### COURSE CODE | TITLE | CREDIT HOURS
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**COMPULSORY COURSES FOR PHD**
PHY-811 | ELECTROMAGNETIC THEORY II | 3
PHY-812 | STATISTICAL MECHANICS | 3
PHY-813 | ADVANCED QUANTUM MECHANICS II | 3

**Optional/Additional/Specialization Courses**
PHY-814 | COMPUTATIONAL PHYSICS II | 3
PHY-815 | ADVANCED SOLID STATE PHYSICS II | 3
PHY-816 | RELATIVISTIC QUANTUM MECHANICS | 3
PHY-817 | MICROWAVE COMMUNICATIONS | 3
PHY-818 | MAGNETIC MATERIALS AND MAGNETIC PROPERTIES | 3
PHY-819 | MAGNETIC RESONANCE IMAGING | 3
PHY-820 | OPTICAL COMMUNICATIONS | 3
PHY-821 | DIGITAL IMAGE PROCESSING II | 3
PHY-822 | MONTE CARLO SIMULATION | 3
PHY-823 | MODERN OPTICS AND LASER PHYSICS | 3
PHY-824 | TECHNIQUES IN EXPERIMENTAL SOLID STATE PHYSICS | 3
PHY-825 | SATELLITE IMAGE PROCESSING | 3
PHY-826 | FABRICATION OF ELECTROCERAMICS AND THEIR PROPERTY MEASUREMENT TECHNIQUES | 3
PHY-827 | ION’S SPUTTERING | 3
PHY-828 | SATELLITE ORBIT DETERMINATION AND SIMULATION | 3
PHY-829 | ADVANCED COURSE IN RELATIVITY | 3
PHY-830 | ELECTRON MICROSCOPY II | 3
PHY-831 | PLASMA PHYSICS II | 3
PHY-832 | EXPERIMENTAL PLASMA PHYSICS | 3
PHY-833 | BONDING, CRYSTALLOGRAPHY & CRYSTAL DEFECTS | 3
PHY-834 | NUCLEAR WASTE MANAGEMENT | 3
PHY-835 | MATERIALS SCIENCE-II | 3
PHY-836 | QUANTUM FIELD THEORY-II | 3
PHY-837 | TRANSMISSION TECHNIQUES-II | 3
PHY-838 | LASER PHYSICS-II | 3
PHY-839 | NONLINEAR PHYSICS | 3
PHY-840 | MODELLING AND COMPUTATION IN FLUID MECHANICS | 3
PHY-841 | SURFACE FORCES AND INTERMOLECULAR INTERACTIONS II | 3
PhD Course Contents

PHY-811 ELECTROMAGNETIC THEORY-II

Plane Waves in a non-conducting medium; linear and circular polarization; Reflection and Refraction of electromagnetic waves in dielectrics; Total internal reflection; Frequency dispersion in dielectrics, conductors, and plasma; Propagation in ionosphere and magnetosphere; Superposition of waves in one dimension (group velocity); causality in the connection between D and E;

Fields at the surface and inside conductors; Wave guides; Modes in a rectangular waveguides; Energy Flow and attenuation in waveguides; Resonant cavities; Q of a cavity; Earth and ionosphere as resonant cavity; Multimode propagation in optical fibers; Modes in dielectric wave guides.

Fields and radiation of a localized oscillating source; Electric dipoles fields and radiation; Magnetic dipole and electric quadrupole fields; Multipole expansion for localized source; Multipole expansion of the electromagnetic fields; Energy and angular momentum of multipole radiations; Sources of multipole radiation; Multipole radiation from a linear antenna.

Scattering of electromagnetic waves at long wave length; Perturbation theory of scattering; Explanation of blue sky; scattering by a sphere; scalar and vector diffraction theory; Babinet's Principle; optical theorem.

The situation before 1900, Einstein two postulates; some recent experiments; Lorentz transformation and basic kinematic results; addition of velocities, 4-velocity; Relativistic momentum and energy of a particle; Mathematical properties of the space time; Matrix representation of Lorentz transformation; Invariance of electric charge; Transformation of electromagnetic fields; notes on notations and units in relativistic kinematics.

Recommended Books


PHY-812 STATISTICAL MECHANICS


Quantum statistical mechanics, Quantum model of matter, Canonical distribution in quantum statistics, The quantum oscillator, Planck’s formula for the equilibrium radiation of a perfectly black body, Heat capacity of solids, Heat capacity of a diatomic ideal gas, Quantum statistics of a system of similar particles, Bose-Einstein and Fermi-Dirac statistics, Application of Bose-Einstein statistics to the photon gas, Application of Fermi-Dirac statistics to the electron gas in metal, Condensation of an ideal Bose-Einstein gas.

