

## Descriptions of Courses

### PH211 Mathematical Methods in Physics I

This course is intended to give the necessary mathematical foundations to sophomores for majoring in the physical sciences. Topics include: Vector analysis, Coordinate systems, Tensor analysis, Matrices, infinite series, Functions of a complex variable, Differential equations, Prerequisite calculus.

### PH212 Mathematical Methods in Physics II

This course is intended to give necessary mathematical foundations to sophomores who will major in the physical sciences and engineering. Topics include: Fourier series, Integral transforms, Integral equations, Calculus of variation, Bessel functions, Legendre functions, Special functions.

Topical Prerequisites : Calculus

### PH221 Classical Mechanics I

The aim of this course is to prepare students for advanced mechanics. Newtonian mechanics, Motion of a particle in one, two and three dimensions, Simple harmonic motion and nonlinear oscillation, Gravitation, Central force motion, and Lagrangian and Hamiltonian formalism are the principal subjects to be taught.

### PH222 Classical Mechanics II

The aim of this course is to prepare students for advanced mechanics. Themes such as dynamics of system of particles, motion in a moving reference frame, dynamics of rigid bodies, coupled oscillations, wave mechanics, and special theory of relativity are treated.

### PH231 Electromagnetism I

Principles of electricity and magnetism as well as their applications are taught in this course. Electrostatics, Boundary value problems of electrostatics, Electric current and magnetic field, Electromagnetic induction, and Maxwell's equations are the topics for the study. These basic concepts will be the first step to mathematically formulate the basic knowledge of the phenomenological information learned in General Physics at the freshmen level. Topics include: Electrostatics, Solution of electrostatic problems, Electrostatic field in Dielectric media, Microscopic theory of dielectrics, Electrostatic energy, Electric current, Magnetic field of steady currents, Electromagnetic induction, Maxwell's equations.

Recommended topical prerequisites: Advanced calculus, Vector analysis, Differential equations, Boundary value problems.

### PH232 Electromagnetism II

This course is to help junior level students more fully understand the phenomena of the propagation of electromagnetic fields in free space and inside matter, of the radiation emission by moving charges, and of representations of the electromagnetic field in a moving reference frame at the intermediate level. Topics include: Electromagnetic wave propagation and boundary conditions on the field vectors, Radiation emission, Electrodynamics, Special theory of relativity.

Recommended Topical Prerequisites: Advanced calculus, Vector analysis, Differential equations, Boundary value problems.

### PH241 Modern Physics

This course is to provide students majoring in physics with various basic concepts and subjects of modern physics.

Topics include: Special relativity, Elementary quantum mechanics, Atoms and molecules, Solids and plasma, Atomic radiation, Atomic nuclei, Elementary particles, and the Universe.

Topical Prerequisites: Elementary differential and integral calculus. Elementary classical physics.

### PH243 Introductory Modern Physics

This course is designed to help undergraduate engineering majors understand concepts of modern physics. First, relativity and quantum theory are taught to provide a framework for understanding the physics of atoms and nuclei. The theory of the atom is then discussed with emphasis on quantum mechanical notions. The atomic nuclei and elementary particles will also be examined.

### PH251, PH252 Physics Laboratory I, II

This course provides basic theory and experimentation of analog-digital electronic circuits and devices for physics majors. Analysis and design of electronic circuits, vacuum, high/low temperature devices, high voltage, low signal, noise will be explored.

### PH301 Quantum Mechanics I

This course serves as an introduction to the basic principles of quantum mechanics. Topics include the uncertainty principle, the mathematical basis for quantum mechanics, the properties of operators, problems in 1-D and central field, and orbital angular momentum and spin.

### PH302 Quantum Mechanics II

This course introduces many aspects of real atoms. Topics include: Matrix formalism of Q.M., Addition rules of angular momentum, Time independent and dependent perturbation theory, and Collisions.

Topical Prerequisites: Basic philosophy of quantum physics and eigenstates of the ideal hydrogen atom.

### PH311 Thermal Physics

This course is intended to provide students in physics with the concepts and methods of the thermal properties of systems consisting of many particles.

Topics include: Entropy, temperature, heat, thermodynamic principles, ensembles, ideal gas, and phase equilibrium.

