Hardcore PHYH 1.1: Mathematical Physics-I (3 Credits)

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; Tensor Algebra, Examples of tensors in Physics

(10 hours)

Unit II

Special Functions: Solution of Helmholtz and Laplace equation using variable separation method; 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); **(12 hours)**

Unit III

Integral Transforms: Fourier Transforms; Sine and Cosine Transforms; Inverse Fourier Transforms; Convolution Theorem; Parseval's theorem; Laplace Transforms; Convolution theorem; Inverse Laplace Transforms; Solution of Differential equations using Laplace Transforms.
Sturm-Liovelle Theory; Self-adjoint operators; Dirac Delta Function and its Properties;

(8 hours)

Unit IV

Complex Analysis: Analytic Functions: Cauchy-Riemann conditions; Cauchy Integral Theorem; Cauchy Integral Formula; Singularities; Taylor and Laurent expansion; Definite Integrals using Calculus of Residues. **(10 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.

(8 hours)

Reference Books:

1. G. Arfken and H.J.Weber, Mathematical Methods for Physicists, Academic Press,5th ed. (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. Mathematical Methods for Physics and Engineering: K.F.Riley, M.P.Hobson and S.J.Bence, 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.

Hardcore PHYH 1.2: Classical Mechanics (4 Credits)

Unit-I & II

Lagrangian Mechanics: Constraints,classification. degrees of freedom, generalised coordinates and velocities. Principle of virtual work, D'Alembert's principle, Generalised forces, Lagrange's equation of motion. Properties of Lagrangian. Cyclic coordinates, Integrals of motion.

Central force problem: Motion of a particle in a central force field, Conservation of energy and angular momentum, classification of orbits, stability of orbits, Kepler's laws of planetary motion. Scattering in a central potential in Laboratory and centre of mass frames, Impact parameter, Total and differential cross section, Rutherford scattering.

(26 Hours)

Unit-III & IV

Hamiltionian Mechanics: Generalized momenta, Legendre transform, Hamiltonian, Hamilton's equations of motion. Canonical coordinates, Phase space, Phase trajectories. Cyclic coordinates, conservation laws. Canonical transformations, Generating functions. Poisson bracket and its properties. Hamilton-Jacobi theory, relation to canonical transformations, Principal and characteristic function. Action-Angle variables.

Hamilton's principle of least action. Euler-Lagrange and Hamilton's equations of motion from Hamilton's principle.

(26Hours)

Unit V

Elements of rigid-body dynamics: Fixed and moving co-oridnates systems, Rotations, Eulerian angles, Euler's and Chasles' theorem. Inertia Tensor. Euler's equation of motion for a rigid body.

Elementary Fluid Dynamics: Velocity, streamlines and particle paths, pressure density, Lagrangian and Eulerian description of flow. Equations of continuity, equation of motion for inviscid flow. Steady irrotational, incompressible flow, velocity potential, vorticity, circulation. Introduction to viscous flow, Navier-Stokes equation.

(12 Hours)

Textbooks:

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 Heinnemann.
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).

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Hard Core PHYH 1.3: Classical Electrodynamics (4 credits)

Unit I and II

Electrostatics: Electric field; Gauss law; Electric Potential; Work and energy in electrostatics; Laplace and Poisson equations; Uniqueness theorems for Laplace's equation; Methods of solving Lap lace's equation: 1) Variable separable method, 2) Method of Images 3)Green's function method; Multipole expansion of electric potential; Polarization of matter; Gauss law in the presence of a dielectric medium; Electric field in a dielectric medium; susceptibility, permittivity, dielectric constant.

Magnetostatics: The Lorentz Force Law; The Biot-Savart Law; Ampere's Law; Magnetic vector potential; Multipole expansion of vector potential; Magnetization of matter; Ampere's law in the presence of medium; Magnetostatic field in a linear medium; magnetic susceptibility, permeability;

(26 hours)

Unit III

Electrodynamics: 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; Propagation of plane electromagnetic waves in free space, non-conducting and conducting medium. The concept of skin depth.