Recommended Books

PHY-813 ADVANCED QUANTUM MECHANICS

Pre-requisites, Advanced Quantum Mechanics I

Course contents: Molecular structure, Born-Oppenheimer approximation, H\textsuperscript{+2} ion, H\textsubscript{2} molecule, ionic and covalent bonding, solids, molecular spectra, rotation and vibrational transitions, Field theory, from phonons to photons, from particles to fields, classical field theory of harmonic atomic chain, quantization of atomic chain, phonons. Classical theory of the EM field, waveguide, quantization of the EM field and photons. Time-dependent perturbation theory, Rabi oscillations in two level systems, perturbation series, harmonic perturbations and Fermi’s Golden rule, Radiative transitions, Light-matter interaction, spontaneous emission, absorption and stimulated emission, Einstein’s A and B coefficients, dipole approximation, selection rules, lasers. Scattering theory, Elastic and inelastic scattering, Born approximation, scattering of identical particles, Relativistic quantum mechanics, Klein-Gordon equation, Dirac equation, relativistic covariance and spin, free relativistic particles and the Klein paradox, coupling to EM field, minimal coupling and the connection to non-relativistic quantum mechanics, field quantization.

Reference Books


PHY-814 COMPUTATIONAL PHYSICS-II


Recommended Books


PHY-815 ADVANCED SOLID STATE PHYSICS-II

Surface effects, Classification of solids, Cohesive energy, Failure of the static lattice model, Classical theory of the Harmonic crystals, Quantum theory of the Harmonic crystals, Measuring the phonon dispersion relations, Anharmonic effects in crystals, Phonons in metals, Dielectric properties of insulators, Homogeneous
semiconductors, Inhomogeneous semiconductors, Defects in crystals, Diamagnetism and paramagnetism, Electron interactions and magnetic structures, Magnetic ordering, Superconductivity.

**Recommended Books**


**PHY-816 RELATIVISTIC QUANTUM MECHANICS**

Relativistic quantum mechanics of spin ½ particles, Probability conservation in relativistic quantum mechanics, The Dirac equation, Simple solutions, Non-relativistic approximations, Plane waves, Covariant perturbation theory, Natural units and dimensions, S-matrix expansion in the interaction representation, First order processes, Mott scattering and hyperon decay, Two photon annihilation and Compton scattering, The electron propagator, Mass and charge renormalization, Radiative corrections, Green’s function and field theory (Fermions), Pictures, Green’s Functions, Wick’s theorem, Diagrammatic analysis of perturbation theory, Fermi systems, Hartree-Fock approximation, Imperfect Fermi gas, Degenerate electron gas, Linear response and collective modes, General theory of linear response to an external perturbation, Bose systems, Perturbation theory and Feynman rules, Weakly interacting Bose gas, Finite Temperature formalism, Field theory at finite temperature, Physical systems at finite temperature, Imperfect Bose gas near Tc, Specific heat of an imperfect Fermi gas at low temperature, Electron gas, Real time Green’s function and linear response.

**Recommended Books**


**PHY-817 MICROWAVE COMMUNICATIONS**

Microwave spectrum, Microwave applications, Elementary fields and waves, Maxwell’s equations and boundary conditions, Wave propagation in perfect insulators, Transmission line theory, The impedance transformation. The smith chart, Impedance matching and tow port network analysis, Microwave transmission line, The open two wires line, The coaxial line, Rectangular and circular wave-guides, Coaxial and strip line components, TEM to TEM transmissions, Attenuators and phase shifters, Wave-guide components, Reciprocal multiport junctions, Microwave resonators and filters, Narrowband and wideband microwave filters.

**Recommended Books**


**PHY-818 MAGNETIC MATERIALS AND MAGNETIC PROPERTIES**

Origins of magnetic moments, Basic concepts and magnetic properties (Magnetic poles, Permeability, Retentivity, Hysteresis and its causes, Saturation magnetization, Remanence, Coercivity, Differential permeability, Curie temperature).

Classification of materials on the basis of magnetic properties, Classification of soft and hard magnetic materials, Instances of magnetic materials.
Diamagnetism, Ionic and Covalent materials, Metals, Paramagnetism, Classical theory, Quantum theory, Temperature and field dependence of paramagnetic susceptibility, Pauli Paramagnetism, Paramagnetic cooling.

Physical significance, exchange integral, exchange energy, variation in heat capacity, $B - H$ curves, Band structures, Applications of ferromagnetic materials (Electromagnets, Transformers, Electromagnetic relays, magnetic recording, permanent magnets, Inductance cores, Ceramic magnets, etc).

Magnetic domains, domain walls and their properties, Bubble domains, Block walls, Properties of domain boundaries (exchange energy, anisotropy energy, width), $180^\circ$ and non-$180^\circ$ domain walls and the effects of stress on them. Antiferromagnetism and Molecular Field Theory, Néel temperature, Ferrimagnetism and Molecular Field Theory.

