

Hardcore PHYH 1.1: Mathematical Physics-I (4 Credits)

Revised Syllabus (Applicable from the academic year 2025-26)

Unit-I

Vectors and Tensors: Concept of Gradient, Divergence and Curl; Vector Identities; Orthogonal Curvilinear Co-ordinates. Metric in Orthogonal Curvilinear Co-ordinates; Gradient, Divergence, Curl and Laplacian in orthogonal curvilinear coordinates; Line, surface and volume integrals of vectors; Gauss's, Green's and Stoke's theorems (without proof) and their applications

Definition of Tensors; Contravariant and Covariant tensors, Inner and Outer product of tensors; Quotient Rule; Metric tensor; Examples of tensors in Physics **(13 hours)**

Unit II

Partial Differential Equations; Classification; Examples of hyperbolic, parabola and elliptic equations; PDE's solvable by direct integration; Solution of Helmholtz and Laplace equation using variable separation method;

Special Functions: Series solution method for obtaining Bessel, Legendre, Hermite and Laguerre polynomials; Generating functions, Recurrence relations and Orthogonality properties for Bessel, Legendre, Hermite and Laguerre polynomials; Spherical Bessel functions, Associated Legendre polynomials and Spherical harmonics (brief reference only); Gamma and beta functions **(14 hours)**

Unit III

Fourier Transforms; Sine and Cosine Transforms; Inverse Fourier Transforms; Properties; Convolution Theorem; Problem solving

Laplace Transforms; Definition; Properties; Inverse Laplace Transforms; Problem Solving; Convolution theorem; Solution of Differential equations using Laplace Transforms. Dirac Delta Function and its Properties. **(12 hours)**

Unit IV:

Complex Analysis: Analytic Functions: Cauchy-Riemann conditions (in Cartesian and polar form) Cauchy Integral Theorem; Cauchy Integral Formula; Singularities; Taylor and Laurent expansion; Residues; Cauchy's Residue theorem; Definite Integrals using Calculus of Residues. **(12 hours)**

Unit V:

Calculus of Variations: Variation of a system with one independent and one dependent variable; Euler's equation, Variation of a system with one independent and many dependent variables; Constraints; Lagrange multipliers, Variation subject to constraints.

Error Analysis: Definition, classification of errors, propagation of errors – addition, subtraction, multiplication, division, exponentials, logarithm. Deviation from mean value, standard deviation.

Curve Fitting: Principle of least square and method of least square fitting **(13 hours)**

REFERENCE BOOKS:

1. G. Arfken and H.J. Weber, Mathematical Methods for Physicists, 5th edition, Academic Press. (2000)
2. M.L. Boas, Mathematical Methods in the Physical Sciences, 2nd edition, Wiley (1983)
3. P.K. Chattopadhyaya, Mathematical Physics, Wiley Eastern (1990)
4. S. Hassani, Mathematical Physics, Springer (1998)
5. I.N. Sneddon, Special Functions of Mathematical Physics and Chemistry, Longman (1980)
6. L.A. Pipes and I.R. Harwell, Applied Mathematics for Physicists and Engineers, McGraw-Hill (1971)
7. C.R. Wylie and L.C. Barrett, Advanced Engineering Mathematics, 5th edition, Wiley Eastern, McGraw-Hill (1982)
8. J. Mathews, R.L. Walker, Mathematical Methods of Physics, 2nd ed., Addison-Wesley (1971)
9. K.F. Riley, M.P. Hobson and S.J. Bence, Mathematical Methods for Physics and Engineering: Cambridge University Press, Cambridge (1998)
10. M.R. Spiegel in Schaum's Outline Series, McGraw-Hill (1964) a) Vector Analysis, b) Complex Variables c) Laplace Transforms d) Differential Equations e) Matrices
11. John R Taylor, An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, University Science Books, 2nd Edition (1997)
12. Philip R. Bevington and D. Keith Robinson, Data Reduction and Error Analysis for the Physical Sciences, McGraw-Hill Education, 3rd edition (2002)

Hardcore PHYH 1.2: Classical Mechanics (4 Credits)
Revised Syllabus (Applicable from the academic year 2025-26)

Unit-I

System of Particles: Centre of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, angular momentum and energy

Lagrangian Formalism: Constraints and their classification, degrees of freedom, generalized coordinates and velocities; Virtual displacement, Principle of virtual work, D'Alembert's principle, Generalized forces, Lagrange's equation of motions of motion; Properties of Lagrangian. Simple applications of the Lagrangian formulation: 1. Free particle in a) Cartesian co-ordinates b) plane polar co-ordinates 2. Atwood's machine 3. Simple pendulum
(12 Hours)

Units-II and III

Hamiltonian Formalism: Generalized momenta, Legendre transformations and Hamilton's Equations of motion. Hamiltonian of a system; Examples of a) Hamiltonian of a particle in a central force field, b) Simple harmonic oscillator; Cyclic coordinates; Canonical transformations: Generating functions (4 basic types), Examples of canonical transformations, the harmonic oscillator in one dimension: Poisson brackets; properties; Equations of motion in terms of Poisson brackets;

Hamilton-Jacobi theory, relation to canonical transformations, Principal and characteristic function. Action-Angle variables. The Hamilton-Jacobi equation; Linear Harmonic oscillator using Hamilton-Jacobi method

(24 hours)

Unit-IV

Central force problem: Motion of a particle in a central force field, classification of orbits, stability of orbits; Reduction of two particle equations of motion to the equivalent one-body problem; Conservation theorems (First integrals of motion), Kepler's laws of planetary motion.

Scattering in a central force field; General description of scattering cross-sections; Total and differential cross sections, Impact parameter; Rutherford scattering; Center of mass and laboratory co-ordinate systems;

Motion in non-central reference frames: Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, Coriolis force, deviation due east of a falling body, the Foucault pendulum

(14 Hours)

Unit V

Elements of rigid-body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of Inertia tensor, Principal moments of inertia, classification of rigid bodies (spherical, symmetric and asymmetric); Euler's and

Chasles' theorem; Euler's equations of motion; Torque free motion of a rigid body, Precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body;

Elementary fluid dynamics: Definition of a fluid (ideal vs real), Continuum hypothesis, Basic properties of fluids: density, pressure, viscosity, compressibility, steady, incompressible and irrotational flows; Lagrangian and Eulerian descriptions; Stream lines and path lines; Velocity field and acceleration of a fluid element; Equation of continuity, Euler's equation for inviscid flow, Navier-Stokes equation, Bernoulli's equation; Viscosity and Internal Friction; Newton's law of viscosity,. **(14 Hours)**

REFERENCE BOOKS:

1. H. Goldstein, Classical Mechanics, 3rd Edition, Narosa Pub. House(1989).
2. I. Percival and D. Richards, Introduction to Dynamics, Cambridge University Press (1987)
3. L.D. Landau and Lifshitz, Classical Mechanics, Butterworth Heinemann.
4. N.C. Rana and P.S. Joag, Classical Mechanics, Tata-McGraw Hill,(1991).
5. M.G. Calkin, Lagrangian and Hamiltonian Mechanics, World Scientific(1996)
6. R.G Takwale and P.S Puranik, Introduction To Classical Mechanics, Tata-McGraw Hill (1979).
7. K.C. Gupta, Classical Mechanics of Particles and Rigid Bodies, Wiley Eastern(1988).
8. K N Srinivasa Rao, Classical Mechanics, Universities Press(2001).

Hard Core PHYH 1.3: Classical Electrodynamics (4 credits)
Revised Syllabus (Applicable from the academic year 2025-26)

Unit I :

Electrostatics: Electric field due to a continuous charge distribution; Curl and Divergence of electrostatic field, Laplace and Poisson equations; Uniqueness theorem; Method of images; Multipole expansion of electric potential

Magnetostatics: Magnetic field due to steady currents; Curl and Divergence of Magnetostatic field;

Ampere's law; Multipole expansion of magnetic vector potential;

Polarization of matter; Gauss law in the presence of a dielectric medium;

Electric field in a linear dielectric medium; electric susceptibility, permittivity, dielectric constant

Magnetization of matter; Ampere's law in the presence of medium; Magnetostatic field in a linear medium; magnetic susceptibility, permeability; **(13 hours)**

Unit II:

Time-dependent fields and Faraday's Law; Equation of continuity; Contribution of Maxwell in modifying Ampere's Law; Maxwell's equations in vacuum and in material medium; The wave equation; Plane wave solutions--Transverse nature, Propagation in free space, non-conducting and conducting medium. The concept of skin depth;

Energy in an electromagnetic field; Poynting theorem;

Maxwell's equations in terms of potentials; Gauge Transformations; Coulomb and Lorentz gauge. **(13 hours)**

Unit III:

Boundary conditions for Maxwell's equations; Reflection and Refraction of plane electromagnetic waves; Fresnel laws for reflection and refraction of electromagnetic waves polarized parallel and perpendicular to the plane of incidence; Implications of Fresnel's laws—Signification of Brewster's angle

Dispersion of EM waves; Frequency dependence of permittivity and refractive index; Normal and anomalous dispersion; Dispersion in plasma; plasma frequency

Transverse electromagnetic waves in a coaxial transmission line; Rectangular wave guides, Cavity resonators **(13 hours)**

Unit IV:

Interference: General theory of interference of two monochromatic waves. Two-beam and Multiple-beam interference with a plane-parallel plate; Fabry-Perot interferometer; Construction, resolving power and its application.

