List of Ph.D. Course work subjects that can be offered under Physics Group from 2024

Group I		Group II		Group III		Group IV	
Subject Code	Name of the subject	Subject Code	Name of the subject	Subject Code	Name of the subject	Subject Code	Name of the subject
PHPHY101	NANOSCIENCE AND TECHNOLOGY	PHPHY201	QUANTUM MECHANICS	PHPHY301	SOLID STATE PHYSICS	PHPHY401	GLASSES AND CERAMICS
PHPHY102	MATHEMATICAL PHYSICS	PHPHY202	ATOMIC AND MOLECULAR PHYSICS	PHPHY302	ELECTRONICS	PHPHY402	COMPOSITE MATERIALS
PHPHY103	ATMOSPHERIC SCIENCE	PHPHY203	NUCLEAR PHYSICS	PHPHY303	OPTICAL FIBER COMMUNICATION	PHPHY403	ENERGY PHYSICS
PHPHY104	GROWTH AND CHARACTERIZATION OF THIN FILMS	PHPHY204	ELECTRODYNAMICS	PHPHY304	LASER PHYSICS	PHPHY404	MATERIALS SCIENCE
PHPHY105	RADIATION PHYSICS					PHPHY405	BIOPHYSICS

Group-I

PHPHY101: NANOSCIENCE AND TECHNOLOGY

Introduction: Origin of Nanotechnology, Nano materials, Types of nanomaterials, Surface area to volume ration, Quantum confinement effect, band theory of nanomaterials. Physical and chemical properties of nanomaterials. **Synthesis of nanomaterials:** Bottom-up approach and Top-down approach with examples. Physical methods: Inert gas condensation, Arc Discharge, RF-plasma, plasma arc technique, electric explosion of wires, lasers ablation, laser pyrolysis, ball milling, molecular beam epitaxial, electro deposition. Sol-gel technique, Combustion synthesis, ultrasonic precipitation process, chemical vapour deposition.

Characterization of Nanomaterials: Structural characterization techniques: X-Ray Photoelectron Spectroscopy (XPS), X-Ray topography, Energy Dispersive X-Ray Analysis (EDAX), Principles and applications of X-Ray Diffraction: Small angle X-Ray Diffraction and Wide angle X-Ray Diffraction; Electron Diffraction, Electro probe microanalysis (EPMA), Ion beam techniques: RBS. **Surface characterization Techniques:** Scanning electron microscopy (SEM), Transmission electron microscopy, Basic principles and applications of scanning probe techniques (SPM), Atomic force microscopy, and scanning tunneling microscopy. Spectroscopic techniques: UV-Visible spectroscopy, Infrared (IR) & Fourier Transform infrared (FTIR) Spectroscopy, Raman Spectroscopy techniques: Photo luminescence Spectroscopy. **Electrical characterization Techniques:** Hall Measurement, capacitance, and voltage measurements, I-V analysis. Magnetic & Dielectric Characterization: SQUID, Dielectric measurements, impedance and ferroelectric measurements.

Carbon nanostructures: Allotropes of Carbon, Graphene, Properties of Graphene, Applications of graphene, Fullerenes, Fullerene synthesis and purification, Properties of fullerenes. Carbon nanotubes, Structure, Types of Carbon nanotubes, Synthesis of Carbon nanotubes, Purification of Carbon nanotubes, Properties of Carbon nanotubes, Applications of Carbon nanotubes. **Inorganic nanostructures:** Overview of relevant semiconductor physics - Quantum confinement in semiconductor nanostructures - The electronic density of states - Fabrication techniques - Physical processes in semiconductor nanostructures - The characterisation of semiconductor nanostructures, Applications of semiconductor nanostructures.

Nanotechnology and Society Introduction to Societal Implications of Nanoscience and Nanotechnology, Nanotechnology Goals: Knowledge and scientific understanding of nature, Industrial manufacturing, materials and products, Medicine and the human body, Sustainability, Agriculture, water, energy, materials and clean environment, Space exploration, National security, Moving into the market.

REFERENCE BOOKS:

[1] Nano: The Essentials: Understanding Nanoscience and Nanotecnology, T. Pradeep, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2008.
[2] Nanoscale Science and Technology, Robert W. Kelsall, Ian W. Hamley and Mark Geoghegan, John Wiley & Sons, Ltd., UK, 2005.
[3] Introduction to Nanotechnology, Charles P. Poole Jr and Frank J. Owens, Wiley Interscience, 2003. 4. Principles of Nanotechnology by Phani kumar (Scitech Publications, Chennai).
[4] Nanotechnology by Schmid etal (Spriger International edition).
[5] Nanomaterials by A.K.Bandhyopadhyay (New Age International Pub. New Delhi).
[6] Fundementals of Nanoelectronics by George W. Hanson (Perason education, NewDelhi).
[7] MEMS & Microsystems: Design & Manufacture by Tai-Ran Hsu, (Tata McgrwHill, NDelhi).
[8] Concept Document "Nanoscience & Technology Initiative" of DST, GOI, New Delhi, 2002.
[9] Winner, Langdon, "Societal Implications of Nanotechnology", Testimony to - on science of the US House of Representatives, 2003.

PHPHY 102: MATHEMATICAL PHYSICS

Differential equations Ordinary differential equations: First order homogeneous and non-homogeneous equations with variable coefficients. Second order homogeneous and non-homogeneous equations with constant and variable coefficients. Partial differential equations: Classifications, systems of surfaces and characteristics, examples of hyperbolic, parabola and elliptic equations, method of direct integration, method of separation of variables.

Special differential equations Power series method for ordinary differential equations, Legendre's differential equation: Legendre polynomials and their properties, Generating functions, Recurrence Formulae, orthogonality of Legendre's polynomial. Bessel's differential equation: Bessel's polynomial - generating functions, Recurrence Formulae, orthogonal properties of Bessel's polynomials. Laguerre's equation, its solution and properties. Hermite differential equation: Hermite polynomials, generating functions, recurrence relation.

Laplace transforms Laplace transforms: Linearity property, first and second translation property of LT, Derivatives of Laplace transforms, Laplace transform of integrals, Initial and Final value theorems, Transform of Dirac delta function, periodic function and derivatives. Methods for finding LT: direct and series expansion method, Method of differential equation. Inverse Laplace transforms: Linearity property, first and second translation property, Convolution property, Solution of linear differential equations with constant coefficients. Physical applications.

