Physics

Sl.No	Subject Code	Name of the Subject
1	14PHDPHY001	Mathematical Physics
2	14PHDPHY002	Classical Mechanics and Statistical Mechanics
3	14PHDPHY003	Quantum Mechanics
4	14PHDPHY004	Atomic, Nuclear and Molecular Physics
5	14PHDPHY005	Solid State Physics, Nano Science and Technology
6	14PHDPHY006	Material Science
7	14PHDPHY007	Physics of Liquid Crystals and Polymer Science
8	14PHDPHY008	Flourescence Spectroscopy and X-ray Crystallography
9	14PHDPHY009	Laser Physics and Biophysics
10	14PHDPHY010	Electronics and Instrumentation
11	Compulsory	Research Methodology

14PHDPHY001: MATHEMATICAL PHYSICS

UNIT-1: Differential equations

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.

UNIT-2: 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.

UNIT-3: 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.

UNIT-4: Group Theory

Groups, subgroups, classes. Homomorphism and isomorphism. Group representation. Reducible and irreducible representations. Character of a representation, character tables. Construction of representations. Representations of groups and quantum mechanics. Lie groups. The three dimensional rotation group SO(3). The special unitary groups SU(2) and SU(3). The irreducible representations of SU(2). Representations of SO(3) from those of SU(2) Some applications of group theory in physics

UNIT-5: Numerical Techniques

Numerical Methods. Solutions of algebraic and transcendental equations: Bisection, iterative and Newton-Raphson methods. Interpolation: Newton's and Lagrange's methods.

Curve fitting: Method of least squares. Differentiation: Newton's formula. Integration: Trapezoidal rule, Simpson's 1/3 and 3/8 rules. Eigen values and eigen vectors of a matrix. Solutions of ordinary differential equations: Euler's modified method and Runge-Kutta methods.

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.

9. Introductory Methods of Numerical Analysis: S. S. Sastry, PHI, 1995.

10. Numerical Methods: E. Balagruswamy (TMH, 2001).

14PHDPHY002: CLASSICAL MECHANICS AND STATISTICAL MECHANICS

UNIT-1: Newtonian mechanics and Lagrangian formulation

Single and many particle systems - Conservation laws of linear momentum, angular momentum and energy. Application of Newtonian mechanics: Two-body central force field motion, Kepler's laws of planetary motion. Scattering in a central force field; Scattering cross-section; The Rutherford scattering problem.

Constraints in motion. Generalised co-ordinates, Virtual work and D'Alembert's principle. Lagrangian equations of motion. Symmetry and cyclic co-ordinates. Hamilton variational principle, Lagrangian equations of motion from variational principle. Simple applications.

UNIT-2: Hamiltonian formalism , Relativistic mechanics, Continuum mechanics

Hamilton's equations of motion - from Legendre transformations and the variational principle. Simple applications. Canonical transformations. Poisson brackets - Canonical equations of motion in Poisson bracket notation. Hamilton-Jacobi equations.

a. **Relativistic mechanics:** Four-dimensional formulation-four-vectors, four-velocity, four-momentum, and four-acceleration. Lorentz co-variant form of equation of motion
b. **Continuum mechanics:** Basic concepts, Equations of continuity and motion; Simple applications

UNIT-3: Microcanonical, Canonical and Grandcanonical ensembles

Microcanonical distribution function, Two level system in microcanonical ensemble, Gibbs paradox and correct formula for entropy, The canonical distribution function. Contact with thermodynamics - Two level system in canonical ensemble, Partition function and free energy of an ideal gas, Distribution of molecular velocities.

Equipartition and Virial theorems, The grand partition function, Relation between grand canonical and canonical partition functions.

Fluctuations in canonical, grand canonical and microcanonical ensembles. The Brownian motion and Langevin equation. Random walk, diffusion and the Einstein relation for mobility. Fockker-Plank equation. Johnson noise and shot noise.

UNIT-4: Bose-Einstein, Fermi-Dirac and Maxwell-Boltzmann Distributions

Bose-Einstein and Fermi-Dirac distributions, Thermodynamic quantities, Fluctuations in different ensembles, Bose and Fermi distributions in microcanonical ensemble - Maxwell-Boltzmann distribution law for microstates in a classical gas - Physical interpretation of the classical limit, Derivation of Boltzmann equation for change of states without and with collisions, Boltzmann equation for quantum statistics, Equilibrium distribution in Boltzmann equation.