Diffraction: Integral theorem of Helmholtz and Kirchhoff Fresnel-Kirchoff diffraction Formula; Conditions for Fraunhofer and Fresnel diffraction. Fraunhofer diffraction due to a circular aperture. **(12 hours)**

Unit V: Retarded potentials, Lienard Wiechert potentials, Qualitative discussion of electric and magnetic dipole radiation;

Minkowski space; Four vector formalism, Review of Lorentz transformations; Covariant formulation of electrodynamics; Electromagnetic field tensor; Transformation of electric and magnetic fields under Lorentz transformation; Invariants of the electromagnetic field;

(13 hours)

REFERENCE BOOKS:

1. D. J. Griffiths, Introduction to Electrodynamics, 3rd edition, Pearson Education (1999)
2. J.D. Jackson, Classical Electrodynamics, 3rd edition, John Wiley (2003)
3. J.R. Reitz, F.J. Milford and R.W. Christy, Fundamentals of Electromagnetic Theory; 3rd edition, Narosa Publishing House (1979)
4. P.Lorrain and D.Corson, Electromagnetic Fields and Waves, CBS Publishers and Distributors (1986)
5. E.M.Lifshitz, L.D. Landau, L.P. Pitaevskii, Electrodynamics of Continuous Media, 2nd edition, Butterworth-Heinemann.
6. M. Born and E Wolf. Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light, 7th (Expanded) Edition, Cambridge University Press, 1999.
7. B.E.A. Saleh, and M.C., Teich, Fundamentals of Photonics, 2nd Edition, Wiley-Interscience, 2007.
8. E. Hecht, Optics, 5th Edition, Pearson Education, 2017.
9. A. Ghatak, , Optics, 6th Edition, McGraw Hill Education, 2017.
10. F. L. Pedrotti, L. S. Pedrotti and L. M. Pedrotti, , Introduction to Optics, 3rd Edition, Cambridge University Press, 2017.

Hardcore Paper 1.4: ELECTRONICS (04 Credits)
Revised Syllabus (Applicable from the academic year 2025-26)

Units-I and II

Operational Amplifier: Basic information of Op-Amp, Characteristics of an ideal operational amplifier - comparison with 741, IC Op-Amp 741, equivalent circuit, open loop Op-Amp configurations – differential, inverting and non-inverting amplifiers (qualitative). Op-Amp as a feedback amplifier – feedback configurations, voltage-series feedback amplifiers – negative feedback, closed loop voltage gain, input & output impedance, bandwidth and voltage follower, differential amplifiers.

Applications of an Operational Amplifier-I: Linear Applications: Summing, scaling, averaging amplifiers, ideal and practical integrator, and differentiator. Non-Linear Applications: Comparators, Schmitt-trigger, 555 timer –astable & monostable multivibrator.
(24 hours)

Unit III

Applications of an Operational Amplifier-II

Active Filters: First order & second order low-pass filters, first order & second order high-pass filters, band-pass filters, all pass filters (qualitative).

Interface Circuits: D/A Converters - R-2R Ladder, Weighted Register DAC; A/D Converters- Successive Approximation, Dual Slope ADC, Accuracy & Resolution.
(13 hours)

Unit-IV

Boolean algebra and Logic Gates: Number systems, binary, decimal, octal, hexa decimal; Boolean operations and expressions, Boolean analysis of logic gates, universal gates, simplification of Boolean expression, SOP & POS simplification, NAND and NOR implementation, Karnaugh map: two, three and four variable map, simplification of Boolean expressions using K-map, don't care conditions; Tabulation method, determination and selection of prime implicants.
(13 hours)

Unit-V

Combinational and Sequential logic circuits: Introduction, design procedure, Digital adders and subtractors; Multiplexer and demultiplexers.

Flip Flops, types - SR, JK, D & T, MS-JK flip-flops, triggering of Flip Flops, timing diagrams, Flip flop excitation tables; Registers and types; Counters, Synchronous and Asynchronous Counters.

Basics of Optoelectronics: Principle, working and choice of materials for LED, Photodiode and Laser diode.
(14 hours)

REFERENCES BOOKS :

1. Ramakanth A Goyakwad, “Op-Amp and Linear Integrated Circuits”: 2015.
2. M. Morris Mono, “Digital Logic and Computer Design”, PHI,2001.
3. Albert Malvino, David J Bates, “Electronics Principals”2002
4. T. L. Floyd , “Digital Fundamentals”, 7th edn. (Pearson Education Asia 2002).
5. S L Kakani, K C Bhandari, “Electronic Devices and Circuits”2012
6. A P Malvino and D P Leach, “Digital Principles and Applications”, TATA McGraw Hill, 2006.
7. Robert F. Coughlin and Fredericks, Driscoll, “Operational Amplifiers and Linear Integrated Circuits”: PHI 2001.
8. D Chattopadhyaya, “Electronics-Fundamentals and Applications”, 2008.
9. Pallab Bhattacharya, “Semiconductor Optoelectronic Devices”, Pearson Education, (Singapore pvt.ltd.), Printed in India by Tan Prints(I), Pvt. Ltd., 2004.

Hardcore PHYH 2.1: Mathematical Physics-II (4 Credits)
Modified Syllabus (Applicable from the academic year 2025-26)

Unit I

Linear Vector Spaces: Definition; Examples of different kinds of vector spaces such as space of polynomials; Complex Euclidean Space; Inner Products; Schwartz inequality; Orthogonality; Gram-Schmidt Orthogonalisation procedure and examples
(12 hours)

Unit II

Matrices as Linear Transformations(operators) and their representation in different basis; Effect of change of basis; Types of Matrices, Eigenvalues and Eigenvectors, Similarity transformations, Diagonalization of matrices
Direct product of two vector spaces—The Kronecker product space **(12 hours)**

Unit III

Group Theory: Definition, Groups as symmetry operations; Finite groups; Invariant subgroups Homomorphism and Isomorphism. Group representations; Equivalent and Inequivalent representations; Invariant subspaces, Reducible and Irreducible representations. Schur Lemma, Group characters.

General structure of Lie groups and Lie algebras. Rank of a Lie group. Casimir operators; General linear groups $GL(n,C)$ and $GL(n,R)$; Special linear groups $SL(n,C)$, $SL(n,R)$; Orthogonal groups $O(n, C)$, $O(n, R)$, $SO(n, C)$, $SO(n,R)$; Unitary groups $U(n)$, $SU(n)$; Homogeneous Lorentz group $SO(3,1)$ **(14 Hours)**

Unit IV

Green's functions: Green's function for 1-dimensional and higher dimensional problems. Eigen function expansion for Green's functions; Fourier transform method for finding Green's functions; Green's function for the Laplacian, Heat equation and wave equation with source.

Linear Integral Equations: Transformation of a differential equation in to an Integral equation. Fredholm and Volterra integral equations of the first and second kind, Neumann series method and separable kernel method of solving integral equations, Hilbert-Schmidt Theory; **(14 Hours)**

Unit V

Monte Carlo Method of Calculations: Random variables, discrete random variables, continuous random variables, probability density function, discrete probability density function, continuous probability distributions, cumulative distribution function, law of large numbers, central limit theorem, random numbers and their generation, tests for randomness, inversion random sampling technique including worked examples, integration of simple 1-D integrals including worked examples. **(12 hours)**

REFERENCE BOOKS:

1. G. Arfken and H.J Weber, Mathematical Methods for Physicists, Academic Press, 5th ed (2000).
2. G Barton, Elements of Green's Functions and Propagation, OUP(1989)
3. A.W. Joshi, Matrices and Tensors in Physics, 3rd edition, Wiley(2002)
4. A.W.Joshi, Elements of Group Theory for Physicists, 4th edition, New Age *International* (1997).
5. K.N Srinivasa Rao, Linear Algebra and Group Theory for Physicists, 2nded, New Age *International* (1996)
6. K.N Srinivasa Rao, The Rotation and Lorentz Groups and their Representations for Physicists, Second Edition, Wiley(1988).
7. P.K. Chattopadhyay, Mathematical Physics, Wiley Eastern (1990).
8. Athanasios Papoulis and S. Unnikrishna Pillai, Probability, Random Variables, and Stochastic Processes, Fouth Edition, McGraw Hill.2001
9. Malvin H. Kalos and Paula A. Whitelock, Monte Carlo Methods, Second edition, Wiley-VCH, Verlag GmbH & Co. KGaA.2008

Hardcore PHYH 2.2: Elements of Nuclear and Particle Physics (4 Credits)

Revised Syllabus (Applicable from the academic year 2025-26)

Unit I

General properties of nuclei: Nuclear radius by mirror nuclei, muonic X-ray method, electron scattering. Binding energy, spin, nuclear electric and magnetic moments, mass, parity.

Nuclear reactions: Q value of nuclear reactions, threshold energy, reaction induced by proton, deuteron, alpha particles, and gamma particles. Concept of nuclear reaction cross section; Bohr's independence hypothesis; Experimental verification

Nuclear forces: General features of nuclear forces; Short range, saturation and charge independence, spin dependence, Exchange character, non-central, isospin formalism. Yukawa's theory of nuclear forces **(13 Hours)**

Unit II

Nuclear models: Liquid Drop Model; semi-empirical mass formula, application to isobar stability and nuclear fission. Fermi-gas model, Kinetic energy in the ground state, asymmetry energy, nuclear evaporation. Shell Model, Evidence of magic numbers, and Prediction of energy levels in an infinite square well potential. spin orbit coupling, Prediction of ground state spin, parity and magnetic moment of odd-A nuclei. **(13 Hours)**

Unit III

Interaction of charged particle with matter: Interaction of heavy charged particle with matter, Bethe-Bloch formula. Interaction of fast electrons with matter, its energy loss in both collision and radiation, range-energy relations, radiation length.

Interaction of Gamma rays matter: Interaction mechanisms; photoelectric absorption. Compton scattering and pair production.