Fourier series and integrals Fourier series definition and expansion of a function, Fourier's theorem. Cosine and sine series. Change of interval. Complex form of Fourier series. Fourier integral. Extension to many variables. Fourier transform. Transform of impulse function. Constant unit step function and periodic function. Some physical applications.

REFERENCE BOOKS:

[1] Mathematical Physics by P K Chattopadhyay, Wiley Eastern Ltd., Mumbai.
[2] Mathematical Physics, B D Gupta, 3rd Edition, Vikas Publishing House Pvt. Ltd., 2006.
[3] Mathematical Physics by Satya Prakash, S Chand and Sons, New Delhi.
[4] Introduction to Mathematical Physics by C Harper, PHI.
[5] Mathematical Physics, B S Rajput, 17th Edition, Pragati Prakasam, 2004.
[6] Advanced Engineering mathematics, Erwin Kreyszig, 7th Edition, Wiley Eastern Limited Publications, 1993.
[7] Mathematical Methods for Physics, G Arfken, 4th edition, 1992.
[8] Special Function, W W Bell, 1996.

PHPHY103: ATMOSPHERIC SCIENCE

Introduction to the atmosphere: Evolution of the atmosphere, hypothesis, theory and scientific methods involved in the atmosphere, observation of the atmosphere, different spheres of the atmosphere, composition of the atmosphere, ozone depletion, extent of the atmosphere, thermal structure of the atmosphere, troposphere, stratosphere, mesosphere, thermosphere, ionosphere, vertical variations in composition, temperature variation in the boundary layer and free atmosphere, water vapour in the air, static stability, change of pressure with altitude, weather and climate, annual mean conditions, dependence on time of the day, seasonal dependence and variability.

Atmospheric interactions: Earth-Sun relationships, earth's motion and orientation, different seasons, solstices and equinoxes, energy heat transfer, form of energy, temperature, heat, mechanisms of heat transfer, conduction, convection, radiation, reflection and scattering, absorption by earth's surface and atmosphere, radiation emitted by the earth's surface, heating the atmosphere, greenhouse effect, role of clouds in heating earth, heat budget, latitudinal heat balance, Models of the atmosphere, constant density model, isothermal model, polytropic model, US standard atmosphere, atmospheric reduced height, geometry of atmospherics scattering, particles in the atmosphere, dust particles, hygroscopic particles, aerosols and size distribution.

Atmospheric observations: Importance of meteorological observations, measurements of temperature, mechanical and electrical thermometers, wet and dry bulb thermometers, maximum and minimum thermometers, cycles of air temperature, importance of temperature measurement in the atmosphere, absolute and relative humidity, hygrometers, movement of water through the atmosphere.

Atmospheric observations (Continued): Dew point temperature, atmospheric stability and daily weather, pressurebarometer, wind-anemometers, horizontal and vertical distribution of pressure, surface winds, rainfall rate-rain gauges, formation and classification of clouds, types of fog, precipitation and its forms, air borne instruments-Radiosonde, Rawinsonde, Rocketsonde, Ozonesonde, Pyroheliometer, Pyregeometer, weather radar, space borne instruments, Radar applications.

REFERENCE BOOKS:

[1] Atmospheric Science by John M. Wallace and Peter V. Hobbs, Academic Press, Elsevier, 2006.
[2] Atmospheric Physics: J.V. Iribrine and H.R. Cho, D. Reidel Publishing Co. 1980.
[3] Radar Meteorology by Henry Sauvageot. Artech House Publishers, 1992.
[4] Radar Meteorology by S Raghavan, Kulwer Academic Publishers, 2003.
[5] Sun, weather and climate by J Herman and RA Goldberg, NASA , Washington, USA, 1978.
[6] The Atmosphere by Frederick K. Lutgens and Edward K. Tarbuk, Prentice Hall Inc., 2007.
7. The Physics of Atmosphere by John Hougton, Cambridge University Press, 1976.
[7] Basics of Atmospheric Science, A Chandrashekar, PHI Publications, 2010.
[8] Atmosphere, weather and climate, K Siddhartha, Kisalaya Publications, 2007.

PHPHY104: GROWTH AND CHARACTERIZATION OF THIN FILMS

Growth of Thin Films: Physical Methods, Vacuum evaporation: Types of evaporation sources, Resistive heating, electron beam evaporation, Two-source evaporation, Flash evaporation, Laser ablation, Reactive evaporation, Sputtering technique. **Chemical Methods:** Electroplating, Spray pyrolysis, chemical vapour deposition (CVD); Sol-Gel process; Screen printing, Plasma Chemical vapour deposition (PCVD), Metal organic chemical vapor deposition (MOCVD).

Thickness measurement: optical methods, interferometry, ellipsometry, spectral reflectometry, quartz crystal microbalances. **Characterization:** Surface analytical techniques: X-ray Photoelectron Spectroscopy (XPS), Auger Electron Spectroscopy (AES), Secondary Ion Mass Spectroscopy (SIMS) and Rutherford Back Scattering (RBS). Imaging and optical analytic techniques: Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM). Optical analytical techniques: Fourier Transform Infrared Spectroscopy (FTIR)-Photo Luminescence (PL).

Transport Properties: Metallic films: Sources of resistivity in metallic conductors, sheet resistance and temperature coefficient of resistance of thin films, Influence of thickness on the resistivity of structurally perfect thin films, Fuchs Sondhemier theory, Hall effect, Annealing, agglomeration and oxidation. **Optical Properties:** Reflection and transmission at an interface, Reflection and transmission by single film, Reflection from an absorbing films, Optical absorption, Determination of optical constants by ellipsometry.

Applications: Thin film resistors, Thin film capacitors, Thin film solar cells, Gas sensors, Transparent conducting coatings, Thin films for superconducting devices, hard coatings, Photolithography.