(13 hours)

Unit IV

Maxwell's equations in terms of potentials; Gauge Transformations; Coulomb and Lorentz gauge as illustrations; Energy in an electromagnetic field; Poynting theorem;

Boundary conditions for Maxwell's equations; Reflection and Refraction of plane electromagnetic waves; Fresnel laws; Implications of Fresnel's laws;

Dispersion of EM waves; Frequency dependence of permittivity; Simple discussion of dispersion in non-conductors; complex refractive index; anomalous dispersion; Cauchy's equation; Dispersion in conductors and plasma; plasma frequency **(13 hours)**

Unit V

Retarded potentials, Electric and magnetic dipole radiation; Lienard Wiechert potentials; Fields of a point charge in motion, power radiated by a point charge;
Review of Lorentz transformations; Transformation of electric and magnetic fields; Covariant formulation of Lorentz and Maxwell equations; Potential formulation of Lorentz and Maxwell's equations; **(12 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.

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Hardcore Paper 1.4: ELECTRONICS (03 Credits)

Unit I & II
Op Amps and Applications

Operational Amplifier: Basic Information of Op-Amp, Ideal Operational Amplifier, Operational Amplifier Internal Circuit, IC Op-Amp 741, FET Operational Amplifier. DC Characteristics, AC Characteristics

Operational Amplifier Applications: V to I and I to V Converter, Differentiator, Integrator, Comparators, Wave Generators - Square (Monostable Multivibrator), Triangular & Sine, *Voltage Regulators*- Series Op-Amp Regulator, IC Voltage Regulators, General Purpose Regulator 723, Switching Regulator

Active Filters: First order Low-Pass, First order High-Pass, First order Band –Pass Filters, Second order Low-Pass, Second order High-Pass, Second order Band-Pass Filters, Narrow Band and Wide Band-Pass Filters

(20 Hours)

Unit III
Digital Electronics

Boolean Algebra and Logic Gates: Definitions, Theorems and Properties of Boolean algebra, Boolean functions, canonical and standard forms, the map method of simplification of boolean functions. Two-Three-Four variable maps, product of Sum simplification, NAND and NOR implementation, don't care conditions, The Tabulation Method, determination and selection of prime implicants

Combinational and Sequential logic: Introduction, design procedure, Adders – binary parallel adder, decimal adder, Subtractor, Code conversion, decoders and multiplexers; Flip Flops, types-SR, JK, D & T, triggering of Flip Flops, Flip flop excitation tables, Registers and types, Counters, Synchronous and Asynchronous Counters

(10 Hours)

Unit IV
Memories: Basics of Semiconductor Memories, ROM Cells & Circuits, Address Decoding, Access Time, Examples of Integrated Circuit ROMs, PROMs, EPROMs, EEPROM, Static Read/Write (RAM) Memory

(8 Hours)

Unit V
Interface Circuits: D/A Converters R-2R Ladder Converter, Weighted Register DAC, Accuracy & Resolution, A/D Converters- Successive Approximation A/D Converter, Dual Slope A/D Converter, Accuracy & Resolution

(10 Hours)

TEXT BOOKS
Ramakanth A Goyakwad, Op-Amp and Linear Integrated Circuits: PHI
M. Morris Mono, Digital Logic and Computer Design, PHI
Floyd T L , Digital Fundamentals, 7th edn. (Pearson Education Asia 2002)
REFERENCE BOOKS
A P Malvino and D P Leach, Digital Principles and Applications, TATA McGraw Hill, 4th edn, 1998

Robert F. Coughlin and Fredericks, **Driscoll**, Operational Amplifiers and Linear Integrated Circuits: PHI, 1992.

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1. **Hardcore Lab PHYP 1.6: General Lab I(2 Credits)**
2. **Hardcore Lab PHYP 1.7: Electronics Lab (2 Credits)**

Hardcore PHYH 2.1: Mathematical Physics-II (3 Credits)

Unit I

Linear Vector Spaces: Basic concepts; Matrices as Linear Transformations (Operators) and their representations in different bases;Effect of change of basis; Types of matrices; Eigenvalues and Eigenvectors; Similarity Transformations; Diagonalization;Complex Euclidean space; Inner Product; Schwartz inequalit; Orthogonality of vectors; Gram-Schmidt Orthogonalisation Procedure ;Direct product of two vector spaces-The Kronecker product space . **(10 hours)**

Unit II

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; Group characters; Schur Lemma.General structure of Lie groups and Lie algebra.Rank of a Lie group.Casimir operators;General linear groups GL(n,C) and Gl(n,R);Special linera 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 groupSO(3,1). **(12 hours)**

Unit III

Green's functions : Green's function for one, two and three dimensional equations; Eigenfunctions 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. **(9 hours)**

Unit IV

Probability Theory: A set theory primer;Sample space; Conditional and marginal probabilities;Bayes theorem;Average and Standard deviation;Random variables,Probability distributions;Binomial,Poisson and Gaussian(or normal) distribution.