Topical Prerequisites: College level physics, Elementary differential and integral calculus.

### PH312 Statistical Physics

This course is designed to provide senior physics majors the basic physical concepts and methods appropriate for the description of systems involving many particles such as the gas, liquid, solid and plasma states.

Topics include: Statistical Physics, Quantum Statistics, Elementary Kinetic Theory, Transport Theory, and Irreversible Processes.

Topical Prerequisites: Random walk and binomial distribution, Probability distribution and statistical ensemble, Temperature and entropy, Thermodynamics of ideal gases.

### PH351 Physics Laboratory III

This course is intended to teach experimental techniques of modern physics to junior physics majors. Topics include: Fine structure and the one-electron system, Field emission microscope, Measuring the speed of light, the Zeeman effect, Radioactive decay, Electron spin resonance, Compton effect and X-ray fluorescence, Extinction of beta and gamma rays, Frank-Hertz experiment, Interferometer.

Topical Prerequisite: Modern Physics

### PH352 Physics Laboratory IV

This course is intended to teach experimental techniques of modern physics to junior physics majors. Topics include: Atomic spectra of two-electron systems, Millikan experiment, Planck's constant (Photoelectric effect), Electron diffraction, Faraday effect, Kirchhoff's law, Rutherford scattering, Alpha-spectroscopy, Coincidence of events.

Topical Prerequisite: Modern Physics.

### PH361 Solid State Physics I

This course is intended to provide students with basic concepts of solid state physics. Topics include: Crystal structure and symmetry, Crystal binding, Lattice vibration, Electrons states, Energy bands, and semiconducting properties. More advanced topics are covered in the sequel to this course: Solid State Physics II.

Prerequisites: PH301 Quantum Mechanics I.

### PH391 Optics I

This course is designed to give junior and senior physics majors the basic understanding of modern optics, providing them with the ability to study advanced subjects. Topics include: Waves, Propagation of light, Geometric optics, and Polarization.

Topical Prerequisites: Electromagnetism (College Physics Level), Fourier Transformations, Special Functions.

### PH392 Optics II

This course is designed to give junior and senior physics majors the basic understanding of modern optics, providing them with an ability to study advanced subjects in optics and optoelectronics. Topics include: Interference, Diffraction, Fourier optics, Coherence theory, Quantum nature of light, Contemporary optics (Lasers, Holography, and Nonlinear Optics).

Topical Prerequisites: Electromagnetism (College Level Physics), Fourier Transformations, Special Functions.

### PH401 Atomic and Molecular Physics

This course presents in detail the physics of atoms and molecules from a modern view point. It is designed for senior undergraduate students following up on some study of quantum theory. Topics include: many electron atoms and the Hartree Fock approximation, Interaction of many electron atoms with electromagnetic fields, Various atomic phenomena; LS-term, Spin orbit coupling, the Zeeman effect, the Stark effect, the Lamb shift, Radiation damping, Light absorption, Emission and scattering, Photoelectric effect, Electron-atom collision, Atomic spectra, Molecular structure and bonding, including LCAO, Molecular vibration mode, Molecular spectra.

Topical Prerequisites: Elementary quantum mechanics including wave-particle duality, the Schrödinger wave equation, the Harmonic oscillator, the Hydrogen atom, the Angular momentum state, Time independent and dependent perturbation theory, etc.

### PH413 Computational Physics

The main topic of this course is an introduction to the basic methods in computational physics and an overview of the recent progress in scientific computing. Many examples from recent research in physics and related areas including bio-informatics are introduced. Basic computational tools including the random numbers, differential equations, spectral analysis, and matrix operations, are dealt with through relevant examples, and more advanced topics, such as Monte Carlo simulations, molecular dynamics, and parallel computing will also be treated and trained. The purpose of this course is to understand how to utilize this knowledge for research and teaching in physics through studying various practical examples.

Topical Prerequisites: Programming language (any kinds)

### PH421 Chaos & Nonlinear Dynamics

This course is an introductory class on the subject of chaos and nonlinear dynamics in dynamical systems. It is intended to serve both undergraduate and graduate students. It is also intended to serve as an interdisciplinary course.

