry; phenomena of nonlinear optics; relevant areas of physics, nonlinear science, and engineering; material requirements; approaches to solving Maxwell's equations in the presence of nonlinear polarization; quantum mechanical descriptions of nonlinear optics phenomena. **Prerequisites:** PHYS 414; PHYS 305; PHYS 221; graduate classification or approval of instructor.

PHYS 673 Laser Physics

Credits 3. 3 Lecture Hours. Absorption and emission of light; optical cavities; molecular spectroscopy; photoelectron spectroscopy; mass spectroscopy. **Prerequisites:** Graduate classification or approval of instructor.

PHYS 674/ECEN 674 Introduction to Quantum Computing

Credits 3. 3 Lecture Hours. Introduces the quantum mechanics, quantum gates, quantum circuits and quantum hardware of potential quantum computers; algorithms, potential uses, complexity classes, and evaluation of coherence of these devices. **Prerequisites:** MATH 304; PHYS 208. **Cross Listing:** ECEN 674/PHYS 674.

PHYS 681 Seminar

Credit 1. 1 Lecture Hour. Subjects of current importance; normally required of all graduate students in physics.

PHYS 684 Professional Internship

Credits 1 to 4. 1 to 4 Other Hours. An experience in a physics-related setting that provides the student with the opportunity for engaged learning through professional involvement and professional supervision. May be taken for credit up to four hours. Must be taken on a satisfactory/unsatisfactory basis. **Prerequisites:** Approval of instructor; graduate classification.

PHYS 685 Directed Studies

Credits 1 to 9. 1 to 9 Other Hours. Individual problems not related to thesis. **Prerequisite:** Approval of instructor.

PHYS 689 Special Topics in...

Credits 1 to 4. 1 to 4 Lecture Hours. 0 to 4 Lab Hours. Selected topics in an identified area of physics. May be repeated for credit. **Prerequisite:** Approval of instructor.

PHYS 691 Research

Credits 1 to 23. 1 to 23 Other Hours. Research toward thesis or dissertation. **Prerequisite:** Baccalaureate degree in physics or equivalent.