REFERENCE BOOKS:

[1] Hand book of thin film technology by L. I. Maissel and R. L. Glang, Mc Graw Hill Book Co., 1970.
[2] Thin Film Phenomena by K. L. Chopra by Mc Graw Hill Book Co., New York, 1969.
[3] Hand Book of Technologies for Films and Coatings by R. F. Bunshah, Noyes publication, 1996.
[4] Materials Science of Thin Films, Deposition and Structure, Milton Ohring, Academic Press (2002). 5. Thin Film Phenomenon, K.L. Chopra, McGra-Hill (1969).

PHPHY105: RADIATION PHYSICS

Interaction of Radiation with Matter: Ionizing and non-ionizing radiation, Basic principles of production of X-rays and gamma rays. Interaction of gamma rays and X-rays with matter, Attenuation coefficients: Mass attenuation coefficient, Mass energy-absorption coefficient. Interaction cross-sections: Absorption and scattering cross-sections. Interaction mechanisms: Photoelectric absorption, Compton scattering, Rayleigh scattering, Pair production, Triplet production. Relative predominance of individual effects. Attenuation coefficients in practical conditions: Measurement of K and L edge and their applications in physical and biological science. Theory and general features for charged particles – Energy loss mechanism, the BetheBloch equation, Energy loss of β-particles and Range-energy relation. (Ref. 1, 2, 3, 4)

Radiation Effects and Protection Biological effects of radiation at molecular level, acute and delayed effects, stochastic and non-stochastic effects, Relative Biological Effectiveness (RBE), Linear energy transformation (LET), Dose response characteristics. Permissible dose to occupational and non-occupational workers, maximum permissible concentration in air and water, safe handling of radioactive materials. The ALARA, ALI and MIRD concepts, single target, multitarget and multihit theories, Rad waste and its disposal.

Radiation Shielding Thermal and biological shields, shielding requirement for medical, industrial and accelerator facilities, shielding materials, radiation attenuation calculations – The point kernal technique, radiation attenuation from a uniform plane source. The exponential pointKernal. Radiation attenuation from a line and plane source. Practical applications and some simple numerical problems.

Radiation Detectors: Gas-filled counters - ionization chambers, proportional and Geiger counters, Scintillators-properties of different phosphors, Semiconductor detectors: silicon, germanium & Si(Li) detector, Solid State Nuclear Track Detector (SSNTD) Plastic detector. **Statistics for Data Analysis:** Energy Peak Analysis: Measures of Centroid, Dispersion, Full Width Half Maximum, Distribution function: Binomial distribution, polynomial distribution, Poisson distribution, Gaussian distribution, $\chi 2$ distribution, Measurement uncertainty: systematic errors, Random errors, counting statistics. (Ref. 1, 9, 10, 11)

REFERENCE BOOKS:

[1] Radiation detection and measurement, G F Knoll, 3rd edition, John Wiley & Sons, 2000.
[2] Nuclear Physics: R R Roy and B P Nigam (Wiley Eastern).
[3] Nuclear Physics: D C Tayal (Himalaya).
[4] Nuclear Physics: S N Ghoshal (S. Chand).
[5] Nuclear Reactor Engineering, S Glasstone and A Seasonke, Reinhold, 1981.
[6] Radiation Biology, A Edward Profio, Prentice Hall, 1968.
[7] Radiation Theory, Alison P Casart.
[8] Introduction to Radiological Physics and Radiation Dosimetry, F.H. Attix, Wiley VCH, 1986.
[9] Nuclear Radiation Detectors: Kapoor and Ramamurthy.
[10] Measurement and detection of radiation: Nicholas Tsonlfanidis. 11. Introduction to Experimental Nuclear Physics: Singru.
[1] ergamon Press.

Group-II

PHPHY201: QUANTUM MECHANICS

Physical basis of quantum mechanics: Experimental background, inadequacy of classical physics, summary of principal experiments and inferences, Uncertainty and complementarity. Wave packets in space and time and their physical significance. **Schrodinger wave equation:** Development of wave equation: One-dimensional and extension to three dimensions inclusive of forces. Interpretation of wave function: Statistical interpretation, normalisation, expectation value and Ehrenfest's theorem. Energy Eigen functions: separation of wave equation, boundary and continuity conditions.

Some exactly soluble Eigen value problems One dimensional: Square well and rectangular step potentials, Rectangular barrier, Harmonic oscillator. **Three dimensional:** Particle in a box, Particle in spherically symmetric potential, Rigid rotator, Hydrogen atom.

General formalism of quantum mechanics Hilbert space. Operators-definition and properties, Eigen values and Eigen vectors of an operator, Hermitian, unitary and projection operators, commuting operators, complete set of commuting operators. Bra and Ket notation for vectors. Representation theory: matrix representation of an operator, change of basis. Co-ordinate and momentum representations. The basic formalism: The fundamental postulates, expectation values and probabilities; quantum mechanical operators, explicit representation of operators, uncertainty principle. Matrix method solution of linear harmonic oscillator. Quantum dynamics: Equations of motion, Schrodinger, Heisenberg and Interaction pictures. Poisson brackets and commutator brackets.

Approximation methods for stationery states: Time-independent perturbation theory; non-degenerate and degenerate cases, perturbed harmonic oscillator. The variation method: Application to ground state of Helium. **WKB method:** Application to barrier penetration. Bohr-Sommerfield quantum condition. Theory of scattering: Scattering cross-section, wave mechanical picture of scattering, scattering amplitude. Born approximation. Partial wave analysis: phase shifts, scattering amplitude in terms of phase shifts, optical theorem; exactly soluble problem-scattering by square well potential.

REFERENCE BOOKS:

[1] Quantum Mechanics: L. I. Schiff (McGraw-Hill, 1968).
[2] Quantum Mechanics: F. Schwabl (Narosa, 1995).
[3] Text book of Quantum Mechanics: P. M. Mathews and K. Venkateshan (TMH, 1994).
[4] Quantum Mechanics: V. K. Thankappan (Wiley Eastern, 1980).
[5] Quantum Mechanics: B. K. Agarwal and Hari Prakash (Prentice-Hall, 1997).