UNIT-5: Thermodynamics, Microstates and Macrostates

Basic postulates of thermodynamics, Fundamental relations and definition of intensive variables, Intensive variables in the entropic formulation, Intensive variables in the entropic formulation - Equations of state, Euler relation, densities - Gibbs-Duhem relation for entropy - Thermodynamic potentials and extensivity properties, Maxwell relations, Energy differential and thermodynamic potentials of systems in external magnetic field - Thermodynamic relations, Microstates and macrostates, Ideal gas, Microstate and macrostate in classical systems, Microstate and macrostate in quantum systems, Density of states.

REFERENCE BOOKS:

1. Classical Mechanics: H Goldstein, (Addison-Wesley, 1950).
2. Introduction to Classical Mechanics: R G Takawale and P S Puranik (TMH, 1979). 3. Classical Mechanics: N C Rana and P S Joag (Tata McGraw, 1991).
4. Mechanics: Landau L D and Lifshitz E M (Addition-Wesley, 1960).
5. An Introductory Course of Statistical Mechanics, Palash B. Pal, Narosa Publishing House, New Delhi, 2008.
6. Elements of Statistical Mechanics, Kamal Singh & S. P. Singh, S. Chand & Company, New Delhi, 1992.
7. Statistical Mechanics an Elementary Outline, Avijit Lahiri, University Press, Hyderabad, 2002.

14PHDPHY003: QUANTUM MECHANICS

UNIT-1

a. 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.

b. 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. 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.

UNIT-2: 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.

UNIT-3

a. 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.

b. 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.

c. Time-dependent phenomena

Perturbation theory for time evolution, first and second order transition amplitudes and their physical significance. Applications of first order theory: constant perturbation, wide and closely spaced levels-Fermi's golden rule, scattering by a potential. Harmonic perturbation: interactions of an atom with electromagnetic radiation, dipole transitions and selection rules; spontaneous and induced emission, Einstein A and B coefficients. Sudden approximation.

UNIT-4

a. **Identical particles and spin:** Indistinguishability of identical particles. Symmetry of wave function and spin. Bosons and Fermions. Pauli exclusion principle. Singlet and triplet states of He atom and exchange integral Spin angular momentum, Pauli matrices.

b. **Angular momentum:** Definition, eigenvalues and eigenvectors, matrix representation, orbital angular momentum. Addition of angular momenta, Clebsch-Gordon coefficients for simple cases: $j_1 = ½$, $j_2 = ½$ and $j_1 = 1$, $j_2 = ½$.

UNIT-5

a. **Symmetry principles:** Symmetry and conservation laws, symmetry and degeneracy. Space-time symmetries, Displacement in space- conservation of linear momentum, Displacement in time, conservation of energy, Rotation in space, conservation of angular momentum, Space inversion,parity. Time reversal invariance.

b. **Relativistic wave equations:** Schrodinger's relativistic equation: free particle, electromagnetic potentials, separation of equations, energy level in a coulomb field.

Dirac's relativistic equation: free particle equation, Dirac matrices, free particle solutions, charge and current densities. Electromagnetic potentials. Dirac's equation for central field: spin angular momentum, approximate reduction, spin orbit energy. Separation of the equation. The Hydrogen atom, classification of energy levels and negative energy states.

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).

14PHDPHY004: ATOMIC, NUCLEAR AND MOLECULAR PHYSICS

UNIT-1

a. 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. (Ref: 1, 6, 7)

b. 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. (Ref: 1, 6, 7)

UNIT-2

a. 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. (Ref: 1, 6, 7)

b. 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)

UNIT-3: Microwave, Infra-red spectra ,

UV-Visible 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. (Ref: 2-7)

UV-Visible spectra

Electronic spectra of diatomic molecules, Born-Oppenheimer approximation, vibrational coarse structure- band progressions and sequences, Frank-Condon principle- intensity 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. UV-Visible absorption and fluorescence spectrophotometers and applications. (Ref: 2-7)

UNIT-4

a. **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.

b. **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.

c. **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.

d. **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.