Nuclear Detectors: Scintillation process in organic and inorganic Scintillators, NaI (Tl) based gamma ray spectrometer (GRS). **(13 Hours)**

Unit IV

Radioactive decay: Alpha decay, General properties, Geiger-Nuttall law, Gamow's theory of Alpha decay.

Beta decay: General properties, Neutrinos and Anti-neutrinos, Fermi-theory of beta decay, Fermi Curie plots and 'ft' values, selection rules, electron capture.

Gamma Decay; Multipolarity of gamma rays, selection rules, Internal conversion (Qualitative) **(12 Hours)**

Unit V

Elementary Particle Physics:

Classification of fundamental forces and their properties. Types of interaction between hadrons and leptons.

Symmetries and Conservation Laws: Translation, rotation, time reversal, charge, isospin, parity symmetry, Non-conservation of parity in weak interactions (Cobalt 60 experiment); Handedness of neutrinos, Lepton number conservation, Lepton family and three generations of neutrinos, Charge conjugation symmetry, CP violation in weak interactions, Strange particles, Conservation of strangeness in strong interactions, Baryon number conservation, Gellmann-Nishijima formula, Eightfold way (qualitative)

Quarks and gluons; Quark model; Quark content of Mesons & Baryons; Standard model (Qualitative). **(13 Hours)**

REFERENCE BOOKS:

1. W E Burcham and M Jobes, Nuclear and Particle Physics, Addison Wesley (1995)
2. K.S. Krane, Introductory Nuclear Physics, John Wiley (1988).
3. W. Greiner & J A Maruhn, Nuclear Models, Springer Verlag(1996).
4. W.S.C. Williams, Nuclear and Particle Physics, Clarendon Press (1991).
5. D.H. Perkins, Introduction to High Energy Physics, Addison Wesley (1987).
6. D.Griffiths, Introduction to Elementary particle physics, Wiley (1987)
7. J.J. Sakurai, Invariance Principles and Elementary Particles, Princeton University Press (1964).
8. D.B. Lichtenberg, Unitary Symmetries and Elementary Particles, 2nd Edition, Academic Press (1978)
9. J.M. Blatt and V.F. Weisskopf. Theoretical Nuclear Physics. John Wiley (1952).
10. S.B Patel, Nuclear Physics, New Age(1991)
11. W N Cottingham and D A Greenwood, An Introduction to Nuclear Physics, Cambridge(2001)
12. I S Hughes, Elementary Particle Physics, 3rd ed, Cambridge(1991)
13. W.E Meyerhof, Elements of Nuclear Physics, McGraw Hill(1967)
14. S N Ghoshal, Nuclear Physics, 3rd ed, S Chand(2003)

Hardcore PHYH 2.3 Elements of Condensed Matter Physics (4 Credits)
Revised Syllabus (Applicable from the academic year 2025-26)

Unit I

Crystal structure: Periodic array of atoms, Lattice translation vectors, Basis and the Crystal Structure, Primitive lattice cell, Fundamental types of Lattices, Two dimensional lattice types, Three-Dimensional lattice types, Index systems for Crystal planes, Crystal structures, Sodium chloride structure, Cesium Chloride structure, Hexagonal Close-Packed structure (hcp), Diamond Structure, Cubic Zinc Sulphide structure, Direct imaging of atomic structure, Non-ideal Crystal structures, Random Stacking and Polytypism.

Diffraction of waves by crystals: X-rays, Neutrons, Electrons diffraction by crystals. Bragg's Law in direct and reciprocal lattice, Atomic scattering factor, Geometrical structure factor, Study of systematic absence in Simple cubic crystals, Experimental methods of diffraction techniques-Laue, rotation and powder method. **(13 hours)**

Unit II

Types of binding: Ionic binding, Cohesive energy of Ionic crystals, Evaluation of Madelung constant for NaCl, Covalent Bonding, Metallic Bonding, Hydrogen Bonding, Van der Waals Bonding, Examples.

Free Electron theory of Metals: Fermi-Dirac distribution, Derivation of electronic specific heat, Paramagnetism of free electron. The Fermi surface, electrical conductivity, effects of Fermi surface on thermionic emission from metals, field enhanced electron emission from metals, Change of work function due to adsorbed atoms, Hall Effect, Thermal conductivity.

Lattice Dynamics: Wave motion in monatomic and diatomic lattices, normal modes of vibrations, Phonons, Debye theory of specific heat, thermal conductivity, Anharmonicity and thermal expansion. **(13 hours)**

Unit III

Energy bands: Nearly Free Electron Model, Origin of Energy Gap, Magnitude of the energy gap, Bloch functions, Kronig-Penny Model, Wave equation of electron in a periodic potential, Restatement of Bloch theorem, Crystal momentum of an electron, Solution of central equation, Kronig Penny model in Reciprocal Space, Empty lattice approximation, Approximate solution, Near a zone boundary, Number of orbitals in a band metals and insulators.

Semiconductor Crystals: Band Gap, Equation of Motion, Physical Derivation of $\hbar k = F$, Holes, Effective Mass, Physical Interpretation of the effective mass, Effective masses in semiconductors, Silicon and Germanium, Intrinsic carrier concentration, Intrinsic Mobility, Conductivity, Donor States, Acceptor States, Thermal Ionization of Donors and Acceptors. **(12 hours)**

Unit IV

Dielectric Properties: Introduction, review of basic formulae, microscopic concepts of polarization, different kinds of polarization, in solids (qualitative), Macroscopic electric field: depolarization field E_1 , local electric field at an atom, Lorentz-Lorentz relation, electronic polarizability, Different types of electric polarization in solids(qualitative).

Magnetic Materials: Introduction, response of a substance to magnetic field, atomic theory of magnetism, Quantum number, origin of a permanent magnetic moments, Classification of magnetic materials, classical theory of diamagnetism, paramagnetism and ferromagnetism.

(13 hours)

Unit V

Non-crystalline Solids: Diffraction Pattern, Monoatomic Amorphous Materials, radial distribution function, Structure of Vitreous Silica, SiO_2 Glasses, Viscosity and the Hopping rate, Amorphous ferromagnets, Amorphous Semiconductors and their electrical properties;

Superconductivity: Introduction, sources of superconductivity, response of magnetic field, Meisner effect, Thermodynamics of superconductors, London equations, Cooper pairs, Temperature dependence of superconducting energy gap(qualitative), coherence length, elements of BCS theory, Flux quantization(two fluid model).

(13 hours)

REFERENCE BOOKS:

1. Charles Kittel, Introduction to Solid State Physics (V edition), Wiley,1976.
2. A.J. Dekker, Solid State Physics, Prentice Hall, (1957).
3. N.W.Ashcroft and N.D.Mermin, Solid State Physics, Saunders college publishing (1976).
4. M.A. Omar, Elementary Solid State Physics, Addison Wesley, New Delhi,(2000).
5. A. C. Rose-Innes and E. H. Rhoderick, *Introduction to superconductivity*, Oxford University Press.
6. Charles Kittel, Introduction to Solid State Physics (VII edition), Wiley,2005.
7. S.O. Pillai, Solid State Physics, New Age International Publication (2002).
8. M.A.Wahab, Solid State Physics, Narosa Publishing House, New Delhi(1999).
9. H.C.Gupta, Solid State Physics, Vikas Publishing House, New Delhi (2002).

Hardcore PHYH 2.4: Quantum Mechanics-I (4 Credits)
Revised Syllabus (Applicable from the academic year 2025-26)

Units I and II

Basics: Inadequacies of Classical Physics; Dual nature of matter and waves; Double-slit experiment for photons and electrons as an illustration. Bohr Complementarity and Correspondence Principles; Waves, wave packets, phase velocity and group velocity; Time-dependent Schrödinger equation; Time independent Schrodinger equation as an energy eigenvalue equation; Born's interpretation of wave function; Fundamental Postulates of Quantum Mechanics; Superposition principle, Canonically conjugate variables; Expectation values-in terms of eigenvalues of an observable; Continuity equation in probability density, probability current; Generalized uncertainty principle; Ehrenfest's Theorem; Eigenvalues and eigenvectors of a complete set of mutually commuting operators. Dirac Bra-Ket notation; Position and momentum representations; Virial theorem; Problems on normalization of wave functions, evaluation of expectation values, probability current, Commutators of two observables; (26 hours)

Unit III

Exactly solvable problems in one-dimension: Admissibility criterion on wave functions; Bound states, examples of particle in a box, Finite potential well, Simple Harmonic Oscillator--wavefunction and operator approach; Unbound states, Examples of scattering from a one-dimensional rectangular potential well and barrier, Tunneling, Transmission and Reflection co-efficients: , Ramsauer -Townsend effect, Resonance Scattering, Alpha decay, cold emission of electron in a metal, (12 Hours)

Unit IV

Angular Momentum: Orbital Angular Momentum: Angular momentum operators and their Algebra. Eigenvalues and eigenfunctions of L^2 and L_z ;

SPIN: Stern-Gerlach experiment and the concept of spin; Use of Angular momentum algebra to establish half odd integral quantum numbers for angular momentum; Matrix representation for spin angular momentum operators of a spin $\frac{1}{2}$ particle; Pauli-spin matrices and their properties **Addition of angular momentum :** Addition of angular momentum, Eigenfunctions and eigenvalues of total angular momentum operator $\mathbf{J}^2$ and $\mathbf{J}_z$; Uncoupled and coupled bases in the total angular momentum space; Clebsch- Gordon co-efficients; Evaluation of C-G coefficients for a two electron system; Singlet and Triplet state (13 hours)