Numerical Methods: Curve fitting by Least Squares method; Chi-square fit;Approximating functions;Polynomial Interpolation;Newton and Lagrange form of Interpolation polynomial;Types of errors,Error propagation.

(9 hours)

Unit V

Linear Integral Equations: Transformation of a differential equation into an Integral equation.Fredholm and Volterra Integral equations of the first and second Kind,Neumann series method and seperable kernel method of solving integral equations,Hilbert-Schmidt Theory. **(8 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. M.L.Boas, Mathematical Methods in the Physical Sciences, 2nd edition, Wiley (1983)
4. S. Hassani, Mathematical Physics, Springer (1998)
5. C.R. Wylie and L.C. Barrett, Advanced Engineering Mathematics, 5th edition, Wiley Eastern, McGraw-Hill (1982)
6. K.N.Srinivasa Rao, Linear Algebra and Group Theory for Physicists, 4th ed. New Age (1996)
7. K.N.Srinivasa Rao, The Rotation and Lorentz Groups and their Representations for Physicists, Wiley (1988)
8. M.R. Spiegel in Schaum's Outline Series, McGraw-Hill (1964) a)Vector Analysis, b) Matrices c) Group Theory.

Hardcore PHYH 2.2: Elements of Nuclear and Particle Physics (3 Credits)

Unit I

General properties of nuclei: size, shape, binding energy, spin, electric and magnetic moments, mass, parity.
Nuclear forces: Short range, saturation and charge independence. Exchange character. Yukawa's theory.
Nuclear models: *Liquid drop*: Semi-empirical mass formula.
Shell Model: Evidence of magic numbers, levels in an infinite square well potential. spin orbit coupling, Prediction of ground state spin, parity and magnetic moment of odd-A nuclei.

(10 Hours)

Unit II & III

Radioactive decay: *Alpha decay*: General properties, Geiger Nuttal law, Gamow's theory of Alpha decay.
Beta decay: General properties, Neutrinos and Anti-neutrinos, Fermi-theory, Fermi Curie plot , selection rules, electron capture.
Electromagnetic transitions: Electromagnetic interactions with Nuclei, multipole transitions, transition probability in nuclear matter, selection rules, Internal conversion, Photo disintegration of deuteron and radiative capture of neutron by proton.
Nuclear reactions: Cross section for a nuclear reaction. Kinematics in the centre of mass and laboratory systems, 'Q' equation of a reaction in laboratory system, threshold energy for a reaction.

(18 Hours)

Unit IV & V

Particle Physics: Classification of fundamental forces and their properties. Symmetries and Conservation Laws: Translation, rotation, parity, time reversal, charge conjugation, CPT theorem, Isospin, G-parity.
Quark model: Elementary discussion on SU(2) and SU(3) groups and their representations. Quarks, Quark model of Mesons, Quark model of Baryons. Hadron masses, Gell-Mann-Nishijima formula, Gell-Mann-Okubo and Coleman -Glashow mass formulae. Non-conservation of parity in weak interactions, CP violation.

(20 Hours)

<u>Textbooks:</u>

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. Wiliams**, 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)

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Hardcore PHYH 2.3 Elements of Condensed Matter Physics (4 Credits)

Unit I

Crystal structure: Space lattice, Unit cell and Bravias lattices, Miller indices, Crystal systems, symmetry elements, Point groups and Space groups (qualitative), Simple cubic structures, Representation of planes.

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. **(14 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.

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.

(12 hours)

Unit III

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.

(13 hours)

Unit IV

Band Theory: Bloch functions, Kronig-Penny Model, formation of energy bands gaps at Brillouin zone boundaries, density of states. Effective mass and the concept of hole. Classification - insulators, conductors and semiconductors

Intrinsic Semiconductors: Introduction, expressions for carrier concentrations and Fermi energy, Mobility, drift velocity and law of mass action, temperature and charge carrier dependence of electrical conductivity, experimental determination of energy gap.

(12 hours)

Unit V

Dielectric Properties: Introduction, review of basic formulae, microscopic concepts of polarization, different kinds of polarization, in solids (qualitative), local electric field, Clausius-Mosotti and Lorentz-Lorenz relation.