**Recommended Books**


**PHY-819 MAGNETIC RESONANCE IMAGING**

**PHY-820 OPTICAL COMMUNICATIONS**

Band pass for Wavelength Division Multiplexing (WDM) systems, Edge filter for rejection of pump radiation from an Erbium doped fiber amplifier, Gain equalization coatings for an Erbium doped fiber amplifier that functions in the reflective mode, Gain equalization coatings for an Erbium doped fiber amplifier that functions in transmissive mode, Realities in Mirages, Identification of distant objects by the use of optical images, Effect of non-homogeneous medium on images of distant objects, viewed through optical telescope, Sodha theory of rays tracing in a medium with a refractive index, Optical ray propagation under arctic mirages conditions and Sodha model, Dynamic holography and phase conjugation in photo refractive crystals, Optical fiber sensors, Non-linear dynamics of beams of various spatial profiles and polarization.

**Recommended Books**


**PHY-821 DIGITAL IMAGE PROCESSING-II**

Image enhancement and restoration, Image enhancement, Image restoration models, Algebraic spatial image restoration techniques, Specialized spatial image restoration techniques, Luminance, Colours and spectral image restoration, Image analysis, Image feature extraction, Symbolic image description, Image detection and registration, Image understanding systems, Image coding, Analog processing image coding, Digital point processing image coding, Digital spatial processing image coding, Image coding performance analysis.

**Recommended Books**

PHY-822 MONTE CARLO SIMULATION

Monte-Carlo, Random number generation, Monte-Carlo integration, Monte-Carlo simulation method and its application introduction, Monte-Carlo methods modeling and simulation of surface chemical reactions, Elementary steps in surface chemical reaction process outlook of some specific reaction models, Monte-Carlo simulation of catalytic reactions.

Recommended Books


PHY-823 MODERN OPTICS AND LASER PHYSICS

Realities in mirages, Maximum and minimum in the range of observations and height of objects, Maximum range for vertical objects, Maximum range for looming, Photo refractive two beam and related phenomena, Coupled wave formulations of DTWM and DFWM, Reflective optic fiber sensor, Non-linear propagation of two degenerate transverse modes of a laser beam, Non-linear dynamics of polarized laser beam, Moment theory of self focusing.

Recommended Books


PHY-824 TECHNIQUES IN EXPERIMENTAL SOLID STATE PHYSICS

PHY-825 SATELLITE IMAGE PROCESSING

PHY-826 FABRICATION OF ELECTROCERAMICS AND THEIR PROPERTY

MEASUREMENT TECHNIQUES (Practical)

Synthesis and evaluation of electroceramic compositions, electrical characterization techniques, dielectric spectroscopy and its frequency dependence, piezoelectric properties (d33, d31, d3 and g33 coefficients) of available electroceramic samples, measurement of electromechanical properties of ferroelectrics (resonant and ultrasound methods, Hysteresis loop testing etc.). Ultrasonic measurement, the velocity of ultrasonic wave in solid state, the pulse echo method, the determination of elastic constants.

Recommended Books

PHY-827 ION’S SPUTTERING

PHY-828 SATELLITE ORBIT DETERMINATION AND SIMULATION

Fundamentals, Equations of motion, Two body problem, Astrodynamics, Coordinate systems, Analytics of the two body problem, Determination of an orbit from two position vectors and time, Determination of an orbit from angles only, Mixed data determinations, Differential correction orbits, Secular perturbations.

Recommended Books


PHY-829 ADVANCED COURSE IN RELATIVITY

Geometrical foundation for space time theories, Geometrical structures, Affine geometry, Metrical geometry, Structure of space time theories, Absolute space time theories, Newtonian mechanics, Special relativity, Relativistic particle dynamics, Relativistic continuum mechanics, Microscopic theory, Relativistic continuum mechanics, Macroscopic theory, Dynamical space time theories, Foundations of general relativity, Solutions of Einstein equations, Experimental tests for general relativity, Further consequences of general relativity, Cosmology.

Recommended Books


PHY-830 ELECTRON MICROSCOPY II

Practical standard sample preparation procedures and use of scanning and transmission electron microscopes. Training in initial alignment of the instrument, sample insertion, imaging and interpretation of results, Technical/scientific report based on phase and microstructural analysis of samples investigated. Atomic lattice fringe image recording (when possible) and spectra using Energy-dispersive X-ray spectroscopy in SEM & TEM.