### PH441 Introduction to Plasma Physics

This course is designed to help students build their ability to understand basic plasma concepts. Topics include discharge processes and application of plasmas, motion of charged particles in electric and magnetic fields, plasmas as fluids (magnetohydrodynamics), diffusion in weakly and fully ionized plasmas, waves in fluid plasmas, and kinetic theory and nonlinear effects.

Topical Prerequisite: Electromagnetism

#### PH450 Nuclear and Elementary Particle Physics

This course serves to introduce the basic concepts of elementary particle physics. Topics includes quarks and leptons as the basic building blocks of matter, phenomenology of the electroweak and strong interactions, the standard model, physics beyond the standard model such as grand unification, super-symmetry and neutrino masses.

Topical Prerequisites: Quantum Mechanics I and II

#### PH451 Special Topics in Experimental Physics

This course introduces learning various experimental techniques and performing basic experiments for research. More than ten professors in experimental physics will participate in this course. Two hours of lecture and three hours of experimental instruction are provided each week. Topics include: Vacuum techniques and surface analysis of thin film, High power laser and power amplification experiments, Semiconducting multilayered laser devices, Fabrication and characterization of magnetic superlattice films, Magnetic resonance and nuclear magnetic resonance measurements, Amorphous semiconducting thin film deposition techniques. Principles and applications of optical fibers, Generation and characterization of plasma, Remote sensing, High power pulsed laser and laser-plasma interactions, Ultrasonics and magnetism, Crystal growth and X-ray diffraction, Raman spectroscopy, and Optical property measurements of semiconductors.

Topical Prerequisites: Completion of 1st, 2nd, and 3rd year experimental physics courses.

#### PH462 Solid State Physics II

This course follows Solid State Physics I, and is intended to introduce students in physics, chemistry, electrical engineering, and materials science to advanced topics in solid state physics. Particular emphasis will be placed on making strong connections between the basic laws of quantum mechanics, electromagnetism, and thermodynamics and solid state phenomena. Topics include: thermal and optical properties of solids, advanced band-structure theory, ferroelectricity, magnetism, superconductivity, surface phenomena, and some applications.

Topical Prerequisites: one dimensional Schrödinger equation, the hydrogen atom, angular momentum operators, Maxwell's equations, Fermi Dirac and Einstein Bose distribution functions.

#### PH471 Theory of Relativity and Cosmology

This course is intended to provide an introduction to general theory of relativity and its application to cosmology. Topics includes special relativity and flat spacetime, gravity as spacetime geometry, black holes and gravitational radiation, Friedmann-Robertson-Walker Universe, physics of early universe such as nucleosynthesis, baryogenesis and inflation.

Prerequisites: Modern Physics

#### PH481 Astrophysics

This course is designed to help students understand the astronomical phenomena in terms of basic physical principles. Topics include the physical properties of interstellar medium, stellar structure and evolution, structure and dynamical evolution of galaxies, and theories of cosmological evolution.

#### PH489 Special Topics in Physics

#### PH490 B.S. Thesis Research

#### PH495 Individual Study

#### PH496 Seminar

Seminars are given by faculty members or outside experts on current research topics. The level of these talks is intended for undergraduate students in physics.

#### PH503 Quantum Mechanics I

This course introduces the mathematical foundation of quantum mechanics to the first year physics graduate students. Topics include: Hilbert space, Measurement theory, Theory of rotation and Angular momentum, Group theory and application to quantum mechanics, Wigner Eckart theorem, Clebsch Gordon coefficients, Stationary perturbation, Time dependent perturbation, Applications to atoms, molecules and solids.

Topical Prerequisites: One year of undergraduate Quantum Mechanics, Mathematical Physics, Mechanics, Electromagnetism.

#### PH504 Quantum Mechanics II

This course is designed to help the first year physics graduate students understand complicated phenomena of scattering and to give an introduction to the second quantization and Dirac equation for future use in solid state physics and particle physics. Topics include: Scattering, Nonrelativistic Second Quantization, Fermion Systems and Boson Systems, Dirac Equation.

Prerequisites: PH503 Quantum Mechanics I.