UNIT-5

a. **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 half-life systematics. Gamma decay: Qualitative consideration of multipole character of gamma radiation and systematics of mean lives for gamma multipole transitions.

b. **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.

c. 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.

d. 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. 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.
8. The Atomic Nucleus: R D Evans (TMH).
9. 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).
10. Physics of Nuclei and Particles: P Mermier and E Sheldon (Academic Press).
11. Atomic and Nuclear Physics: S N Ghoshal (S. Chand). 6. Nuclei and Particles: E Segre (Benjamin).
12. Nuclear Physics: D C Tayal (Himalaya).
13. Introduction to Nuclear Physics: S B Patel (Wiley Eastern).

14PHDPHY005: SOLID STATE PHYSICS,NANO SCIENCE AND TECHNOLOGY

UNIT-1

a. **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. (Ref: 1-3)

b. **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. (Ref: 1-3)

c. **Crystal binding:** Types of binding. Van der 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. (Ref: 1-3)

d. **Lattice vibrations:** Vibrations of monoatomic lattices. First Brillouin zone. Quantization of lattice vibrations - Concept of Phonon, Phonon momentum. Specific heat of lattice (qualitative). (Ref: 1-3)

UNIT-2

a. **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). (Ref: 1-3)

b. **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. (Ref: 1-3)

c. **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. (Ref: 1 and 4)

d. **Superconductors:** Superconductivity, Zero resistance,. Meissner effect, Critical field, Classification into Type I and Type II, Thermodynamics of superconducting transition, Electrodynamics of superconductors. (Ref: 1 and 2)

UNIT-3

a. Introduction: Origin of Nanotechnology, Nano materials, Types of nonmaterials, Surface area to volume ration, Quantum confinement effect, band theory of nonmaterials. Physical and chemical properties of nonmaterials.

b. 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.

c. 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.

UNIT-4

a. 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.

b. 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.

UNIT-5: 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. Elementary Solid State Physics: Principles and applications, M. A. Omar, Addison-Wesley.
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.

6. Nano: The Essentials: Understanding Nanoscience and Nanotecnology, T. Pradeep, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2008.
7. Nanoscale Science and Technology, Robert W. Kelsall, Ian W. Hamley and Mark Geoghegan, John Wiley & Sons, Ltd., UK, 2005.
8. Introduction to Nanotechnology, Charles P. Poole Jr and Frank J. Owens, Wiley Interscience, 2003.

. Principles of Nanotechnology by Phani kumar (Scitech Publications, Chennai). 5. Nanotechnology by Schmid etal (Spriger International edition).

10. Nanomaterials by A.K.Bandhyopadhyay (New Age International Pub. New Delhi).
11. Fundementals of Nanoelectronics by George W. Hanson (Perason education, NewDelhi).
12. MEMS & Microsystems: Design & Manufacture by Tai-Ran Hsu, (Tata Macgraw Hill, New Delhi).
13. Concept Document "Nanoscience & Technology Initiative" of DST, GOI, New Delhi, 2002.
14. Winner, Langdon, "Societal Implications of Nanotechnology", Testimony to - on science of the US House of Representatives, 2003.
15. Ethics in Engineering, M. Martin & R. Schinzinger, 4th edition, McGraw-Hill.
16. Nanotechnology Regulation and Policy Worldwide (Artech House), Jeffrey H. Matsuura 2006.

14PHDPHY006: MATERIALS SCIENCE

UNIT-1

- **a. Engineering Materials:** Materials science and engineering, Classification, Levels of structure, Structure-property relationship in materials. (Ref: 1, 2 and 3)
- **b. Structure of Solids:** The crystalline and Non-crystalline states, Covalent solids, Metals and alloys, Ionic solids, The structure of silica and silicates. (Ref: 1, 2 and 3)
- **c. 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. (Ref: 2 and 5)
- **d. Crystal imperfections:** Point imperfections, Dislocation, Edge and Screw dislocation, Concept of Burger vector and Burger circuit, Surface imperfections, Colour centres in ionic solids. (Ref: 1, 2 and 3)

UNIT-2

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-$Fe_2O_{3;}$ Eutectic, eutectoid, peritectic and peritectoid systems. (Ref: 1, 2 and 3).