Unit V

Exactly solvable problems in three dimensions: Wavefunction of a free particle in Cartesian, cylindrical and spherical coordinates. Bound state problems. Examples of a particle confined in a rectangular box, cylindrical and spherical wells; Simple harmonic oscillator in 3-dimensions; Degeneracy of energy levels; Two-particle bound state problems. Reduction to a one-particle problem. Schrodinger's equation for the hydrogen atom and its solution, properties of its wavefunctions. Degeneracy of energy levels; Position expectation value in the ground state of Hydrogen atom; (13 Hours)

REFERENCE BOOKS:

1. **E. Merzbacher**, Quantum Mechanics. 3rd edition, John Wiley(1994).
2. **V.K. Thankappan**, Quantum Mechanics, Wiley Eastern (1985).
3. **P.M. Mathews and K. Venkatesan**, A Textbook of Quantum Mechanics, TMH(1977).
4. **R.L.Liboff**, Introduction to Quantum Mechanics,Pearson Education(2003).
5. **R. Shankar**,Principles of Quantum Mechanics,2nd edition,Plenum US (1994).
6. **A Ghatak and S Lokanathan**, Quantum Mechanics, Theory and Applications,Macmillan(2004)
7. **LI Schiff**, Quantum Mechanics, 3rd ed. McGraw-Hill(1968).
8. **J.J. Sakurai**, Modern Quantum Mechanics, Addison Wesley (1985).
9. **B.Bransden,C.Joachain**, Quantum Mechanics, 2nd ed, Pearson/Prentice Hall, (2000).
10. **J.S.Townsend**,A Modern Approach to Quantum Mechanics, 2nd ed, McGraw Hill.
11. **C.Cohen-Tannoudji, B.Diu, F.Laloe**, Quantum Mechanics (Volume 1 and 2) Wiley-Interscience(1996).

Open Elective PHYE 2.5: Atmospheric Physics 02 credits;

Unit I

Atmospheric composition:

Layers of the atmosphere, Atmospheric composition from surface to exosphere, Major and trace gases in the atmosphere, Weather versus Climate: Definitions and differences:

Earth's radiative balance; Instruments for meteorological observations: Scope and importance of atmospheric physics: **(5 hours)**

Unit II

Atmospheric thermodynamics:

Sun as the primary source of energy; Black body radiation: Planck's law, Stefan's Boltzmann law, Wien's displacement law, Kirchhoff's law; Solar constant and energy received by earth, Albedo and Earth's reflectivity; Spectral distribution of solar radiation and atmosphere interaction, Absorption spectra of atmospheric gases **(8 hours)**

Unit III

Remote sensing of the atmosphere: Radar equation (conceptual); Signal processing and detection; Various type of atmospheric radars; Application of radars to study atmospheric phenomena; Atmospheric correction techniques for remote sensing data; Lidar and its applications, Application of Lidar to study atmospheric phenomenon. **(7 hours)**

Unit IV

Radiative transfer in the atmosphere:

Absorption, reflection and scattering of solar radiation, Role of gases, clouds and aerosols; Rayleigh scattering and Mie scattering; Beer-Lambert law;

Atmospheric Aerosols: Classification and properties; Production and removal mechanisms, Concentrations and size distribution; Modification of earth's energy balance (Radiative effects); Greenhouse effect, aerosol radiative effects (direct and indirect); Health effects linked to radiative transfer; Ozone layer depletion, global warming; Brief Overview on Air pollution/pollutants—Health effects **(10 hours)**

REFERENCE BOOKS:

1. C. N. Banwell and E.M McCash, Fundamentals of Atmospheric Physics, Tata McGraw Hill
2. Atmospheric chemistry and physics: from air pollution to climate change, John H. Seinfeld, Spyros N. Pandis, 2nd edition, John Wiley & sons, inc.
3. K Siddartha, Atmosphere, Weather and Climate, Kishore Publications, New Delhi (2001)
4. Thomas Lillesand, Ralph W Kiefer, Jonathan Chipman, Remote Sensing and Image interpretation, Wiley, 7th edition (2015)
5. S. Fukao and K. Hamazu, Radar for meteorological and atmospheric observations, Springer Japan (2014)
6. George Joseph and C. Jeganathan, Fundamentals of Remote Sensing, (2017). 3rd Edition, Universities Press (India), Hyderabad (2018)

Hardcore PHYH 3.1: Atomic and Molecular Physics (4 Credits)
Modified Syllabus (Applicable from the academic year 2025-26)

Unit I

Brief review of early atomic models of Bohr and Sommerfeld: One electron atom; Atomic orbitals, spectrum of Hydrogen atom: Energy levels and selection rules, Rydberg atoms, relativistic correction to the kinetic energy, spin – orbit interaction and fine structure in alkali spectra, Lamb shift. Magnetic dipole hyperfine structure, energy shift, hyperfine transition on Hydrogen, Isotope shifts **(13 Hours)**

Unit - II

Interaction with external fields: (Quantum mechanical treatment) Zeeman effect and Anomalous Zeeman effect – magnetic interaction energy, selection rules, splitting of levels in Hydrogen atom. Linear Stark effect order correction to energy and Eigen states: Paschen-Back effect, Two electron atom: ortho and para states, role of Pauli Exclusion Principle, level schemes of two electron atoms. Many electron atoms: LS and JJ coupling scheme, Lande interval rule **(13 Hours)**

Unit III

Microwave Spectra: Theory of rotational spectra of diatomic molecules-experimental techniques structural information.
Infrared spectra: Theory of vibrating rotator, vibration-rotation spectra, IR spectrometer. Application to chemical analysis.
Molecular Spectra: Basic principles of NMR, resonance condition, NMR spectrometer, structural studies using NMR **(12 Hours)**

Unit IV

Raman Spectroscopy: Rotational and vibrational Raman spectra. Correlation with IR spectra Polarization of Raman lines. Laser Raman studies.
Electron Spectroscopy: Electronic spectra of diatomic molecules, coarse and fine structure. Franck-Condon principle. Rotational fine structure, formation of band head and shading. **(11Hours)**

Unit V

Fluorescence and Phosphorescence: Mirror image symmetry of absorption and Fluorescence bands, basic principles of photoelectron spectra. Determination of ionization potential.
Lasers: Population Inversion techniques: Electrical and Optical pumping, building up of Laser action, criteria for lasing, threshold condition. Overview to Gas laser, solid state laser, semiconductor laser.
Overview of atomic clocks and their applications: Introduction to quartz crystals: stability, accuracy and crystal/clock characterization method (Allan deviation); atomic clocks over quartz oscillator or conventional clocks. **(14 hours)**

REFERENCE BOOKS:

1. C N Banwell and E M Mccash, Fundamentals of Molecular Spectroscopy, 4th ed, TMH(1994)
2. B.H. Bransden and C.J. Joachain, Physics of Atoms and Molecules, Longman Inc. New York (1983).
3. E.U. Condon and G.H. Shortley. The Theory of Atomic spectra, first edition, Cambridge University Press (1935)
4. G.Herzberg, Molecular Spectra and Molecular Structure -I Spectra of Diatomic Molecules, first edition, D. Van Nostrand Inc. (1939).
5. G. Herzberg, Molecular Spectra and Molecular Structure -II Infrared and Raman Spectra of Polyatomic Molecules, first edition, D. Von Nostrand Inc. (1956).
6. G. Herzberg, Atomic Structure and Atomic Spectra, Dover Pub. Co. 2nd Edition, (1944).
7. H.E. White, Introduction to Atomic Spectra. McGraw-Hill (1954).
8. P.S. Sindhu, Molecular Spectroscopy, Tata McGraw-Hill (1985).
9. E. U. Condon and H. Odabasi, Atomic Structure. Cambridge Universtiy Press (1980).
10. H.A. Bethe and E.E. Salpeter. Quantum Mechanics of One- and Two- Electron Atoms, Plenum Press (1977).
11. James Jespersen and Jane Fitz-Randolph, From Sundials to Atomic Clocks, Dover Publications, New York (1999):
12. F G Major, The Quantum Beat: Principles and Applications of Atomic Clocks, Springer (2007):

Hardcore PHYH 3.2: Quantum Mechanics-II (4 credits)

Revised Syllabus (Applicable from the academic year 2025-26)

Unit I

Approximation methods I:

Time Independent perturbation Theory: Non-degenerate case, Corrections to the energy and wavefunction upto second order. First order degenerate perturbation theory. Stark and Zeeman effect;

Rayleigh-Ritz Variational method: variational principle, trial wavefunctions, best estimate of the ground state energy; Illustration using simple examples; Ground state energy of the Helium atom;

The WKB Approximation: The Classical Region; Tunneling; (13 Hours)

Unit II

Approximation methods II: Time dependent perturbation theory: Perturbation expansion, Formal solution of the Schrodinger equation in a time dependent perturbing potential; First order perturbation, Harmonic perturbation; mechanism of stimulated emission and Resonant absorption; Spontaneous emission; Transition to continuum, Fermi golden rule; The Einstein's A and B coefficients; Einstein's derivation of Planck Radiation formula; Adiabatic and Sudden approximation, validity and illustration with examples.

Interaction of Radiation with atom: The semi classical treatment, dipole approximation; Selection rules for electric dipole transitions; (13 Hours)

Unit-III

Quantum Dynamics: The Schrödinger, Heisenberg and Interaction pictures. Simple illustrations of Heisenberg picture for free particle and linear harmonic oscillator.

Time dependent problems: Time evolution of two level system kept in (i) constant magnetic field (ii) sinusoidal magnetic field.

Pure and Mixed states: The density matrix, Properties; equation of motion for density matrix (Quantum Liouville equation); Density matrix for spin $\frac{1}{2}$ system; Qubits; Brief introduction to quantum computation; (12 hours)

Unit IV

Time independent scattering Theory: Scattering cross section. scattering amplitude and differential cross section. Green's functions in scattering theory; Born approximation, validity, example of Yukawa potential, Rutherford scattering formula.