PHPHY202: ATOMIC AND MOLECULAR PHYSICS

One electron System: Quantum states of one electron atoms, atomic orbitals, hydrogen spectrum. Spectra of alkali elements, spin-orbit interaction and fine structure in alkali spectra. **Two electron Systems:** LS-coupling, equivalent and non-equivalent electrons, spectral terms, Pauli exclusion principle, coupling schemes for two electrons, interaction energies for LS coupling, fine structure splitting for sp electron configuration, Lande interval rule. jj-coupling– spectral terms, interaction energies for jj-coupling, fine structure splitting for sp electron configuration. Qualitative consideration of selection and intensity rules for LS and jj–coupling. Hyperfine structure for one and two electrons and Lande interval rule.

Weak magnetic field effects: Normal and anamolous Zeeman effect, magnetic moment of a bound electron and Lande g-factor, magnetic interaction energy, selection rules, Zeeman pattern for principal series doublet, intensity rules. Zeeman effect for two electrons–magnetic moment of the atom and g-factors, expression for magnetic interaction energy, selection rules, Zeeman pattern transitions for diffuse-series singlet, intensity rules. **Strong magnetic field and Electric field effects:** Paschen-Back effect, expression for total energy shift, transitions for principal series doublet. Qualitative treatment of Paschen–Back effect and complete Paschen- Back effect for two electrons. Isotope structure. Stark effect–first and second order Stark effects in hydrogen. Width of spectral lines (qualitative). (Ref: 1,6,7)

Microwave and Infra-red spectra Types of molecules- linear, symmetric top, asymmetric top and spherical top molecules. Theory of rotational spectra for rigid and non-rigid rotator diatomic molecules, energy levels, intensity of rotational lines. Microwave spectrometer and applications. Vibrational energy of diatomic molecule as simple harmonic and anharmonic oscillators, Morse potential energy curve, energy levels and vibrational spectra. Diatomic molecule as a vibrating-rotator, vibration-rotation spectra-P,Q,R branches. IR- spectrometer and applications.

UV-Visible spectra Electronic spectra of diatomic molecules, Born-Oppenheimer approximation, vibrational coarse structure- band progressions and sequences, Frank-Condon principleintensity of vibrational-electronic spectra, dissociation energy and dissociation products. Rotational fine structure of electronic-vibration transitions, determination of vibrational and rotational constants. Molecular orbital. Classification of electronic states and multiplet structure, selection rules for electronic transitions and simple electronic transitions. UVVisible absorption and fluorescence spectrophotometers and applications.

REFERENCE BOOKS

[1] Introduction to Atomic Spectra : H E White, McGraw Hill,
[2] Fundamentals of Molecular Spectroscopy: C N Banwell and E M McCash, Tata McGraw Hill, 1999, 4th Edition.
[3] Molecular Spectra and Molecular Structure Vol. 1: Spectra of Diatomic Molecules: G. Herzberg, Von Nostrand.
[4] Spectroscopy, Vols. 1, 2 and 3: B P Straughan and S Walker ,Chapman and Hall
[5] Introduction to Molecular Spectroscopy: G M Barrow, McGraw Hill.
[6] Physics of Atoms and Molecules: B H Bransden and C J Joachain, Longman, 1983.
[7] Spectra of Atoms and Molecules: P F Bernath, Oxford University Press 1995.

PHPHY203: NUCLEAR PHYSICS

Properties of Nucleus: Nuclear constitution. The notion of nuclear radius and its estimation from Rutherford's scattering experiment; the coulomb potential inside the nucleus and the mirror nuclei. The nomenclature of nuclei, and nucleon quantum numbers. Nuclear spin and magnetic dipole moment. Nuclear electric moments and shape of the nucleus. **Nuclear Forces:** General features of nuclear forces. Bound state of deuteron with square well potential, binding energy and size of deuteron. Deuteron electric and magnetic moments - evidence for non-central nature of nuclear forces. Yukawa's meson theory of nuclear forces.

Nuclear Reactions: Reaction scheme, types of reactions and conservation laws. Reaction kinematics, threshold energy and Q-value of nuclear reaction. Energetics of exoergic and endoergic reactions. Reaction probability and cross section. Bohr's compound nucleus theory of nuclear reactions. **Nuclear Models:** The shell model; Evidence for magic numbers, energy level, scheme for nuclei with Infinite Square well potential and the ground state spins. The extreme single particle prediction of nuclear spin and magnetic dipole moments -Schmidt limits. The liquid drop model: Nuclear binding energy, Bethe-Weizsacker's semi empirical mass formula; stability limits against spontaneous fission and nuclear decay.

Nuclear Decays: Alpha decay: Quantum mechanical barrier penetration, Gammow's theory of alpha decay and alpha half-life systematics. Beta decay: Continuous beta spectrum, neutrino hypothesis, and Fermi's theory of beta decay, beta comparative halflife systematics. Gamma decay: Qualitative consideration of multipole character of gamma radiation and systematics of mean lives for gamma multipole transitions. **Interaction of Radiation with Matter:** Interactions of charged particles with matter, ionisation energy loss, stopping power and range energy relations for charged particles. Interaction of gamma rays; photoelectric, Compton and pair production processes. Nuclear radiation detectors-G M counter and Scintillation detector.

Nuclear Energy: Fission process, fission chain reaction, four factor formula and controlled fission chain reactions, energetics of fission reactions, fission reactor. Fusion process, energetics of fusion reactions; Controlled thermonuclear reactions; Fusion reactor. Stellar nucleo synthesis. **Fundamental Interactions and Elementary Particles:** Basic interactions and their characteristic features. Elementary particles, classification; Conservation laws in elementary particle decays. Quark model of elementary particles.

REFERENCE BOOKS:

[1] The Atomic Nucleus: R D Evans (TMH).
[2] Nuclear and Particle Physics : W.E. Burcham and M. Jobes (Addison Wesley, 1998).
[3] Nuclear Physics: R R Roy and B P Nigam (Wiley Eastern).
[4] Physics of Nuclei and Particles: P Mermier and E Sheldon (Academic Press).
[5] Atomic and Nuclear Physics: S N Ghoshal (S. Chand).
[6] Nuclei and Particles: E Segre (Benjamin).
[7] Nuclear Physics: D C Tayal (Himalaya).
[8] Introduction to Nuclear Physics: S B Patel (Wiley Eastern).