- **a. 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. (Ref: 1, 2 and 3)
- **b. Diffusion in Solids:** Theory of diffusion, Self-diffusion, Fick's law of diffusion, Kirkindal effect, Activation energy for diffusion, Applications of diffusion. (Ref: 1, 2, 3)

PROPERTIES OF NANOMATERIALS

UNIT-3: Electrical and mechanical properties

Introduction, Energy Storage Basics, General Information: Electrical Energy Storage Devices and Impact of Nanomaterials, Batteries, Capacitors - Gold Standards (State of the Art) for Both Batteries and Capacitors - Electrochemical Properties of Nanoscale Materials - Aerogels and Structure-Directed Mesoporous and Macroporous Solids - Nanoparticles - Nanotubes, Nanowires, and Nanorolls. Nanoscale Mechanics - Introduction, Mechanical properties, Density Considered as an Example Property, The Elasticity of Nanomaterials, Elasticity of Bulk Nanomaterials, Plastic Deformation of Nanomaterials - The Physical Basis of Yield Strength, Crystals and Crystal Plasticity, From Crystal Plasticity to Polycrystal Plasticity.

UNIT-4: Nanooptics

Absorption: direct and indirect bandgap transitions - Emission: photoluminescence and Raman Scattering, Emission: Chemiluminescence and Electroluminescence, Shape dependent optical properties, Optical absorption, Optical emission, Surface plasmon resonance (SPR) - Surface enhanced Raman scattering (SERS).

Nanocatalysis

Introduction, nanomaterials in catalysis, metals, recent progress, nanostructured adsorbant, metals, controlled pore size materials, pelletized nanocrystal, nanoparticles as new chemical reagents, metals, metal oxide reactions, nanocomposite polymers, fluids, inks and dyes, block co polymers and dendrimers, nanocrystal superlattices.

UNIT-5: Nanomagnetism

Introduction, fundamental concepts, magnetic materials, dia, para and ferromagnetism - magnetic phenomena in ferromagnetic materials, magnetic anisotropy, magnetic domains, hysteresis small particle magnetism, single domain particles, coercivity of single domain particles, superparamagnetism, the coercivity of small particles - review of some issue in nanoscale magnetism.

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.
5. Nanomaterials: Mechanics and Mechanisms, K. T. Ramesh, Springer, 2009.
6. Nanoscale materials in chemistry, Kenneth J. Klabunde, John Wiley & Sons, 2009.
7. Nanoscale materials in chemistry, Kenneth J. Klabunde, John Wiley & Sons, 2001.
8. Nanoscopic materials; Size dependent phenomena, Emil Roduner, RSC publishing, 2006.
9. Optical properties and spectroscopy of nanomaterials, Jin Zhong Zhang, World Scientific, 2009.
10. Nanoelectronics and nanosystems, K. Goser, P. Glösekötter and J. Dienstuhl, Springer 2008.

14PHDPHY007: PHYSICS OF LIQUID CRYSTALS AND POLYMER SCIENCE

UNIT-1: Liquid crystals

Introduction, classification of liquid crystals, thermotropic liquid crystals (rod like molecules), chirality in liquid crystals, nematic, cholestrric and smectic mesophases, polymorphism in thermotropic liquid crystals, polymer liquid crystals and their applications, distribution functions and order parameter, measurement of order parameters by X-ray diffraction.

a. **Theories of phase transition:** Nature of phase transitions and critical phenomena in liquid crystals, Mier-Saupe theory for nematic-isotropic and nematic-smectic A transitions, optical properties of cholesteric liquid crystals, the blue phases, pressure induced mesomorphism.

b. **Continuum Theory:** Continuum theory of the nematic state, liquid crystals in electric and magnetic fields, magnetic coherence length, Freedericksz transitions, field-induced cholesteric-nematic transition, continuum theory of smectic. A Phase, Reentrant phenomena in liquid crystals.

UNIT-2: Ferroelectric and discotic liquid crystals

Ferroelectric liquid crystals, applications of ferroelectric liquid crystals, discotic liquid crystals, he columnar liquid crystal, the discotic nematic phase. Lyotropic liquid crystals, constituents of lyotropic liquid crystals, structures of lyotropic liquid crystal phases, biological membranes.