Method of partial waves: Motivation, Partial wave expansion, scattering amplitude, phase shifts, partial wave amplitude, differential and total cross sections for short range potentials. Optical theorem. Low and high energy scattering from a hard sphere. Low energy scattering from a potential well and bound states, scattering length. Resonance scattering and quasi-bound states, Breit-Wigner formula.

(12 Hours)

Unit V

Relativistic Quantum Mechanics: The Klein-Gordon (KG) equation. Plane-wave solutions. KG equation in a electromagnetic field. Continuity equation. Limitations of KG equation and its correct interpretation. Non-relativistic reduction of KG equation.

Dirac Equation: The free particle Dirac equation. Pauli-Dirac representation. Continuity equation. Plane wave solutions of the Dirac equation in the Pauli-Dirac representation, Normalization. Dirac equation in an electromagnetic field. Non-relativistic approximation., Conservation of angular momentum; Spin of Dirac particles; Negative energy solutions and Hole theory. Covariant formulation of Dirac equation; Concept of Helicity; Brief discussion on application of Dirac theory to the hydrogen atom; Lamb Shift; Need for Quantum Field Theory and its basic premise. **(14 hours)**

REFERENCE BOOKS

1. E. Merzbacher, Quantum Mechanics, 3rd edition, John Wiley(1994).
2. V. K. Thankappan, Quantum Mechanics, Wiley Eastern (1985).
3. P. M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw-Hill (1977).
4. R. L. Liboff, Introduction to Quantum Mechanics, Pearson Education(2003).
5. R. Shankar, Principles of Quantum Mechanics, 2nd edition, Plenum US (1994).
6. A. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Macmillan (2004)
7. L. I. Schiff, Quantum Mechanics, 3rd ed. McGraw-Hill(1968)
8. B. Bransden and C. Joachain, Quantum Mechanics, 2nd edition, Pearson/Prentice Hall (2000).
9. J. J. Sakurai, Modern Quantum Mechanics, revised edition, Addison Wesley(1985).
10. J. J. Sakurai, Advanced Quantum Mechanics, Addison Wesley(1967).
11. R. P. Feynman, R. B. Leighton and M. Sands, The Feynman Lectures on Physics, Vol.3, Narosa Pub. House(1992).
12. J. S. Townsend, A Modern Approach to Quantum Mechanics, 2nd ed, McGraw Hill.
13. C. Cohen-Tannoudji, B. Diu, and F. Lalœ, Quantum Mechanics (2 vol. set), Wiley-Interscience (1977):
14. Ryder H. Lewis, Ghatak A. K and Lokanathan S, Quantum Field Theory, 6th ed, Cambridge university (1985).
15. Mandal F and Shaw G, "Quantum Field Theory" (John Wiley and Sons Ltd., 1984)
16. V. Devanathan, "Relativistic Quantum mechanics and Quantum Field Theory", (Narosa 2011)

Hardcore PHYH-3.3: Statistical Mechanics (4 Credits)

Unit I

Fundamentals: Systems with a very large number of degrees of freedom: the need for statistical mechanics: Specification of the states of a system; Microstates and Macrostates; Postulate of equal a priori probability; Phase space; The concept of ensembles; Ergodic Hypothesis; Liouville's Theorem; Density of states; Dependence of density of states on energy; Quasi-static processes; Thermodynamic potentials; Maxwell's relations and its applications **(13 hours)**

Unit II and III

Classical Statistical Mechanics: Reversible and Irreversible processes and the attainment of equilibrium; Thermal interaction between macroscopic systems and approach to equilibrium; Boltzmann formula for entropy; Microcanonical, Canonical and Grand Canonical Ensembles; Thermodynamic Probability, Canonical and Grand Canonical Distributions; Partition function and its properties; Translational, rotational, vibrational and electronic partition functions; Derivation of Thermodynamic relations from statistical mechanics; Gibbs paradox and its resolution; Equipartition theorem and its applications; **(25 hours)**

Unit IV

Quantum Statistical Mechanics: Systems of identical, indistinguishable particles, spin, symmetry of wave functions; Bosons; Fermions; Pauli Exclusion principle; Derivation of the Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac distributions functions in the quantum scenario; Ideal Bose-Einstein Gas; Bose-Einstein condensation; Thermodynamic properties of an ideal Bose-Einstein gas; Liquid Helium; Two-fluid model of liquid helium II, Superfluidity; Ideal Fermi-Dirac Gas; Electrons in metals; thermionic emission; **(14 hours)**

Unit V

Irreversible Processes and fluctuations; One dimensional Random Walk Problem; Analysis of Brownian motion; Einstein Theory; Langevin Theory; Fluctuation-Dissipation Theorem; Fourier Analysis of Random functions; Wiener-Khintchine relations; Noise in electrical circuits; Nyquist's theorem; Onsager Relations. **(12 hours)**

REFERENCE BOOKS:

1. F.Reif, Fundamentals of Statistical and Thermal Physics, McGraw-Hill (1988)
2. E.S.R. Gopal, Statistical Mechanics and properties of matter, Ellis Horwood (1974)
3. R. Bowley and M. Sánchez, Introductory Statistical Mechanics, 2nd Edition, Oxford University Press (1999)
4. W. Greiner, L. Neise, and H. Stöcker, Thermodynamics and Statistical Mechanics, Springer-Verlag (1995)
5. K. Huang, Statistical Mechanics, 2nd Edition, John Wiley & Sons (1987)
6. D. Chandler, Introduction to Modern Statistical Mechanics, OUP (1987)
7. H. B. Callen, Thermodynamics and an Introduction to Thermostatistics, 2nd Edition, John Wiley & Sons (1985)
8. Sheng-keng Ma, Statistical Mechanics, World Scientific (1985)
9. R.K.Pathria, Statistical Mechanics, 2nd edition, Butterworth-Heinemann (1996).
10. B.B. Laud, Statistical Mechanics, 3rd edition, New Age International(2022)

PHYS 3.4.1: Condensed Matter Physics – I (4 Credits)
Modified Syllabus (Applicable from the academic year 2025-26)

Unit I

Electrical Conductivity of Metals: Simple model, ideas of drift velocity and relaxation time. Boltzmann transport equation, Sommerfeld theory of electrical conductivity, temperature dependence of resistivity of metals at high, low and at very low temperatures. Electron-phonon collision, Matthiessen's rule and concept residual resistivity.

Thermal Conductivity of Insulators and Metals: Phonon-Phonon interactions-Normal and Umklapp process, Thermal conductivity of insulators at high and at low temperatures. Effect of impurities and imperfections on the thermal conductivity. Effect of finite size of the specimen, Derivation of the expression for thermal conductivity of metals. Comparison of (i) Thermal conductivity of metals due to electrons and phonons and (ii) Thermal conductivity of metals and dielectrics.
(12 hours)

Unit II

Hopping conduction: Thermoelectric effects, thermo electric power, solid state description of thermoelectric effect, Kelvin's thermodynamic relations, analysis of thermoelectric generators, basic assumptions, temperature distribution and thermal energy transfer for generator, co-efficient of performance for thermoelectric cooling. Methods to determine TEP, and to determine carrier concentration; Polarons, small polaron band conduction; large polaron band conduction; small polaron hopping conduction;
Optical properties: Interaction of phonons and electrons with photons; direct and indirect transition; Polaritons;
(12 hours)

Unit III and IV

Dielectric Properties: Macroscopic and microscopic view of dielectric response, complex dielectric constant and dielectric losses, Dielectric relaxation in solids, Debye equations. Electronic, ionic and orientation polarisabilities. The classical and quantum theory, electronic polarisation and optical absorption. Experimental determination of dielectric constant.

Ferroelectrics: General properties and classifications of ferroelectrics, dipole theory of ferroelectricity, objections against the dipole theory, ionic displacements and the behavior of Barium Titanate above Curie temperature: Ferroelectric domains, Theory of spontaneous polarization of Barium Titanate, Polarisation catastrophe. Thermodynamics of ferroelectric transitions, Ferroelectrics for transducer and detector applications.

Piezoelectric effect: History of Piezoelectric effect, Applications of Piezoelectric effect, applications of the direct effect, applications of the inverse effect, applications of the combined effect, Mechatronic applications.
Piezoelectric material parameters, Electric behavior, Dielectric behavior, mechanical behaviour: elasticity, Electro-mechanical behavior, Piezo-electric constitutive equations, Symmetry and Piezoelectricity, Piezoelectric ceramics operation modes, Piezoelectric constants, Coupling Coefficient.
(24 hours)

Unit V

Impurity semiconductors: Thermal ionization of impurities, impurity states and band model, statistics of impurity semiconductors; case of incomplete ionization of impurity levels (very low temperatures). Conductivity, Hall effect and magneto resistance, band structure of real semiconductors, High Electric field and hot electrons, Gunn effect.

Semiconductor Devices: Introduction, p-n junction, the junction transistors, tunnel diode MIS tunnel diode, Degenerate and non-degenerate semiconductor, MIS Switch Diode, MIM Tunnel diode. IMPATT diode. Gunn Diode semiconductor lasers, field effect transistor, the semiconductor lamp. MOSFET, quantum hall Effect, hetero junctions, quantum wells and super lattices (qualitative).