PHPHY 204: ELECTRODYNAMICS

Electrostatics: Static electric charge, Coulomb's law, the electrostatic field and Gauss law. The static field laws in integral and differential forms. The electrostatic scalar potential, Poisson and Laplace equations. The potential energy of charges and field energy density. The electric potential and fields due to monopole, dipole and quadrupole. The dipole in an external field and the dipole interaction energy. The multipolar expansion of potential and for the energy of localised charge distribution in an external field, the physical significance of various multipoles. The electrostatic fields in matter, polarisation, macroscopic field equations. The electrostatic energy in dielectric media. The electrostatic boundary conditions.

Magnetostatics: The steady electric current, Biot-Savart law, magnetic field and Ampere's law. The magnetostatic field laws in integral and differential forms. The magnetic scalar and vector potentials. Potential and field of a circular current element- magnetic dipole. The dipole in an external field and the dipole interaction energy. The multipolar expansion for the potential of localized current distribution, the physical significance of multipoles. Magnetic fields in matter, magnetisation of the microscopic equations. The energy in the magnetic field. The magnetostatic boundary conditions.

Electromagnetics: The nonsteady currents and charges, Lorentz force law and Faraday's law of induction. The displacement current. Maxwell's electromagnetic field laws in integral and differential forms. The macroscopic equations and boundary conditions. The electromagnetic potential, Coulomb, and Lorentz gauges. Energy in the electromagnetic field. Poynting's theorem and energy momentum conservation.

Electromagnetic waves The wave equation, light and its electromagnetic character. Plane Waves in free space, waves in non conducting media and polarisation. Electromagnetic waves in conducing media, skin depth. Electromagnetic waves in bounded media; Reflection and refraction of waves. Energy flux in a plane wave. The retarded potentials, Lienard-Wiechart potentials and fields for a moving point charge.

REFERENCE BOOKS:

[1] Introduction to Electrodynamics: D J Griffith (Prentice-Hall, 1989).
[2] Classical Electromagnetic Radiation: J B Marion (Academic, 1968).
[3] Classical Electrodynamics: C D Jackson (Wiley Eastern, 1978).
[4] Electromagnetics: B B Laud (Wiley Eastern, 1987).
[5] The Feynman Lectures on Physics, R P Feynman et al, Narosa Publishing, 2008.
[6] Classical Electricity and Magnetism: W Panofsky & M Philips (Addision Wesley, 1962).

Group-III

PHPHY301: SOLID STATE PHYSICS

Crystal structure: Crystal systems, Crystal classes, Bravais lattice. Unit cell: Wigner-Seitz cell, equivalent positions in a unit cell. Notations of planes and directions. Atomic packing: packing fraction, Co-ordination number. Examples of simple crystal structures: NaCl, ZnS and diamond. Symmetry operations, point groups and space groups. **X-ray diffraction:** X-ray diffraction, Bragg law. Laue equations. Atomic form factor and Structure factor. Concept of reciprocal lattice and Ewald's construction. Experimental diffraction methods: Laue, Rotating crystal method and Powder method.

Crystal binding: Types of binding. Vander Waals-London interaction, Repulsive interaction. Modelung constant. Born's theory for lattice energy in ionic crystals and comparison with experimental results. Ideas of metallic binding, Hydrogen bonded crystals.) **Lattice vibrations:** Vibrations of monoatomic lattices. First Brillouin zone. Quantization of lattice vibrations - Concept of Phonon, Phonon momentum. Specific heat of lattice (qualitative).

Energy bands in solids: Formation of energy bands. Free electron model: free electrons in one and three dimensional potential wells, electrical conductivity, heat capacity, paramagnetism, Fermi-Dirac distribution, density of states, concept of Fermi energy. Kronig-Penny model. Nearly Free Electron Model (qualitative). Tight Binding model (qualitative). **Defects in solids:** Point defects: Schottky and Frenkel defects and their equilibrium concentrations. Line defects: Dislocations, multiplication of dislocations (Frank-Read mechanism). Plane defects: grain boundary and stacking faults.

Semiconductors: Intrinsic and extrinsic semiconductors, concept of majority and minority carriers. Statistics of electrons and holes, electrical conductivity. Hall effect. Experimental determinations of resistivity of semiconductor by four probe method. **Superconductors:** Superconductivity, Zero resistance,. Meissner effect, Critical field, Classification into Type I and Type II, Thermodynamics of superconducting transition, Electrodynamics of superconductors.

REFERENCE BOOKS:

[1] Elementary Solid State Physics: Principles and applications, M. A. Omar, AddisonWesley.
[2] Introduction to Solid State Physics, C. Kittel, Wiley Eastern.
[3] Solid State Physics, A. J. Dekkar, Prentice Hall Inc.
[4] Semiconductor Physics, P. S. Kireev, MIR Publishers. 5. Solid State Physics, S. O. Pillai, New Age Publisher, 2010.

PHPHY302: ELECTRONICS

Operational amplifiers: The ideal Op-Amp-inverting, non-inverting and differential amplifiers-CMRR; OpAmp IC building blocks-emitter coupled differential amplifier, active load, level shifting and output stage; Op-Amp characteristics-open-loop input output characteristics, frequency response and slew rate; Op-Amp applications-adder, subtractor, integrator, differentiator, comparator, voltage-to-current converter, current-to-voltage converter and logarithmic amplifier.

Digital electronics: Logic gates-Boolean algebra and De-Morgan's theorem; Boolean laws and theorem-Sum-of-Products and Products-of-Sums method-Karnaugh simplifications; **Multiplexers and Demultiplexers;** BCD-to-Decimal decoders-Seven segment decoders; Decimal-to-BCD encoder; Half-adder and Full-adder circuits. **Flip-Flops:** Types of Flip-Flops-RS Flip-Flop, Clocked RS Flip-Flop, D Flip-Flop, J-K Flip-Flop and J-K Master-Slave Flip-Flops; Schmit Trigger; 555 Timer-Astable and Monostable circuits.

Registers and Counters: Types of Registers-Serial in-Serial out, Serial in-Parallel out, Parallel in-Serial out, Parallel in-Parallel out Registers; Types of Counters-Ring Counters, Asynchronous and Synchronous Counters, Shift Counters; D/A and A/D Converters.