UNIT-3: Identification of liquid crystal phases and liquid crystal technology

Identification of nematic, smectic and chiral liquid crystal phases by optical polarizing microscopy (Visual appearance and texture), Phase identification with Differential Scanning Calorimetry, liquid crystal display, the twisted nematic liquid crystal displays, liquid crystal displays using polymers, applications of liquid crystals.

POLYMER SCIENCE

UNIT-4

a. **Introduction and methods of synthesis:** Macromolecular concepts, structural feature of polymers, correlation between structure and properties of various polymerization methods.

b. **Industrial methods for polymer production & characterization techniques:** Bulk, solution, suspension and emulsion polymerization techniques, interfacial, melt and solution polycondensation, some other miscellaneous techniques.

c. **Concepts on chemical & physical properties**

Chemical bonds, polymer solubility, chemical reactivity, polymer degradations, toxicity, diffusion and permeability, flammability, recycling, reclamation etc.

UNIT-5: Rheology of polymers

Stress and strain, types of deformation, Newtonian and non-newtonian fluid, apparent viscosity, the power law, molecular hole concept, Weisenberg effect, melt fracture, ideal elastic behaviour, viscoelastic behaviour, plastic stress-strain behaviour, creep, toughness, measurement methods.

a. **Microstructure of polymers and order in crystalline polymers:** Microstructures based on chemical and geometrical structures, properties related to structures, crystalline and non-crystalline polymers degree of crystallinity, factors affecting crystallinity and crystallisability, helix structure, spherulites

b. **Transition temperatures & properties of polymers:** Glass transition temperature, melting temperature, measurement methods, factors affecting transition temperatures as well as properties, Heat distortion temperature.

REFERENCE BOOKS:

1. Liquid Crystals by S. Chandrasekhar.
2. Thermotropic Liquid Crystals by Vertogen and Jeu.
3. The Physics of Liquid Crystals by de Geenes and Prost.
4. Ferroelectric Liquid Crystals by Goodby et al.
5. Polymer Science by V. R. Gowarikar.
6. Polymer Science and Tech. of Plastics and Rubber by P. Ghosh.
7. Plastic materials and processing by A. Brent strong.
8. Introduction to polymers by Young & Lovell.

14PHDPHY008: FLOURESCENCE SPECTROSCOPY

AND X-RAY CRYSTALLOGRAPHY

UNIT - 1: Solvent and Environmental Effects on Fluorescence spectra

Stokes' shifts and solvent relaxation, general and specific solvent effects, other mechnisms for spectral shifts. Lippert equation, Derivation of Lippert equation, Applications of Lippert equation, Specific solvent effects. Temperature effects, Additional factors that affects the emission spectra - locally excited and internal charge transfer states, excites state intramolecular proton transfer, effects of viscosity, probe-probe interaction and effect of solvent mixtures.

UNIT - 2: Fluorescence Quenching

Introduction, quenchers of fluorescence, Theory of collidal quenching, Derivation of Stern-Volmer equation, Interpretation of bimolecular quenching constants, theory of static quenching, Comparision between static and dynamic quenching. Combined dynamic and static quenching with examples. Deviation from the Stern-Volmer equantion - Quenching sphere of action. Derivation of the quenching sphere of action, Origin of the Smoluchowski equation.

Mechanisms and Dynamics of Fluorescence Quenching

Introduction, comparision of quenching and resonance energy transfer, distance dependence of resonance energy transfer and quenching, encounter complexes nd quenching efficiency, mechanisms of quenching: Intersystem crossing or heavy atome effect, electron exchange, photoinduced electron transfer. Transient effects in quenching,

Fluorescence Sensing

Optical Clinical Chemistry and spectral observable, spectral observable for fluorescence sensing, Mechanism of sensing, sensing collisional quenching - oxygen sensing, chloride sensors, energy transfer sensing - pH and pCO_2 sensing by energy transfer, glucose sensing by energy transfer, ion sensing by energy transfer, theory of energy transfer sensing.