(16 hours)

REFERENCE BOOKS:

1. Charles Kittel, Introduction to Solid State Physics (V edition), Wiley, 1976.
2. A.J. Dekker, Solid State Physics, Prentice Hall, (1957).
3. N.W.Ashcroft and N.D.Mermin, Solid State Physics, Saunders College publishing (1976).
4. J.S. Blakemore, Solid State Physics,(II edition), Cambridge University Press,(1974).
5. Harald bath and Hans Luth, Solid State Physics, Springer International Student editon, Narosa Publishing House, (1991).
6. M.A. Omar, Elementary Solid State Physics, Addison Wesley, New Delhi,(2000).
7. S.O. Pillai, Solid State Physics, New Age International Publication,(2002).
8. M.A.Wahab, Solid State Physics, Narosa Publishing House, New Delhi,(1999).
9. H.C.Gupta, Solid State Physics, Vikas Publishing House, New Delhi,(2002).
10. 10 J.H. Fendler: Nanoparticles and Nanostructure Films: Preparation,Characterization and Applications 1998 WILEY-VCH Verlag GmbH 15 Dec 2007
11. S. Raimes: Many Electron Theory. Published by North-Holland Pub. Co (1972)
12. O. Madelung: Introduction to Solid State Theory. Springer Series in Solid-State Sciences Softcover reprint of the original 1st ed. 1978.
13. H. Ibach and H. Luth: "Solid State Physics: An Introduction to Theory and experiments: Edition: 4th ed. 2009
14. J.M. Ziman: Principles of the Theory of Solids. Cambridge University Press second edition 1972 15. Puri and Jaganathan, Material science Nova Science Publishers, 2001
15. A.S Edelstein,R.C.Cammarata: Nano materials application and synthesis. Edited by A. S. Edelstein and R. C. Cammarata, Institute of Physics Publishing, Bristol, UK 1996
16. Dieter-Vollath Nano materials an introduction to synthesis properties and applications. 2 edWiley.VCH
17. Charles.P.Polejr, Frank.J.Owens: introduction Nano technology. John Wiley & Sons, 30-May-2003 19 S.M. Lindsay: Introduction to Nano science, Oxford Univ. press, 2009
18. A.K.Bandyopdhyay ,Nano Materials :New age International (P) limited publishers), 2008
19. JuhTzengLue, Encyclopedia of Nanoscience and Tech.; Physical properties of nano materials: Ed: H.S.Nalva, Vol. X, Page:1-46. 2007.
20. Ryan Richards and Helmut Bonnemmann, Nanofabrication towards biomedical applications: Synthetic approach to metallic Nanomaterials :Editors: CSSR Kumar, J.Hormes, WILEY:VCH, 2005

Soft Core PHYS 3.4.2: Nuclear Physics I (4 Credits)
Modified Syllabus (Applicable from the academic year 2025-26)

Unit-I

Nuclear reactions-I: Compound nucleus, excitation energy of the compound nucleus, continuum theory of cross section, statistical theory of nuclear reactions.

Optical Model, Optical model at low energy and Kapur-Peirls dispersion formula for potential scattering. Giant Resonance. (12 Hours)

Unit-2

Nuclear Reactions-II: Cross section for scattering and reactions, compound nucleus, Briet-Wigner formula, continuity theory, statistical theory of nuclear reactions. Evaporation probability and cross section for specific reactions.

Direct reactions, resonance reactions, Kinematics of pick up and stripping reactions, theory of stripping and pick up reactions. Transfer reactions, classical description, plane wave Born approximation, its prediction of angular distribution-modification. (13 hours)

Unit-3

Semi-conductor detectors: Diffused junction, relation between applied voltage and depletion layer thickness, surface barrier and ion implanted detectors, Silicon Si(Li), Germanium Ge(Li) and HPGe detectors, semiconductor spectrometer, pulse height analysis, Solid State Nuclear Track Detectors(SSNTD), Thermo Luminescence Detectors(TLD).

(13 Hours)

Unit-4

Dosimetric Units & Quantities: Physical and radiation protection quantities and units. Radiation exposure dose, absorbed dose, Equivalent dose(RBE), effective dose, committed and collective dose. Photon and energy fluence, karma and cema, relationship between various dosimetric quantities, radiation protection and radiation shielding. (12 Hours)

Unit-5

Nuclear Electronics: Pre-amplifier circuits: voltage sensitive, charge sensitive, current sensitive pre-amplifiers, linear pulse amplifier, pulse shaping circuits. Analog to digital converters (ADC), flash and Wilkinson type of ADC. Pulse discriminators, coincidence and anticoincidence circuits, single and multichannel analyzers. Working of MCA, Basic principles of measurement techniques-collimation, geometry, shielding. (14 Hours)

REFERENCE BOOKS:

1. G. F. Knoll, Radiation Detection and Measurement, 3rd ed., John Wiley & Sons (2000)
2. S. S. Kapoor and V. S. Ramamurthy, Radiation Detectors, Wiley Eastern (1986):Details appear correct
3. W. R. Leo, Techniques for Nuclear and Particle Physics Experiments, 2nd ed., Springer-Verlag (1994)
4. C. Grupen, Particle Detectors, Cambridge University Press (1996)
5. Klaus Kleinknecht, Detectors for Particle Radiation, 2nd ed., Cambridge University Press (1998)
6. Gerhard Lutz, Semiconductor Radiation Detectors: Device Physics, Springer (1999)

7. Nicholas Tsoulfanidis, Measurement and Detection of Radiation, 2nd ed., Taylor & Francis (1995)
8. S. N. Ghoshal, Nuclear Physics, S. Chand & Company Ltd. (2010):
9. W. B. Mann, R. L. Ayres, and S. B. Garfinkel, Radioactivity and Its Measurement, Pergamon Press (1980).
10. U. A. Bakshi and A. V. Bakshi, Pulse and Digital Circuits: Technical Publications
11. Albert Paul Malvino and Donald P. Leach, Digital Principles and Applications:.

Open Elective PHYE 3.5: Introduction to Quantum Mechanics and Quantum Computing

Unit I

Quantum Physics Essentials: Wave-particle duality; Quantum states as wavefunctions; Hilbert Space; Superposition principle; Measurement postulate;

Two-level systems: Qubits; Density matrix; Bloch sphere representation; Dirac Bra-ket notation **Two-qubit states;** Bell states; Quantum Entanglement (Basic ideas) **(10 hours)**

Unit II

Quantum Gates and Quantum Measurements: Hadamard, Pauli X, Y, Z gates, CNOT, phase gates, Pauli X, Y, Z measurements; Bell measurement;

Physical realization of qubits: trapped ions, superconducting circuits, photonic systems

Quantum Algorithms: Deutsch and Grover's Algorithms (Overview) **(10 hours)**

Unit III

Quantum Communication and Cryptography: Quantum teleportation, Quantum key distribution (QKD): BB84 protocol, Quantum no-cloning theorem, Quantum repeaters and quantum internet, Comparison with classical communication

Overview of Cloud quantum programming platforms: Qiskit; Basic circuit building and implementation; Global quantum initiatives (India, IBM, Google, Microsoft, IonQ); Quantum supremacy and open challenges **(10 hours)**

REFERENCE BOOKS:

1. David J. Griffiths and Darrell F. Schroeter, *Introduction to Quantum Mechanics*, 3rd Edition, Cambridge University Press, 2018. ISBN: 978-1107189638 [2] Leonard Susskind and Art Friedman, *Quantum Mechanics: The Theoretical Minimum*, Basic Books, Perseus Books Group 2015. ISBN-13: 978-0-465-06290-4
2. Michael A. Nielsen & Isaac L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, 2011 (Tenth Anniversary Edition). ISBN-13: 978-1107002173
3. Eleanor G. Rieffel & Wolfgang H. Polak, *Quantum Computing: A Gentle Introduction*, The MIT Press (Scientific and Engineering Computation series), 2011. ISBN-13 978-0262015066

Online Tools:

IBM Quantum Experience: <https://quantum-computing.ibm.com>

Qiskit Textbook: <https://qiskit.org/textbook>

QuTiP (Python QM simulator)

PHYH 4.1: Experimental Techniques (Hardcore) (4 Credits)

Modified Syllabus (Applicable from the academic year 2025-26)

Unit I

Production and measurement of high vacuum: Introduction to vacuum, Production of vacuum using rotary, root and diffusion pumps, Turbo molecular pumps, Sorption pumps and cryopumps. Measurement of Vacuum: Vacuum gauges: Mechanical gauges, Liquid column gauges, Thermal conductivity gauges, Ionisation gauges and other gauges. Applications of vacuum systems in a) thin film technology b) low temperature physics experiments c) accelerators like Linac, Cyclotron, etc, **(13 Hours)**

Unit II

Cryogenic techniques: Review of history, General techniques of Liquefaction of gases – Internal and external work methods, Adiabatic Expansion, Joule-Kelvin effect, Isenthalpic curve, Inversion curve, Regenerative cooling. Adiabatic demagnetization, Liquefiers-Linde's Air Liquefier, Dewar's Hydrogen liquefier, Kammerlingh Onne's helium Liquefier, Uses of Liquefied gases, Maintenance of Cryogenic Temperatures – Dewar flask, Henning cryostat, Hydrogen vapour cryostat. Production of Sub Kelvin Temperatures – Design of Cryostats: Bath type and flow type cryostats. Measurement of low temperature: International temperature scale, secondary standards, Vapor pressure thermometers, Platinum resistance thermometers, Alloy thermometers, Thermocouples, Diodes, Semiconducting thermometer **(13 Hours)**

Unit III

Production and measurement of High Pressure: Introduction to high pressure, Production of hydrostatic pressure using monobloc cylinder and by using multilayer cylinders, production of non hydrostatic pressure using opposed anvil high pressure device (OAHPD), examples of OAHPD and their range of pressure generation (only two types viz Tungsten Carbide anvils and Diamond Anvils). Measurement of Pressure using primary and secondary gauges. Production and measurement of High temperature: Introduction, Design and fabrication of high temperature furnaces like the furnace made of Kanthal heating element and Silicon Carbide furnaces. Measurement of high temperatures using different types of thermocouples. **(13 Hours)**