Magnetic Materials: Classification, classical theory of diamagnetism, paramagnetism and ferromagnetism.

Superconductivity: Basic concepts, Thermodynamics of superconductors, two fluid model, London equations, Cooper pairs, Temperature dependence of superconducting energy gap(qualitative), coherence length, flux quantisation in superconducting ring.

(13 hours)

Text 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. **Rose-Innes and Rhoderick**, Introduction to super conductors, Oxford University Press.

Reference Books:

6. **S.O. Pillai**, Solid State Physics, New Age International Publication (2002).
7. **M.A.Wahab**, Solid State Physics, Narosa Publishing House, New Delhi(1999).
8. **H.C.Gupta**, Solid State Physics, Vikas Publishing House, New Delhi (2002).

Hardcore PHYH 2.4: Quantum Mechanics-I (4 Credits).

Unit I

Basics: The classical description and the inadequacy of Classical mechanics. Dual nature of matter and waves, Double-slit experiment for photons and electrons as an illustration. Waves, wave packets, phase velocity and group velocity. Canonically conjugate variables, General uncertainty principle. Review of Linear vector spaces in Dirac Bra-Ket notation. Position and momentum representations. Wavefunctions. Superposition principle. Schrödinger's equation. probability densities, probability current. Expectation values and Ehrenfest's Theorem. Continuity equation, Fundamental Postulates of Quantum Mechanics.. Commutators. Eigenvalues and eigenvectors of a complete set of mutually commuting operators. **(14 Hours)**

Unit II

Exactly solvable problems in one-dimension*:* Bound states, examples of particle in a box, rectangular potential wells, Simple Harmonic Oscillator: wavefunction and operator approach.

Unbound states, Scattering in one-dimension. Examples of scattering from a one-dimensional rectangular potential well and barrier, Tunneling, Transmission and Reflection co-efficients. Ramsauer -Townsend effect, Alpha decay, cold emission of electron in a metal.

(12 Hours)

Unit III & IV

<u>Angular Momentum:</u>

Orbital Angular Momentum*:* Angular momentum operators and their Algebra. Eigenfunctions and eigenvalues of $\mathbf{L^2}$ and $\mathbf{L_z}$ angular momentum operators using both Schrödinger wave equation and operator method.

SPIN: Stern-Gerlach experiment and the concept of spin, Pauli-spin matrices and their properties, Spin operator and its eigen function and eigen values.

Addition of angular momentum : Addition of Spin and orbital angular momentum, Eigenfunctions and eigenvalues of total angular momentum operator $\mathbf{J^2}$ and $\mathbf{J_z}$ using both Schrödinger wave equation and operator method. Addition of angular momentum of two or more particles and Clebsch- Gordon co-effients.

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 box, cylindrical and spherical well. Simple harmonic oscillator in 3-dimensions. 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.

(24 Hours)

<u>Unit V</u>

Approximation methods

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.

WKB approximation*:* WKB expansion, wavefunction and energy. Application to simple one-dimensional bound state and transmission problems.

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. **(14 Hours)**

Text 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 (2 vol. set),Wiley-Interscience(1996).*********

Elective PHYE2.5: BIO PHYSICS (02 Credits)

Unit-I
Laws of Physics and Chemistry: Introduction, electronic structure of atoms, molecular orbital & covalent bonds, molecular interactions, thermodynamics, radioactivity.
Separation techniques: Chromatography, Electrophoresis.

(12 hours)

Unit-II
Physico-chemical techniques to study biomolecules: Hydration of macromolecules, role of friction, diffusion sedimentation The ultracentrifuge, Viscosity, rotational diffusion, light scattering &small angle x-ray scattering.

(10 hours)

Unit-III
Spectroscopy: UV, Visible, Fluorescence &Phosphorescence (CD) &Optical rotatory dispersion (ORD),Fluorescence, Infrared, Raman &ESR Spectroscopy.

(10 hours)

Text Book:

1. Essentials of biophysics – Narayan P ,New Age international pvt. Ltd, ND(2000)

Reference books::

1. Biophysics, V.Pattabhi, R.Gautham, Narosa Publishing house, ND,(2002)
2. Biophysics for biologists –Daniel.M.Agroblos (India) –2002
3. Principles of biophysics- Palanichanny S Shanmughavelu M Palani Paramount Publications,1996.