#### PH505 Advanced Mechanics

This course is intended to provide its formulations as a springboard for the various branches of modern physics, such as action-angle variables, Hamilton-Jacoby theory, principle of least action. Poisson brackets, and canonical transformation.

Topical Prerequisites: Intermediate classical mechanics and electromagnetism, Calculus, Differential equations.

#### PH507 Advanced Electrodynamics I

This course provides graduate students in physics with an understanding of electricity and magnetism. Topics include: Electrostatics, Magnetostatics, Maxwell's equations, Wave propagation, Wave guides, Radiating systems.

#### PH508 Advanced Electrodynamics II

This course gives students the knowledge of electromagnetic theory accessed in the first course to specific problems, such as relativity, plasma physics, scattering, and moving charges. Topics include: MHD and Plasma physics, Relativity, Collisions and scattering, Radiation by moving charges, and Multipole fields.

Prerequisite: PH507

#### PH509 Statistical Mechanics

This course familiarizes graduate students with the concepts and methodologies of statistical mechanics in order for them to be able to utilize skills in the studies of other subjects as well as further research in statistical mechanics. Topics include: Kinetic theory, Ensembles, Classical and quantum statistics, Phase transitions.

#### PH601 Applied Physics Laboratory I

The main objective of the course is to give students laboratory experiences in condensed matter and plasma physics that form a broad background. Each group of two or three students chooses five experimental themes for a semester. After completion of three-week experimental work on each theme, students are required to submit a report for assessment. The course offers a variety of themes on experimental techniques such as vacuum coating, dielectric and magnetic measurements, NMR spectroscopy, X-ray diffraction, low temperature measurements, photoemission and modulation spectroscopy, nonlinear dynamics measurements, ECR plasma generation and Tokamak operation.

#### PH602 Applied Physics Laboratory II

The main objective of the course is to give students laboratory experience regarding experimental optics. Groups of three or four students are assigned to projects chosen from various essential topics in optics. The course offers good practice in Optical workshop, Multiple quantum well modulator, Laser beam quality evaluation, Twyman-Green interferometer, Femtosecond Ti: Sapphire laser, All-fiber ring resonator, White light interferometer, OTF (Optical Transfer Function), VCSEL and SBS phase conjugation.

#### PH611 Advanced Solid State Physics I

This course is intended to provide graduate students in physics, chemistry, electrical engineering, and materials science with a graduate-level understanding of topics in solid state physics. Topics include: Brillouin zone, Crystal symmetry, Phonons, Electron energy band theory, Electron-electron and electron-phonon interactions, Electron dynamics, and Transport properties.

Prerequisites: PH503 and PH504

#### PH612 Advanced Solid State Physics II

This course follows the course Advanced Solid State Physics I, and is intended to provide graduate students in physics, chemistry, electrical engineering, and materials science with a graduate-level understanding of advanced topics in solid state physics. Topics include: Optical properties, Elementary excitations, Electron correlations, Many body effects, Green's functions, Density functional theory, Magnetism, Superconductivity, and Nonlinear phenomena.

Prerequisites: PH503 and PH504.

#### PH613 Semiconductor Physics

This course is designed to provide graduate students in physics, chemistry, electrical engineering, and materials science with an ability to understand the scientific and technological backgrounds of semiconductors and related devices. Topics include: electronic structure and optical properties of semiconducting materials, defects and impurities, electron transport, electron/optical devices and device structures.

Topical Prerequisites: Schrödinger equation and Hamiltonian, crystal structure and lattices, Boltzman and Fermi-Dirac distributions, Bloch theorem.

Prerequisites: PH611 and PH612

#### PH614 Light Scattering Spectroscopy

This course is designed to give students in Physics, Chemistry, and Chemical Engineering a guide to the current status of light scattering research activities in science and engineering applications. Topics include: Scattering cross sections, Rayleigh, Brillouin and Raman Scattering, Instrumentation, Raman spectroscopy and Molecular structure, Raman scattering from phonons, plasmons and magnons.

Topical Prerequisites: Quantum mechanics of time dependent perturbation theory, Statistical physics of fluctuations, Correlation functions and phase transitions, Classical electrodynamics of radiation.