Molecular Electronics: Molecular Scale Electronics, Introduction, Nanosystems, Engineering Materials At the Molecular Level - Molecular Device Architectures, Molecular Rectification, Switching and Memory Devices, Single Electronic Devices, Optical and Chemical Switches, Nanomagnetic Systems, Nanotube Electronics, Molecular Actuation, Logic Circuits, Computing Architectures, Quantum Computing.

REFERENCE BOOKS:

[1] Text Book of Electronics, S. Chattopadhyay, New Central Book Agency Pvt., Ltd., Kolkata, 2006. 2. Digital Principles and Applications, A.P. Malvino and D.P. Leach, Tata McGraw-Hill, Publishing Co., New Delhi, 1986.

[2] Molecular Electronics from Principle to Practice, Michael C. Petty, John Wiley & Sons. Ltd., 2007.

[3] Electronics Principles, Malvino, 6th Edition, Tata McGraw-Hill Publishing Co., New Delhi, 2001. 5. Electronics Principles and Applications, A.B. Bhattacharya, New Central Book Agency Pvt. Ltd., Kolkata, 2007.

PHPHY303: OPTICAL FIBER COMMUNICATION

UNIT-1

Overview of optical fiber communication: Introduction, Historical development, general system, advantages, disadvantages, and applications of optical fiber communication, optical fiber waveguides, Ray theory, cylindrical fiber (no derivations in article 2.4.4), single mode fiber, cutoff wave length, and mode filed diameter. **Transmission characteristics of optical fibers:** Optical Fibers- fiber materials, photonic crystal, fiber optic cables specialty fibers, Attenuation, absorption, scattering losses, bending loss, dispersion, Intra model dispersion, Inter model dispersion.

UNIT-2

Optical sources, detectors receiver: Introduction, LED's, LASER diodes, Photo detectors, Photo detector noise, Response time, double hetero junction structure, Photo diodes, comparison of photo detectors. Introduction to optical receivers, Optical Receiver Operation, receiver sensitivity, quantum limit. Eye diagrams, coherent detection, burst mode receiver, operation, and Analog receivers, **fiber couplers and connectors:** Introduction, fiber alignment and joint loss, single mode fiber joints, fiber splices, fiber connectors and fiber couplers

UNIT-3

Analog and digital links: Analog links – Introduction, overview of analog links, CNR, multichannel transmission techniques, RF over fiber, key link parameters, Radio over fiber links, microwave photonics. Digital links – Introduction, point–to–point links, System considerations, link power budget, resistive budget, short wave length band, and transmission distance for single mode fibers, Power penalties, nodal noise and chirping.

UNIT-4

WDM concepts, components and optical networks: WDM concepts, overview of WDM operation principles, WDM standards, Mach-Zehender interferometer, multiplexer, Isolators and circulators, direct thin film filters, active optical components, MEMS technology, variable optical attenuators, tunable optical fibers, dynamic gain equalizers, optical drop multiplexers, polarization controllers, chromatic dispersion compensators, tunable light sources. Optical Amplifiers and Networks – optical amplifiers, basic applications and types, semiconductor optical amplifiers, EDFA. , Introduction to optical networks, SONET / SDH, Optical Interfaces, SONET/SDH rings, High – speed light – waveguides.

REFERENCE BOOKS:

[1] "Optical Fiber Communication:, Gerd Keiser, 4th Ed, MGH, 2008

[2] "Optical Fiber Communication", John M Senior, Pearson Education, 3rd Impression, 2007

[3] "Fiber Optical Communication" Joseph C Palais, 4th Ed, Pearson Education

PHPHY304: LASER PHYSICS

Coherence: Coherence, spatial and temporal coherence, measurement of spatial and temporal coherence, coherence time, coherence length, line width and monochromaticity; coherence time and line width via Fourier analysis, complex degree of coherence and fringe visibility in Young's double hole experiment. **Laser rate equations:** Basic structure of a Laser, theory of laser oscillations, round-trip power gain and threshold condition. Rate equations for two, three and four level lasers; variation of laser power around threshold, optimum output coupling.

Optical resonators: Plane-parallel resonator, spherical resonator, confocal resonator, unstable resonator, losses in optical resonator, quality factor Q. **Line broadening mechanisms and laser modes:** Line shape broadening: Doppler broadening, collision broadening, natural radiative lifetime broadening, homogeneous and inhomogeneous broadening. Laser modes: Longitudinal and transverse modes, experimental arrangement for mode selection. Gain saturation, gain saturation in homogeneously and inhomogeneously broadened lasers, hole burning.

Single and multimode oscillations: Multimode oscillations, single-line and single-mode oscillation, frequency pulling, Lamb dip and laser frequency stabilization; ultimate line width of the laser (limit to monochromaticity), laser spiking in time-dependent condition. **Q-switching and mode locking techniques:** Q-switching, production of a giant pulse; methods of Q-switching: Mechanical shutters, electro-optical shutters, acousto-optic Qswitches, shutter using saturable dyes, peak-power emitted during the pulse, giant pulse dynamics. Mode locking: Active and passive mode locking techniques, ultrashort laser pulses, Laser amplifiers.

Types of Lasers Solid state Lasers: Nd:YAG and Nd:Glass lasers. Gas Lasers: Ionic Lasers: Ar+ Laser, Metal vapour Lasers: He-Cd laser and copper vapour laser. Molecular Laser: CO2 Laser and its types. Liquid Lasers: Dye lasers, ring dye laser, tuning techniques. Excimer laser, chemical laser, semiconductor laser, colour center laser, free-electron laser, X-ray laser and gamma laser.

REFERENCE BOOKS:

[1] Optics: Ajoy Ghatak, Tata Mc-Graw-Hill Publishing Co., 1994, 2nd Ed.
[2] Lasers: Theory and Applications, K. Thyagarajan and A. K. Ghatak, Mc-Millan India Ltd., 1997.
[3] Optical Electronics: Ajoy Ghatak and K. Thyagarajan, Cambridge Univ. Press, 1994.
[4] Principles of Lasers: Orazio Svelto, Plenum Press, NY, 1986, 2nd Ed.
[5] An Introduction to Lasers and their Applications: D. C. OShea, W. R. Callen and W. J. Rhodes, Addision, Wiley Publishing Co., 1978.
[6] Lasers and their Applications: M. J. Beesley, Taylor and Francis Ltd, London ,1971.
[7] Lasers and Non-Linear Optics: B. B. Laud, New Age Intl. (P) Ltd. Publ, 1996, 2nd Ed.
[8] Source Book on Lasers: Hecht.