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Hardcore Lab PHYP 2.6: General Physics Lab II (2 Credits)

Hard core Lab PHYP 2.7: General Nuclear Physics Lab.*/General Condensed Matter Physics Lab. (2credits)**

Hardcore PHYH 3.1: Atomic and Molecular Physics(4 Credits)

Unit I & II

Atomic Spectra: Review of atomic models, spin-orbit interaction, Lamb shift. Spectra of hydrogen like ions, elements with two outer valence electrons. LS and JJ coupling, spectra of alkali metals. Penetrating and non-penetrating orbits. Review of Zeeman, Paschen-Back and Stark effect. Hyperfine structure of spectral lines in theory of one electron atom. Zeeman effect and Back-Goudsmidt effect in hyperfine structure. Review of X-ray spectroscopy. Regular and irregular doublet law.

(24 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.

(12 Hours)

Unit IV

Raman Spectroscopy: Rotational and vibrational Raman spectra. Correlation with IR spectra-Polarisation of Raman lines. Laser Raman studies.

Electron Spectroscopy: Electronic spectra of diatomic molecules, coarse structure. Franc-Condon principle. Rotational fine structure, formation of band head and shading. Determination of IR and band region.

(12 Hours)

Unit V

Fluorescence and Phosphorescence: Mirror image symmetry of absorption and Fluorescence bands, basic principles of photoelectron spectra. Determination of ionisation potential.

Lasers: *Population Inversion techniques*: Electrical and Optical pumping, building up of Laser action, criteria for lasing, threshold condition.

He-Ne Laser: Energy level diagram, principle, construction and working, applications.

Ruby lasers and semiconductor diode lasers(Qualitative).

(16 Hours)

Textbooks:

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, Cambridge University Press (1951-1989)
4. **G.Herzberg,** Molecular Spectra and Molecular Structure -I Spectra of Diatomic Molecules, D. Von Nostrand Inc. (1956).
5. **K.S. Krane**, Introductory Nuclear Physics, John Wiley (1988).
6. **G. Herzberg,** Molecular Spectra and Molecular Structure -II Infrared and Raman Spectra of Polyatomic Molecules, D. Von Nostrand Inc. (1956).
7. **G. Herzberg,** Atomic Structure and Atomic Spectra, Dover Pub. Co. 2nd Edition, (1944).
8. **H.E. White,** Introduction to Atomic Spectra. McGraw-Hill (1954).
9. **P.S. Sindhu,** Molecular Spectroscopy, Tata McGraw-Hill (1985).
10. E. U. Condon and H. Odabasi, Atomic Structure. Cambridge Universtiy Press (1980).
11. **H.A. Bethe and E.E. Salpeter**. Quantum Mechanics of One- and Two- Electron Atoms, Plenum Press (1977).

Hardcore PHYH3.2: Quantum Mechanics-II (4Credits).

Unit-I

Quantum Dynamics: The Schrödinger, Heisenberg and Interaction pictures.Equations of motion. **Time dependent problems*:*** Two level systems in a harmonically varying external potential. Example of spin in an external sinusoidal magnetic field. Time evolution of spin vector.

Pure and Mixed states: The density matrix,Properties;equation of motion for density matrix(Quantum Lipuville equation);Density matrix for spin ½ system. **(12 hours)**

Unit II

Time dependent perturbation theory*:* Perturbation expansion,Formal solution of the Schrodinger 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.

(12 Hours)

Unit III & IV

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

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.

(24 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, Normalisation. Dirac equation in an electromagnetic field. Non-relativistic approximation. Spin in Dirac theory, Conservation of angular momentum. Helicity, Negative energy solutions and Hole theory. Covariant formulation of Dirac equation, Brief discussion on application of Dirac theory to the hydrogen atom.

(16 Hours)

<u>Textbooks:</u>

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, 2^{nd} edition,Plenum US (1994).
6. **A.Ghatak and S Lokanathan,** QuantumMechanics: Theory and Applications, Macmillan (2004)
7. **L I Schiff,** Quantum Mechanics, 3rd ed. McGraw-Hill, 1968
8. **B. Bransden,C.Joachain**, Quantum Mechanics, 2nd edition, Pearson/Prentice Hall (2000).
9. **J. J. Sakurai,** Modern Quantum Mechanics, 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, F. Laloe,** Quantum Mechanics (2 vol. set), Wiley-Interscience(1996).