#### PH615 Introduction to Phase Transition

This course introduces both classical theories of phase transition and modern theories of critical phenomena so that students can read most experimental and theoretical papers in the field. It will cover experimental examples of Phase transition, Phase transition anomalies and critical exponents, Landau's classical theory, Critical phenomena and fluctuations, Scaling law and universality, Renormalization group theory, Experimental measurements, Random systems, and Impurity effects.

Topical Prerequisites: Thermodynamics, Statistical Physics

#### PH621 Advanced Wave Optics

This course is designed to convey basic and advanced ideas concerning wave optics including Interference and diffraction theory, Temporal and spatial coherence, Fourier optics, Statistical optics, and the Theory of image

formation. Application of electromagnetic theory on thin film technology, Laser oscillator and crystal optics are also dealt with.

Recommended Prerequisites: PH391 and PH392 (Optics I, II)

#### PH622 Geometrical Optics

This course is designed to teach general concepts on Gaussian optics, Seidel first order aberration theory, and optical design method. Methods of optical testing are also reviewed.

Recommended Topical Prerequisites: Introductory of optics, Introductory on wave optics.

#### PH624 Laser and Quantum Optics

Laser resonator, Laser rate equations, Q-switching, Mode-locking, and Laser amplifiers are covered. Various electro-optic modulators, Laser optic components, Laser applications are also discussed. Introductory quantum optics is treated.

Recommended Topical Prerequisites: Electromagnetic theory, Optics, and Quantum mechanics.

#### PH625 Advanced Spectroscopy

This course is designed to examine basics and advanced ideas on using lasers for high resolution spectroscopy of atoms and molecules. Topics include: Absorption and emission of light by atoms and molecules, Transition probability and line profiles, Classical spectroscopic technique, Doppler-limited absorption and fluorescence spectroscopy, laser Raman spectroscopy, High resolution sub-Doppler Laser spectroscopy, Time resolved spectroscopy.

Recommended Topical Prerequisites: Introduction to laser physics, Quantum Mechanics, Optics

#### PH627 Fiber Optics

This course is designed to provide basic and advanced knowledge of Optical waveguides, Device physics, and Application of optical fibers and Components to telecommunications and sensors. Topics include: Propagation mode in fibers, Basic components, Interferometry, Fiber-optic sensors, Non-linear optics in fibers, Fiber lasers and amplifiers.

Recommended Topical Prerequisites: Electromagnetism, Special Functions, Optics (College Level).

#### PH641 Advanced Plasma Physics

Basic knowledge of plasma kinetic theory, electron and ion fluid equations, and MHD equations will be covered. The Fokker-Planck equation will be derived and the properties of the Vlasov equation and Coulomb collision operator will be studied. Fluid and MHD equations will be derived from the Fokker-Planck equation (and the Maxwell's equations). The MHD property, drift-kinetic equation, gyrokinetic equation, and the quasi-linear RF heating operator will be introduced.

#### PH642 Plasma Waves

Various plasma waves will be studied in detail. MHD waves, fluid waves, and kinetic waves will be compared in unmagnetized and magnetized plasmas. Linear and non-linear Landau damping physics will be studied, together with the Nyquist's method and Gardener's theorem. Drift waves, eta-i mode, trapped particle mode and other waves of current interest will be discussed.

#### PH643 Applied Plasma Physics

This course is intended for graduate students in Physics and other Engineering Departments. This course will start with six chapters of background information on plasma science relevant to industrial plasmas, followed by three chapters on ion, electron, and plasma sources which are common to many industrial applications. We will cover chapters on plasma processing of materials, and on plasma related applications and devices of industrial interest.

#### PH653 Advanced Quantum Mechanics I (Quantum Field Theory I)

This course is designed to introduce quantum theory of fields and its application to particle and condensed matter physics. Topics includes Path integral quantization, Symmetry and symmetry breaking, Collective phenomena and Condensed matter physics in field theory.

#### PH654 Advanced Quantum Mechanics II (Quantum Field Theory II)

This course is designed to introduce the relativistic theory of quantized fields and its application to the high energy physics of elementary particles. Topics include the Theory of quantized gauge fields, Renormalization and renormalization groups, Effective quantum field theory, Supersymmetric field theory.