Group-IV

PHPHY401: GLASSES AND CERAMICS

Introduction to glass: Definition, Enthalpy / Temperature diagram, Principles of glass formation, Kinetic theories of glass formation, Determination of glass forming ability and glass stability. **Glass melting:** Raw material, Compositinal nomenclature, Batch calculations, Mechanism of batch melting, Fining of melts, Homogenizing of melts. c. Immiscibility and phase separation: Mechanism for phase separation, Immiscibility of glass forming systems.

Structure of glasses: Fundamental law of structural model, Elements of structural model, elements of structural models for glasses, Structural models for different oxide glasses. **Density of glasses, Thermal expansion of glasses:** Measurement technique, Transport properties of glasses, Fundamentals of diffusion, Ionic diffusion, Ionic conductivity. **Transport properties:** Introduction to ionic conduction, Compositional effect, Activation energy for electronic conduction, Effect of thermal history on electronic conduction.

Ceramic phase-equilibrium diagrams: Gibb's phase rule, One-component phase diagrams, Technique for determining phase-equilibrium diagrams, Two-component system, Two-component phase diagrams, Three-component phase diagrams, Phase composition versus temperature, The system Al_2O_3-SiO_2 , The system MgO- Al_2O_3-SiO_2, Non equilibrium phase. **Phase transformation and glass ceramics:** Theory of transformation kinetics, Nucleation, Crystal growth, Glass-ceramic formation by controlled crystallization, Properties of glass ceramic materials.

Grain Growth, Sintering, and Vitrification: Recrystalization and grain growth, Solidstate sintering, Vitrification, Sintering with a reactive liquid, Pressure sintering and hot pressing. **Thermal Properties:** Introduction, Heat capacity, Density and thermal expansion of Crystal and glasses. **Dielectric Properties:** Electrical phenomenon, Dielectric constants, of crystal and glasses, Dielectric loss factor for crystal and glasses, Dielectric conductivity, Polycrystalline and polyphase ceramics, Dielectric strength, Ferroelectric ceramics.

REFERENCE BOOKS:

[1] Introduction to Glass Science and Technology, 2nd Edition, J.E. Shelby.
[2] Introduction to Ceramics, 2nd Edition, W.D. Kingery, H.K. Bowen and D.R. Uhlmann.
[3] Glass Science, R. H. Doremus (Wiley, New York, 1973)
[4] Glasses for Photonics, Masayuki Yamane, Yoshiyuki Asahara (Cambridge University Press, 2000)
[5] Properties, processing and applications of glass and rare earth-doped glasses for optical fibres, Dan Hewak (INSPEC, London, 1998.)
[6] Glass ceramics, P.W. Mc Millan (Academic Press, New York, 1964)
[7] Fundamentals of Ceramics, M. W. Barsoum (Taylor & Francis Group, NY, 2003)

PHPHY402: COMPOSITE MATERIALS

Introduction to composites: Types of composite materials – Dispersion strengthened composites, particulate composites, concretes, laminar composites and introduction to fiber reinforced composites. **Reinforcements:** Types of reinforcements – Whiskers and fibers, preparation, structure and properties of different reinforcing fibers, carbon fibers, glass fibers, polymer fibers and alumina fibers.

Types of composites: Fiber reinforced composites with different matrix systems, polymer matrix (thermoset and thermoplastic) matrix composites, metal matrix composites and ceramic matrix composites. **Test procedures:** Test procedures for mechanical testing, physical properties, void content for fiber reinforced composites.

Fabrication techniques Interfaces in composites and micromechanics of composites molding processes for reinforced composites – contact molding, vacuum bag molding, pressure bag molding, vacuum impregnation and injection molding, transfer molding, pultrusion, filament winding, Fabrication of Metal and Ceramic matrix composition.

Properties and applications of composites Mechanical Properties of composite, Effect of fiber volume content, orientation of fibers & void contents on mechanical properties of composite, fracture behaviour of composites, Thermal properties of composites. Applications of composites in different fields.

REFERENCE BOOKS:

[1] Science and Engineering of Materials by D. R. Askeland.
[2] Science of engineering materials by Manas Chandra.
[3] Hand Book of composites by G. Lubin.
[4] Composites Materials by K. K. Chawla.
[5] An introduction to composites materials by D. Hull.

PHPHY403: ENERGY PHYSICS

Sources of energy: A brief survey of various energy sources, present and future needs. Energy conservation, replenishable and non-replenishable energy sources. Estimated reserves of non-replenishable energy sources. Problems and viable solutions of energy utilisation in ecological and sociological perspectives. **Thermodynamics of energy conversion:** Principles of energy conversion and conversion between different forms of energy. Thermodynamics of various conversion processes and their comparison in terms of efficiencies. Heat engines and thermodynamic cycles-Carnot, Otto, Diesel and Rankine cycles and their efficiencies; Comparison of Carnot and other cycles.

Nuclear energy Fission chain reaction, Energy release in fission, Nature of fission fragments, Energy distribution between fission fragments, Emission of neutrons in fission, energetics of fission process, Bohr-Wheeler theory, Particle induced and photo-fission, Reactor materials, Typical power reactors: Gas cooled and graphite moderated reactors, pressurised water reactor, heavy water moderated reactor and fast breeder reactors. Biological and other effects of nuclear radiations. Peaceful utilisation of nuclear energy.

Solar energy, Solar radiation: Sun as source of radiation, spectral composition, solar constant; the basic earth-sun angles, solar time and the equation of time. Effect of earth's atmosphere on solar radiation, terrestrial insolation and its measurements. **Direct electrical conversion of solar energy:** Photovoltaic effect, solar photoemissive and photovoltaic cells. Solar cell characteristics, efficiency and spectral response. Description and comparison of different types of solar cells, homo-junction and hetro-junction cells. Factors affecting efficiency of solar cells. Solar panels and their performances. **Storage and utilisation of solar energy:** Types of storage, brief description of thermal, electrical and chemical storage. Solar production of hydrogen and solar pond. Heating systems: Water heating systems, solar drying, space heating and solar cooler. Power generation, solar thermal generation and tower power generation.