UNIT IV

Introduction, Nature and applications of thin films, Distribution of deposit, Knudsen Cosine law. Thin film technology: Introduction, Electroplating, CVD, solgel, resistive, electron beam, and laser evaporation, DC, Triode and RF diode, ion beam and magnetron sputtering, Optical and crystal film thickness monitors and other simple techniques. Applications: Thin film sensors for measuring strain, pressure, temperature and radiation, Squids, Photovoltaic and Photo thermal coatings. **(13 Hours)**

UNIT V

Radiation detectors: Pyroelectric, ferroelectric, thermoelectric, photo conducting, photoelectric and photomultiplier, scintillation types of detectors. Measurement of high and low electrical resistivity: DC and AC four probe technique, impedance considerations and accuracy; Ion sources –Ionization processes, simple ion source, Duoplasmatron, RF ion source, important applications of accelerators, and Major accelerator installations in India (general awareness). **(12 Hours)**

REFERENCE BOOKS

- 1.C.S.Rangan, G.R.Sharma and V.S.V. Mani, Instrumentation devices and systems, Tata McGraw Hill, (1983).
2. H.H.Willard, L.L.Meritt and John A. Dean, Instrumental methods of analysis, VI edition, CBS Publishers and distributors (1986).
3. R.A.Dunlop, Experimental Physics: Modern methods, Oxford University Press,(1988).
4. D.Malacara (Editor), Methods of experimental Physics, Series of volumes, Academic Press Inc.(1988). 5. J.F. Rebek, Experimental methods in Photochemistry and Photo physics, Part 1 and 2, John Wiley (1982).
6. Chopra K.L., “Thin film Phenomenon”, Robert G. Krieger Publishing Company, NY, 1979.
7. Leon Maissel and ReinhardGlang, “Handbook of thin film technology”, Mcgraw Hill Co.,London,1970.
8. Chopra K.L. and Inderjeet Kaur, “Thin film device applications”, Plenum Press, NY, 1983.
9. G.K. White, “Experimental Techniques at low-temperature”, Monographs on the Physics and Chemistry of Materials-59, OXFORD Univ. press, 2002.
10. E S R Gopal, S.V.Subramanyam et. Al, Science and Technology of high Pressure, Instrumentation Society of India, I,I,Sc., Bangalore.

Soft-core PHYS 4.2.1: Condensed Matter Physics – II (4 Credits)
Revised Syllabus (Applicable from the academic year 2025-26)

Units I and II

Magnetic Properties of Solids: Quantum theory of paramagnetism, Crystal field effect, Orbital quenching effect, Susceptibility of salts nitrates of d block and f block elements, adiabatic demagnetization,

Ferromagnetism: Quantum theory of ferromagnetism, Weiss molecular theory, electrostatic origin of magnetic interaction, Heisenberg theory of exchange interaction, spin waves, Magnon dispersion relation, quantization of spin waves, thermal excitation of magnons, Bloch T^{3/2} law, Ferromagnetic domains. Block wall.

Antiferromagnetism: Molecular field theory, two sub lattice model, Neel temperature. Magnetic susceptibility parallel and perpendicular to the applied magnetic field.

Ferrimagnetism: Structure of ferrites classification of ferromagnetic compounds, specific heat, thermal conductivity, magneto caloric effect, saturation magnetization, Curie temperature and susceptibility of ferrimagnets. **(22 hours)**

Unit III

Quantum mechanics of low dimensional systems: Introduction, Energy consideration: bound states and density of states, Three dimensional DOS (density of states), Two dimensional DOS, One dimensional DOS, Zero dimensional DOS

Quantum confinement: Quantum wells. Quantum wires, Quantum dots, summary of the confined states in quantum well, wire and dots, super lattice, band offsets, quantum transport in Nano cluster/quantum dots.

Different methods of preparation and characterization of Nanomaterials: Top down: UV and electron beam lithography, ball milling; Bottom up: atom manipulation by SPM, Dip pen nanolithography, cluster beam evaporation, Ion beam deposition, Chemical bath deposition with capping techniques, Self-assembled mono layers. Characterization Nano materials by TEM, XRD pattern and light scanning experiments. **(16 hours)**

Unit IV and V

Electrical and Optical properties of thin films: Conduction in metallic thin films, semiconducting thin film and insulating thin films.

Optics of thin films, Transmittance, reflectance of light by transport substrate, type of antireflection coating and conduction.

Solar cells: Introduction and basic structure of solar cells Solar spectrum, Basic mechanism of; solar cell; Solar cell materials and their efficiency; Dye solar cell p-n junction: electrochemical equilibrium of electron in a p-n junction in the dark; potential distribution

across p-n junction, current voltage characteristic of p-n junction, p-n junction with impurity recombination two diode model, hetero-junctions; Schottky contact and role of electron field in solar cells

Limitation on energy conservation in solar cell: Maximum efficiency of solar cell, efficiency of solar cell as a function of their energy gap.

The optimal silicon solar cell: Light trapping, Thin film solar cell: minimal thickness of a solar cell, Equivalent circuit, temperature dependence of open circuit voltage, intensity dependence of the efficiency, efficiencies of the individual energy conversion processes.

Concepts for improving the efficiency of solar cells: Tandem cells: the electrical interconnection of tandem solar cells, Concentrator cells, thermos-photovoltaic energy conversion, impact ionization, energy conversion with hot electrons and holes, two step excitation in three level systems; impurity photovoltaics, up and down conversion of photons.

(26 hours)

REFERENCE BOOKS:

1. Charles Kittel, Introduction to Solid State Physics (V edition), Wiley, 1976.
2. A.J. Dekker, Solid State Physics, Prentice Hall, (1957).
3. N.W. Ashcroft and N.D. Mermin, Solid State Physics, Saunders college publishing (1976).
4. J.S. Blakemore, Solid State Physics, (II edition), Cambridge University Press, (1974).
5. Harald bath and Hans Luth, Solid State Physics, Springer International Student editon, Narosa Publishing House, (1991).
6. M.A. Omar, Elementary Solid State Physics, Addison Wesley, New Delhi, (2000).
7. S.O. Pillai, Solid State Physics, New Age International Publication, (2002).
8. M.A. Wahab, Solid State Physics, Narosa Publishing House, New Delhi, (1999).
9. H.C. Gupta, Solid State Physics, Vikas Publishing House, New Delhi, (2002).
10. Solar energy conversion: The solar cell, by Richard C. Neville. Elsevier scientific pub. Co., 1978.
11. Photoelectrochemical solar cells – Suresh Chandra New York: Gordon and Breach Science Publishers, c1985.
12. Solar energy conversion – A. E. Dixon and J. D. Leslie. Pergamon Press (1979).
13. Solar cells – Martin A. Green Prentice Hall (October 1981)
14. Heterojunction and metal – semiconductor junctions – A.G. Milnes and D. L. Feucht. New York: Academic press, 1972.
15. Solid state electronic devices - B.G. Streetman. Principles of solar Engineering-Frank Kreith and Janf Kreider.
16. Direct energy conservation (4th edition)- Stanley W Angrist. Longman (1976)
17. Handbook of batteries and fuel cells- Lindsey. David
18. Nano Science and Nano technology fundamental to frontiers by M S Ramachandra Rao Shubra Singh.
19. Physics of solar cell from principle to new concepts by Peter Wurfel.

Soft core PHYS 4.2.2: Nuclear Physics- II (4 Credits)
Modified Syllabus (Applicable from the academic year 2025-26)

Unit-1

Electromagnetic interactions with Nuclei: multipole transitions, sources of multipole radiation and multiple moments, transition probability in nuclear matter, selection rules, Internal conversion, Photo disintegration of deuteron and radiative capture of neutron by proton.

(11 Hours)

Unit-2

Nuclear Models: Nuclear Shell Model; oscillator potential well, spin orbit potential, L-S coupling and J-J coupling, magnetic and quadrupole moment, Schmidt lines.

Collective Model; Nuclear rotational motion, rotational energy spectrum and nuclear wave functions of even-even nuclei, vibrational model, Nilsson model, energy levels and prediction of ground state spin.

Nilsson model: Nilsson diagrams.

(15 hours)

Unit-3

Deuteron problem: Properties of Deuteron, Deuteron as a pure S-state, theory of ground state of Deuteron under central force, Deuteron as a mixture of S and D states, normalization of Deuteron wave function, relation between range and depth of potentials. Electric & Magnetic moment of Deuteron.

(13 hours)

Unit-4

Nucleon-Nucleon Scattering: Low energy n-p scattering by partial wave analysis, expression for scattering cross section, spin dependence and scattering length. Effective range theory of n-p scattering. coherent scattering of neutrons from molecular hydrogen, cross section for ortho and para hydrogen. Comparison with experiments. Low energy p-p scattering, Mott's modification of Rutherford formula, high energy n-p and p-p scattering comparison with experimental results.

(14 hours)

Unit 5

Particle Accelerators: Introduction, development of accelerators. Direct-voltage accelerators: Cockroft-Walton generator, Van de Graff generator, Tandem accelerators, Pelletron.

Resonance Accelerators: Cyclotron-fixed and variable energy, principles and longitudinal dynamics of the Uniform field cyclotron. Linear accelerators.

Electron Accelerators: Betatron, Beam focusing and Betatron Oscillation, Microtron.