#### PH692 Nonlinear Dynamics

This course is intended to introduce the basic principles and concept of nonlinear phenomena and dynamics. Topics include 1-dim. map, Periodic doubling, Poincare map, Strange attractor, Lorenz attractor, Soliton turbulence.

#### PH711 Physics of Magnetism

This course introduces from the physics of macroscopic magnetic properties of magnetic materials to the spintronics that handles individual spins quantum mechanically. Topics include the Origin of magnetism, Magnetic domain, Magnetic anisotropy, Magnetoresistance and spin tunneling.

#### PH713 Physics of Superconductivity

Lectures will be given on the physical theories and applications of superconducting phenomena. The BCS theory, Ginsberg-Landau theory, Vortex theory in type II semiconductors, and the Theory of Josephson tunneling will be discussed. The physical principles and fabrication methods of superconducting electronic devices will also be discussed. Recent developments in the field of high-T<sub>c</sub> superconductors and their technological applications will also be included.

#### PH716 Topics in Solid State Physics I

Recent developments in the fields of magnetism, metals, superconductivity, and ferroelectricity will be selected to be introduced at a graduate level. Up to 15 course credits may be obtained by taking the course repetitively on different topics.

#### PH717 Topics in Solid State Physics II

Recent developments in the fields of semiconductors, low-dimensional quantum structures, crystal structure, crystal growth, surface/interface phenomena, and theoretical solid state physics such as many-body theory and group theory will be selected to be introduced at a graduate level. Up to 15 course credits may be obtained by taking the course repetitively on different topics.

#### PH721 Nonlinear Optics

Light-matter interactions, especially nonlinear optical interactions and their applications are discussed. Nonlinear susceptibility, Harmonic generation, Four-wave mixing, Raman scattering, Nonlinear propagation of light, Coherence theory and Nonclassical light are topics of interest in this course.

#### PH724 Laser Plasma Interactions

This course is intended to introduce physics graduate students to current research topics in laser-plasma interactions and provide them with concepts and methods to understand the physical processes in high power laser produced plasma. Topics include: Inertial confinement fusion, EM wave propagation in plasmas, Absorption of laser light, Atomic Physics in high-density plasmas, X-ray lasers, High harmonic generation.



Recommended Prerequisites by topic: Advanced Electrodynamics and Introduction to Plasma Physics

#### PH726 Semiconductor Optics

This course introduces optical processes occurring at semiconductor band edges, and their applications to various opto-electronic devices. Topics include: Band edge absorption, Non-linear absorption, Semiconductor quantum wells/dots, Semiconductor lasers, Photonic crystals and Photonic devices.

Prerequisite: Solid State Physics and Quantum Mechanics.

#### PH741 Topics in Plasma Physics

A detailed study of one or more selected aspects of plasma physics is intended in this course. Topics may include plasma diagnostics, space plasma physics, and computational plasma physics. Up to 15 course credits may be obtained by taking the course repetitively on different topics.

#### PH742 Plasma Confinement Theory

This course covers problems associated with magnetic confinement in fusion devices. Topics to be discussed include Kinetic equations, Collision operators, Toroidal currents, Transport theories, Alpha particle behavior, and Cauchy's linear phenomena.

#### PH754 Advanced Particle Physics

This course is intended to deal with the research-related topics in particle physics and the exact course content may vary from year to year. However, the main topics include the Standard model and related particle phenomenology, Physics beyond the standard model, String theory and compactification, Nonperturbative aspects of quantum field theory.

#### PH757 Topics in Particle Physics

This course is intended to introduce the most recent research topics in particle physics. Some of the recent topics include String duality, Supersymmetry breaking and the Phenomenology of superparticles, Extra dimension, flavor and CP violations, Flux compactification in string theory.

#### PH880 Topics in Physics

This course is intended to introduce the recent research topics in physics.

#### PH960 M.S. Thesis

#### PH965 Independent Study in M.S.

#### PH966 M.S. Seminar

#### PH980 Ph.D. Thesis

#### PH986 Ph.D. Seminar

#### PH990 Physics Colloquium

Colloquia are given by faculty members or outside experts on current research topics. The level of these talks is intended for graduate students in physics.