Recommended Books

PHY-831  PLASMA PHYSICS-II


Recommended books


PHY-832  EXPERIMENTAL PLASMA PHYSICS


Recommended books


PHY-833  BONDING, CRYSTALLOGRAPHY & CRYSTAL DEFECTS

Descriptors, symmetry, bonding, coordination number, packing fraction, order-disorder, structural roadmap

Short-range order, glass transition, pair-distribution function, hard-sphere models, random-walk models, network models, fractal models
Rotation, reflection, inversion, roto-inversion, glide, screw, lattices, unit cells, point groups, Laue groups, space groups, Miller indices, zone axes, the International tables, relation of symmetry to properties, packing, quasi-crystals

Vacancies, interstitials, mobility of point defects, solid solutions, dislocations, dislocation motion, declinations, stacking faults, APBs, grain boundaries, domain walls

Structural hierarchies, deformation microstructures, crystallographic texture, pole figures, transformation microstructures, case studies, MSE 305 Bonding, Crystallography and Crystal Defects.

**Recommended Books**


**PHY-834 NUCLEAR WASTE MANAGEMENT**

Radioactive waste, recycling, waste minimization and immobilization, nuclear decay law, contaminants and hazard, heavy metal contaminations, naturally occurring radioactive materials, and background radiation

Nuclear waste regulations, principles of nuclear waste management, sources of nuclear waste, short-lived waste radio-nuclides, long-lived waste radio-nuclides

Basic management approaches and characterization of radioactive waste, pretreatment of radioactive wastes, treatment of liquid radioactive wastes, treatment of solid wastes

Hydraulic cement in waste immobilization, cementation technology, immobilization of radioactive waste in bitumen, glasses for radioactive waste immobilization, vitrification technology, ceramic and metallic matrices, nuclear waste transportation and storage, nuclear waste disposal, performance assessment.

**Recommended Books**


**PHY-835 MATERIALS SCIENCE-II**


**Recommended Books**


PHY-836 QUANTUM FIELD THEORY-II


Recommended Books:


PHY-837 TRANSMISSION TECHNIQUES-II


Recommended Books:


PHY-838 LASER PHYSICS-II


Recommended Books


PHY-839 NONLINEAR PHYSICS

Basic Equations and Methods, terminology and classification of interactions, multiples time scale perturbation analysis of the Van Der Pol equations, derivation of the Kortewege-de Vries (KdV) equation for nonlinear ion sound waves, solution of the KdV equation, examples and general properties of the solution, nonlinear theory of ion sound waves with the collision less dissipation, one dimensional Cold Plasma Model, exact solution in
Lagrangian variables, Large amplitude oscillations at the upper hybrid frequency, modification due to collisional drag, modification due to finite electron temperature, collision less damping of electron plasma oscillation, review of linear theory, breakdown of linearization effects of particles trapping on the damping of a monochromatic wave, localized electric field disturbances, wave-wave coupling in microscopic plasma models, wave-wave coupling in Vlasov plasma models, nonlinear theory of resonant three wave coupling.

**Recommended Books**


**PHY-840**  
**MODELLING AND COMPUTATION IN FLUID MECHANICS**


Two dimensional motions of a body through a fluid, ballistics of a spherical projectile, initial-value problems , in viscous fluid flows: Incompressible potential flows, numerical solution of second order ordinary differential equations: Boundary value problems, Von K’am’an’s method for approximating flow past bodies of revolution, viscous fluid flows: governing equations for viscous flows, self-similar Laminar boundary-Layer flows, Numerical solutions of the incompressible Navier-Stokes Equation, Flow around a rotating sphere at finite Reynolds numbers, convective and absolute instabilities, flow around a rotating cylinder.

**Recommended Books**


**PHY-841**  
**SURFACE FORCES AND INTERMOLECULAR INTERACTIONS II**

Surface and Interfacial Energy, Unlike surfaces in a third medium, Particle – surface interactions, Adsorbed surface Films, Wetting and Non Wetting.

Interaction potentials between macroscopic bodies, Effective interaction area, the Langbein approximation, Derjaguin Approximation, measurements of surface and intermolecular forces.

Bodies of different geometries (The Hamaker Constant), Vander Waals forces between macroscopic bodies in air, Lifshitz continuum theory of Van der Waals forces, Surface and Adhesion energies, Retardation effects, Surface energies of metals.

The charging of surfaces in liquids: the double layer effect, The Poisson-Boltzmann equation, Counter ions concentration profile, The pressure between two surfaces in water: the contact value theorem, Charged surfaces in electrolyte solution, The DLVO theory (the double layer and Van der Waals forces).

Non DLVO forces, Origin and properties of solvation forces, Repulsive Hydration forces, solvation forces in liquids,
Forces in polymer liquids, Adhesion and surface energies of clusters, contact angle, Hysteresis in contact angle and adhesion measurements. Adhesion forces between solid particles.

BOOKS:

1. Intermolecular and Surface forces; Jacob N. Israelashvili, 3rd edition, Elsiviour, New York, 2011.