(11 hours)

REFERENCE BOOKS:

1. I Kalpana, Nuclear Physics, Addison-Wesley (1962)
2. R R Roy and B P Nigam, Nuclear Physics, New age (1967)
3. S N Ghoshal, Nuclear physics, 3rded , S Chand (2003)
4. M A Preston, physics of the nucleus, Addison-Wwsley
5. E Serge, Nuclei and particles, Benjamin (1977)
6. R D Evans, The atomic nucleus, McGraw Hill(1955)
7. G R Satchler, Introduction to nucelar reactions, Macmillan(1980)
8. D F Jackson, Nuclear reactions, Metheun (1970)
9. J M Pearson, Nuclear physics: Energy and matter, AdamHighler(1986)

Soft core PHYS 4.3.1: Condensed Matter Physics-III (04 Credits)

Revised Syllabus (Applicable from the academic year 2025-26)

Unit I

Superconductivity: Theoretical aspects – London's theory, Superconductivity at high frequency, Thermodynamics of superconducting transitions, Manifestation of energy gap, Copper pairing due to phonons, BCS theory, Josephson's tunneling effect (AC and DC), macroscopic quantum interference, SQUIDS, High T_c superconductors (qualitative).

Superfluidity: Introduction-discovery, superfluidity in Helium; two fluid model. Bose-Einstein condensation, Landau's theory fermi liquid, liquid helium –II, two fluid properties of helium-II. (13 hours)

Unit II

Elastic Properties: Elastic constants and Elastic Waves Geometric theory of strain, Displacement and strain components, Longitudinal and shearing strains, Finite strain, Dilational strain, Stress components, Elastic compliance constants and stiffness constants, Elastic energy density, Reduction of number of elastic constants, Elastic constants of cubic crystals, Cauchy's relation, Elastic waves along principal directions in cubic crystals, Measurement of elastic constants. (13 hours)

Unit III

Imperfection of Crystals: Classification of imperfections, lattice vacancies and interstitial atoms. Frenkel and Schottky defects. Lattice defects in ionic crystals-the hydration energy of ions, the activation energy for the formation of defects in ionic crystals. Mechanism of plastic deformation in solids, Stress and strain fields of screw and edge dislocations, Burgers Vectors, Shear strength of single crystals, Elastic energy of dislocations, Forces between dislocations, Stress needed to operate Frank Read source, Dislocations in fcc, hcp and bcc lattices, Partial dislocations and stacking faults in closepacked structures. Experimental method of detecting dislocations and stacking faults, (13 hours)

Unit IV

Ionic Conductivity and Atomic diffusion in solids: First and second Fick's Law. Solution to the II law. Some applications of diffusion measurements, Random walk treatment of diffusion. The Kirkendall effect, diffusion in alkali halides, Ionic conductivity in pure and with divalent impurity alkali halides. Nernst-Einstein equation.

Luminescence: Introduction, excitation and emission, Frank - Condon principle, Decay mechanisms, temperature dependent and independent Decay, Thermoluminescence and glow curve, electroluminescence, Gudden - Pohl effect, the Destrain effect, carrier injection luminescence. Color Centers: Mechanism of production by various methods, F centers and other centers in alkali halides. (13 Hours)

Unit-V

Nanoparticles: Synthesis and Properties: Carbon Nano materials: Zero dimensional Nano materials: Fullerenes, preparation, properties, applications.

Carbon Nano materials: Carbon Nano tubes, preparation, properties, and applications. Two dimensional carbon Nano materials: Graphene, preparation, properties, applications. (12Hours)

REFERENCE BOOKS:

1. **Charles Kittel**, *Introduction to Solid State Physics* (7th edition), Wiley (1996).
2. **A.J. Dekker**, *Solid State Physics*, Prentice Hall, (1957).
3. **N.W. Ashcroft and N.D. Mermin**, *Solid State Physics*, Saunders College Publishing (1976).
4. **J. M. Ziman**, *Principles of the Theory of Solids*. Cambridge University Press, (1979)
5. **Harold Lüth**, *Solid State Physics*, Springer International Student Edition, Narosa Publishing House, (1991).
6. **M.A. Omar**, *Elementary Solid State Physics*, Addison Wesley, New Delhi, (2000).
7. **S.O. Pillai**, *Solid State Physics*, New Age International (P) Ltd., (2002).
8. **M.A. Wahab**, *Solid State Physics*, Narosa Publishing House, New Delhi, (1999).
9. **H.C. Gupta**, *Solid State Physics*, Vikas Publishing House, New Delhi, (2002).
10. **John P. McKelvey**, *Solid State and Semiconductor Physics*. Krieger Publishing (1966)
11. **K.P. Jain**, *Physics of Low Dimensional Semiconductors*, Narosa Publishing House (1997).
12. **John H. Davies**, *Physics of Low Dimensional Semiconductors*, CUP (1997)
13. **R. Zallen**, *The Physics of Amorphous Solids*; Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim (2004).
14. **N.F. Mott and E.A. Davis**, *Electronic Processes in Non-crystalline Materials*; 2nd ed. Oxford University Press, New York (1979).
15. **H.P. Klug and L.E. Alexander**, *X-ray Diffraction Procedures*; Wiley, New York (1954), Revised 1974.
16. **B.D. Cullity**, *Elements of X-ray Diffraction*. Addison-Wesley Publishing Company (1956).
17. **S. Chandra**, *Superionic Conductors*; North-Holland (1981).
18. **A R Verma and O.N. Srivastava**, *Crystallography for Solid State Physics*. Wiley (1982).
19. **J.B. Wachtman, Zwi H. Kalman**, *Characterization of Materials*. Journal of Materials Science Letters, Vol. 12, Issue 9, pp. 681-683 (May 1993)
20. **William D. Callister Jr.**, *Materials Science and Engineering - An Introduction*. John Wiley & Sons (2007). -
21. **L.V. Azaroff and Martin J. Buerger**, *Powder X-ray Diffraction*. McGraw-Hill (1958). –
22. **S. Fonash**, *Solar Cell Devices - Physics*. Academic Press Inc.; 2nd Revised edition (May 28, 2010).
23. **Suresh Chandra**, *Photoelectrochemical Solar Cells*. Physica Status Solidi (a), Vol. 70, Issue 1, pp. 11-42 (1982).
24. **J. Jacak, P. Hawrylak, and A. Wojs**, *Quantum Dots*. Springer; Softcover reprint of the original 1st ed. 1998 edition (June 4, 2012).
25. **Hari Singh Nalwa (Editor)**, *Handbook of Nanostructured Materials and Nanotechnology*. Academic Press (2000).
26. **S.K. Kulkarni**, *Nanotechnology: Principles and Practices*, 3rd Edition. Springer (2015).
27. **Richard Booker and Earl Boysen**, *Nanotechnology*. John Wiley & Sons (2011).
28. **Robert W. Kelsall, Ian W. Hamley, and Mark Geoghegan (Editors)**, *Nanoscale Science and Technology*. Wiley (2005).

Softcore PHYS 4.3.2: Nuclear Physics- III (4 Credits)
Revised Syllabus (Applicable from the academic year 2025-26)

Unit-1

Nuclear Fission: Fission processes, spontaneous fission, nature of the fission fragments, Bohr-Wheeler theory of nuclear fission, statistical model of fission, Photo fission. Neutron chain reaction, multiplication factor, four-factor formula, condition for critical chain reaction.

Nuclear Fusion: Nuclear fusion in stars, confinement of plasma. Recent trends and development in fusion technology. **(13 hours)**

Unit-II

Neutron Physics: Neutron sources, mono energetic neutron sources, accelerator-based neutron sources, interaction of neutrons with matter, elastic and inelastic collisions, resonance neutrons, foil activation, neutron detection and spectrometry, neutron flux measurements, target for production of neutrons. **(12 hours)**

Unit-III

Diffusion theory of neutrons: Neutron scattering and absorption cross-section, transport and diffusion equation, transport mean free path, solution of diffusion equation for a point source in an infinite medium and for an infinite plane source in a finite medium, diffusion length, Albedo concept of neutrons comparison with the Albedo in optics. **(13 hours)**

Unit-IV

Theory of Reactors: Types of nuclear reactors, slowing down of neutrons, moderators, condition for controlled chain reaction in homogeneous bare reactors, critical size, one group critical equation, Fermi age, solution of age equation for a point source of fast neutron in an infinite medium, slowing down length.

One group method of homogeneous reactor with reflector. infinite multiplication factor, critical size and mass, calculation of buckling for spherical and cylindrical geometry.

Heterogeneous reactor, calculation of thermal utilization factor, core composition and critical mass, multi group equations, fast breeder reactors. **(15 hours)**

Unit-V

Nuclear Fuels: The fuel cycles, production of reactor fuels: sources of Uranium, Production of uranium and its products, Thorium and Plutonium. Properties of fuel materials. Uranium and its compounds, Plutonium and thorium fuel materials. Radioactive waste, Hazard potential, risk factor. **(11 hours)**

REFERENCE BOOKS

1. P. F. Zweifel, *Reactor Physics*. McGraw-Hill (1973)
2. Weston M. Stacey, *Nuclear Reactor Physics*. Wiley (2001)
3. James J. Duderstadt and Louis J. Hamilton, *Nuclear Reactor Analysis*. Wiley (1976)
4. John R. Lamarsh and Anthony J. Baratta, *Introduction to Nuclear Engineering*, 3rd ed. Prentice Hall (2001)
5. John R. Lamarsh, *Introduction to Nuclear Reactor Theory*. American Nuclear Society (2002)
6. S. N. Ghoshal, *Nuclear Physics*, 3rd ed. S. Chand & Company (2003)
7. Samuel Glasstone and Milton C. Edlund, *The Elements of Nuclear Reactor Theory*. Robert E. Krieger Publishing Company (1981)
8. Samuel Glasstone and Milton C. Edlund, *The Elements of Nuclear Reactor Theory*. Reinhold Publishing Corporation (1952):