UNIT-3:

X-RAY CRYSTALLOGRAPHY

Crystal and Symmetry: Growth of single crystals, different methods, Optical properties, ferroelectric, piezoelectric, thermal properties of crystal, Crystal system- Bravais lattices- point group and space group, symmetry elements.

Quasicrystals: definition, preparation, symmetry orientation order in quasicrystals, Quasi-periodic space tiling procedure.

Macromolecules: definition, examples of macromolecules or Bio-molecules-symmetry.

X-rays: Production, white radiation characteristics, radiation - absorption edge, filters - absorption by crystals.

UNIT-4:DIFFRACTION OF

X-RAYS

Direct and reciprocal lattice, Ewald's sphere and Bragg's law, Spacing formula,Transformation equations, Interpretation of rotation photograph.

Scattering of X-rays by a distribution of electron, structure factor, calculation of electron density function, Fourier synthesis, the crystal symmetry and x-ray diffraction pattern, Friedel's law and its break down.

Electron and neutron diffraction, comparison with X-ray diffraction, significance of electron and neutron diffraction, characterization of quasicrystalline sample using electron diffraction.

The Laue method, The Powder method, rotation and Weissenberg methods, The Burger precession method.

UNIT-5:

INTENSITY DATA COLLECTION, STRUCTURE SOLUTION AND REFINEMENT

The single crystal diffractometer method, intensity data collection, corrections to intensity data- Lorentz, polarization, spot shape and absorption effects, primary and secondary extinction effects, absolute scaling and temperature factors.

Fourier techniques, Phase problem, Patterson function and its significance, Heavy atom methods, Isomorphous replacement method, anomalous scattering method, direct methods.

Cyclic Fourier refinement, the difference Fourier refinement, correction for series termination effects, temperature correction, Least squares refinement.

Derived results- bond lengths, bond angles, standard deviations in bond lengths and angles, comparison and averaging of bond lengths and angles, least square planes, absolute configuration and thermal motion.

Text Book:

1. Principles of Fluorescence Spectroscopy, Joseph R Lakowicz, Plenum Press, NewYork, 1986

References:

2. Fundamentals of Photochemistry, Rohtagi - Mukherjee K K, Wiley Eastern Ltd., 1992.
3. Photophysics of Aromatic Molecules, Birks J B, Wiley - Interscience, London 1970.
4. Azaroff. L.V.: Introduction to Solids, McGraw-Hill, New York, 1960.
5. Phillips. F.C. : Inroduction to Crystallography, Longmans, London, 1966.
6. Cullity. B. D.: Elements of X-ray crystallography, prentice hall, 2001.
7. Ponerger. J. J.: X-ray Crystallography, John Wiley, New York, 1942.
8. Burger. M. J.: Crystal Structure Analysis, John Wiley, New York, 1960.
9 Stout. H & Jensen. L. H.: X-ray Structure determination, McGraw Hill, London, 1973.
10. Duncan Mc Kie & Christins Mc Kie: Crystalline Solids, Nelson, London, 1973.
11. Azaroff. L.V. Elements of X-ray crystallography, McGraw-Hill , New York, 1968.
12. Woolfson, M. M.: X-ray Crystallography, Cambridge University Press, 1978.
13. Glusker, J. P. & True blood. K.N.: Crystal Structure Analysis, Oxford Univ. Press, 1985.
14. Bacon. G. E.: Neutron Diffraction, Oxford Univ. Press, 1962.
15. Methods of Experimental Physics, Vol. 6: Part A, Associate Press.
16. Ladd. M. F. C. & Palmer. R. A., Structure Determination, Plenum Press, New York & London, 1985.
17. Janot. C, Quasicrystals, Oxford Science Publications, Clarendon press, Oxford, 1992.
18. David Blow, Outline of crystallography for Biologists, Oxford University press, 2004.

14PHDPHY009: LASER PHYSICS AND BIOPHYSICS

UNIT-1

a. **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.

b. **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.

c. **Optical resonators:** Plane-parallel resonator, spherical resonator, confocal resonator, unstable resonator, losses in optical resonator, quality factor Q.

d. **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.

UNIT-2

a. **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.

b. ***Q*-switching and mode locking techniques:** Q-switching, production of a giant pulse; methods of Q-switching: Mechanical shutters, electro-optical shutters, acousto-optic Q-switches, 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.

c: 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: CO_2 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.