Wind, Tidal, Geothermal and Ocean thermal energies: Energy in the wind. Horizontal and vertical axis windmills. Power in waves, tidal energy and its utilisation. Sources of geothermal energy and its utilisation: Energy in the ocean, thermal gradient and ocean electric power generation. **Electrochemical Energy:** Fuel cells, types of reactions and efficiency of conversion. Solid state batteries, photochemical cells, working and efficiency. **Bioenergy:** Bioconversion and mechanism of photosynthesis, microbial and plant photosynthesis. Biomass systems, assessment, conversion, utilisation and conservation. Types of conversion of biomass, anaerobic conversion and biogas generation, enzymatic conversion and liquid fuel production.

REFERENCE BOOKS:

[1] Renewable Energy: Sorenson.
[2] Principles of Energy Conversion: A Culp.
[3] Nuclear Physics: S N Ghoshal (S. Chand).
[4] Treatise on Solar Energy: H P Garg. 5. Solar Energy Utilisation: G D Rai.
[5] Fundamentals of Solar Cells: Fahrenbruch and Bube.
[6] Solar Cell device Physics: Fonasn. 8. Physics of Semiconductor Devices: S M Sze.
[7] 9. Non-conventional Energy Sources: G. D. Rai

PHPHY404: MATERIALS SCIENCE

Engineering Materials: Materials science and engineering, Classification, Levels of structure, Structure-property relationship in materials. (Ref: 1, 2 and 3) **Structure of Solids:** The crystalline and Non-crystalline states, Covalent solids, Metals and alloys, Ionic solids, The structure of silica and silicates.

Crystal Growth: Crystal growth from melt: Bridgemann technique, Crystal pulling by Czochralski's method, Growth from solutions, Hydrothermal method, Gel method, Zone refining method of purification. **Crystal Imperfections:** Point imperfections, Dislocation, Edge and Screw dislocation, Concept of Burger vector and Burger circuit, Surface imperfections, Colour centres in ionic solids.

Solid Phases and Phase diagrams: Single and multiphase solids, Solid solutions and Hume-Rothery rules, Intermediate phase, The intermetallic and interstitial compounds, Properties of alloys: solid solutions and two component alloy systems; Phase diagram, Gibbs phase rule, Lever rule; First, second and third order phase transitions with examples; Some typical phase diagrams: Pb-Sn and Fe-Fe2O3; Eutectic, eutectoid, peritectic and peritectoid systems.

Phase Transformation: Time scale for phase changes; Nucleation and growth, nucleation kinetics; Growth and overall transformation kinetics, Applications: transformation in steel; Precipitation processes, solidification and crystallization; Glass transition, recovery, recrystallization and grain growth. **Diffusion in Solids:** Theory of diffusion, Self-diffusion, Fick's law of diffusion, Kirkindal effect, Activation energy for diffusion, Applications of diffusion.

REFERENCE BOOKS:

[1] Elements of Materials science and Engineering, L. H. Van Vlack, Addison Wesley (6th edition, 1989).
[2] Materials Science and Engineering, V. Raghvan, Printice Hall of India, 5th edition, 2009.
[3] Materials Science and Processes, S. K. Hazra Chaudary, Indian Distr Co. (1977).
[4] Introduction to Solids, L. V. Azaroff, Tata McGraw Hill education Pvt. Ltd., 1984.
[5] Crystal Growth, B. R. Pamplin, Pergamon Press.

PHPHY405: BIOPHYSICS

Cell biophysics: Cell doctrine; General organisation and composition of the cells. **Bioenergetics:** The biological energy cycle and the energy currency. Thermodynamic concepts; Free energy of a system- Gibb's free energy function, Chemical potential and redox potentials. Energy conversion pathways-Kreb's cycle; respiratory chain, oxidative phosphorylation. Photosynthesis-photosynthetic apparatus; mechanisms of energy trapping and transfer; photophosporylation.

Membrane biophysics: Cell membranes- structure, function and models; Transport across membranes- passive and active processes; Chemiosmotic energy transductionvan't Hoff equation; Ionic equilibrium-electrochemical potential; Nernst's equation; Flow across membranes-membrane permeability. **Neurophysics:** The nervous system. Synaptic transmission; information processing in neuronal systems. Physical basis of biopotentials; Action potential; Nernst-Planck equation. Nerve excitation and conduction; Hodgkin-Huxley model.

Physiological biophysics: Physics of sensory organs- the transmission of information; Generator potentials. Visual receptor- mechanism of image formation; Auditory receptor- mechanism of sound perception; Mechanisms of chemical, somatic and visceral receptors. Mechanism of muscle contractility and motility. Temporal organisation- basis of biorhythms.

Biophysics of the immune system: The Immune system; cellular basis of immunal responses; antibodies and antigens; Immunological memory. **Genetic engineering:** Gene-Structure, expression and regulation; Genetic code and genome organisation; Recombinant technology. Transgenic systems. CyberneticsGenetic information and the brain; neural nets.

REFERENCE BOOKS:

[1] An introduction to biophysics, C Sybesma, Academic, 1977.
[2] Biophysics, V Pattabhi and N Gautham, Narosa 2002.
[3] Essentials of Biophysics, P Narayanan, New Age 2001.
[4] Molecular biophysics: R B Setlow and E C Polland (Addition Wesley, 1962).
[5] Biophysics, W Hoppe, W Lohmann, H Markl, H Ziegler (Springer Verlag, 1983).
[6] Biophysics and Human Approach, I W Sherman and V G Sherman (Oxford, 1979)
[7] Molecular biology of the cell, B. Alterts, D. Bray, J. Lewis, M. Raft, K. Roberts and J D Watson (Garland, 1984).
[8] Molecular Cell Biology, H Lodish, A Berk, S L Zipursky, P Matsudaira, D Baltomore and J Darnel (Freeman, 2000).
[9] Biophysical principles of structure and function: F M Snell, S Shulman, R P Spensor and C Moos, Addition Wesley, 1965.
[10] Principles of Neural science: E R Kendel and J H Schwar (Elsevier, 1982).