UNIT-3

a. Cell biophysics: Cell doctrine; General organisation and composition of the cells.

b. 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 energytrapping and transfer; photophosporylation.

c. Membrane biophysics: Cell membranes- structure, function and models; Transport across membranes- passive and active processes; Chemiosmotic energy transduction- van't Hoff equation; Ionic equilibrium-electrochemical potential; Nernst's equation; Flow across membranes- membrane permeability.

d. 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.

UNIT-4: 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.

UNIT-5

a. Biophysics of the immune system: The Immune system; cellular basis of immunal responses; antibodies and antigens; Immunological memory.

b. Genetic engineering: Gene-Structure, expression and regulation; Genetic code and genome organisation; Recombinant technology. Transgenic systems. Cybernetics- Genetic information and the brain; neural nets.

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.

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

14PHDPHY0010: ELECTRONICS AND INSTRUMENTATION

UNIT-1: Analog IC s and Applications

Integrated Circuits, microelectronics technology; IC packages relevant to BJT and MOS. Basic characteristics of operational amplifier: Offset error voltage and currents, inverting and non-inverting amplification using closed loop concept, input and outputimpedance. Adder and subtractor circuits, voltage to current convertor, current to voltage converter, analog integration and differentiation, analog computation, logarithmic and exponential amplifiers, comparators and voltage regulators. Waveform generators: RC-oscillator, Wein bridge oscillator, multivibrators, square and triangle wave generator, Schmitt trigger. Digital to analog convertor, analog to digital converters. (Ref.: 1 and 2)

UNIT-2: Digital IC s and applications

Combinational digital system: Binary adders, arithmetic function, decoder-demultiplexer, data selector, multiplexer, encoder, read only memory(ROM), PROMs and EPROMs. Sequential circuits and systems: 1 bit memory, clocked flip-flops, S-R, J-K, T and D-type flip-flops, shift registers, asynchronous and synchronous counters and their applications (qualitative). Microprocessors**:** architecture and operation, memory, input/output, timing instructions.(Ref.1-5)

UNIT-3: Transducers

Electrical transducer types and their selection. Resistive Transducers: Strain Gauges-resistance wire gauge and semiconductor gauge. Thermometer, Platinum resistance and thermistor. Inductive Transducer: Principle, variable reluctance type, differential output transducer, linear variable differential transducer (LVDT). Piezoelectric transducer. Photoelectric transducerss: Photomultiplier tube, Photoconductive cell, Photovoltaic cell, semiconductor photo diode, phototransistor. Thermoelectric transducers: Resistance temperature detector (RTD), Thermocouples. Signal conditioning: Need, methods, instrumentation amplifier. (Ref.: 1 and 2)

UNIT-4: Physical methods of analysis

Thermal methods: Differential Thermal Analysis (DTA); Differential Scanning Calorimetry (DSC); Thermo gravimetric analyses (TGA). Electron microscopy: Scanning electron microscopy (SEM), Transmission electron microscopy (TEM). Scanning tunnelling electron microscopy (STEM). Magnetic Resonance Spectroscopy: NMR- principle, spectrometer, application. ESR- principle, spectrometer, applications. Vacuum Technique: Production by rotary and diffusion pumps, measurement by Pirani and Penning gauges. (Ref.: 1 and 2)

REFERENCE BOOKS:

1. Microelectronics: J Millman and Arvin Grabel.
2. Electronic Fundamentals and Application: J D Ryder.
3. Digital Principles and Application: Malvino and Leach.
4. Microcomputers/Microprocessors: John L lHiburn and Paul M Julich.
5. Microprocessor Architecture, Programming and Applications: Ramesh S Gaonkar.
6. Electronic Instrumentation, H. S. Kalsi, TMH, 1995.
7. Handbook of Analytical Instruments, R. S. Khandpur, Tata McGraw-Hill Publishing Company Ltd., New Delhi.
8. Instrumental method of Analysis, Willard, Merritt, Dean and Settle, 6th Edition, CBS Publishers & Distributors, Delhi.
9. Instruments methods of Chemical analysis, Chatwal and Anand, Himalaya Publishing House.