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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; Phase Transitions **(12 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 Microcanonical, Canonical and Grand Canonical ensembles; 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; **(15 hours)**

Unit V

Irreversible Processes and fluctuations; One dimensional Random Walk Problem; Analysis of Brownian motion; Einstein Theory; Langevin Theory; Fluctuation-Dissipation Theorem; Fokker-Planck equation for Brownian motion; 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 Sanchez**, Introductory Statistical Mechanics, 2nd Edition (1999)
4. **W.Greiner**, L.Neise and H.Stocker, Thermodynamics and Statistical Mechanics, Springer-Verlag (1995)
5. **K.Huang**, Statistical Mechanics, John Wiley (1998),
6. **D.Chandler**, Introduction to Modern Statistical Mechanics, OUP (1987)
7. **H.B. Callen**, Thermodynamics and an Introduction to Thermostatistics, John Wiley (1995)
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,
11. **Eisner and Aggrawal,** Statistical Mechanics,

PHYS 3.4.1: Condensed Matter Physics – I (4Credits)

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, residual resistivity, Hall Effect, electronic specific heat.

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.

(14 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 of solids : The dielectric function for a harmonic oscillator, dielectric losses of electrons, Kramers-Kronig relations; Interaction of phonons and electrons with photons; Inter band transition, direct and indirect transition; Absorption in insulators; Polaritons; One-phonon absorption; Optical properties of metals, skin effect and anomalous skin effect.

(14 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. dielectric properties of materials with frequency and temperature.

Ferroelectrics: General properties and classifications of ferroelectrics, dipole theory of ferroelectricity, objections against the dipole theory, ionic displacements and the behaviour of Barium Titanate above Curie temperature, theory of spontaneous polarisation of Barium Titanate, Polarisation catastrophe. Thermodynamics of ferroelectric transitions, Landau theory of the phase transition, ferroelectric domains. transducer and detector applications,

Composites: Introduction to composites, types of composites, single phase ME materials, composite ME materials, ME effect, properties of ME composites; sum properties, product properties, combination property, conditions for getting good ME output in composites, application of ME composites in different fields.

(24 hours)

Unit V

Physics of Nanomaterials,

Different form of nanostructures, idea of 2-d, 1-d and 0-d nanostructures; Hetrostructures Band bending, depletion width and capacitance, inversion layer, 2-d electron gas in triangular well potential, sub band, density of states, surface electron density; exciton, quantum size effect, electron confinement strong and weak limit, spherical well, effect of confinement;

Different methods of preparation 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 scattering experiments;

(12hours)

Text 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 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
16. A.S Edestein,R.C. Cammarata: Nano materials application and synthesis. Edited by *A. S. Edelstein* and *R. C. Cammarata*, Institute of Physics Publishing, Bristol, UK 1996
17. Dieter-Vollath Nano materials an introduction to synthesis properties and applications. 2 ed Wiley.VCH

18 Charles.P.Pole jr, Frank.J.Owens: introduction Nano technology. John Wiley & Sons, 30-May-2003

19 S.M. Lindsay: Introduction to Nano science, Oxford Univ. press, 2009

20 A.K.Bandyopdhyay ,Nano Materials :New age International (P) limited publishers), 2008

21 Juh Tzeng Lue, Encyclopedia of Nanoscience and Tech.; Physical properties of nano materials: Ed: H.S.Nalva, Vol. X, Page:1-46. 2007.

22. Ryan Richards and Helmut Bonnemann, Nanofabrication towards biomedical applications: Synthetic approach to metallic Nanomaterials :Editors: CSSR Kumar, J.Hormes, WILEY:VCH, 2005.

Softcore PHYS 3.4.2: Nuclear Physics-I (4 Credits)

Interaction of Radiation of Matter:
Interaction of heavy charged particles: stopping power, energy loss characteristics, particle range, energy loss in thin absorbers, Scaling laws, interaction of fast electrons, specific energy loss, electron range and transmission curves.

Interaction of Gamma rays: Interaction mechanisms, Photoelectric absorption. Compton scattering and pair production, Gamma ray attenuation, attenuation coefficients, absorber mass thickness and cross-sections.
Interaction of Neutrons: General properties- slow neutron interaction, fast neutron interaction, neutron cross sections.

Basic principles of measurement techniques such as collimation, shielding, geometry calibration etc.

Nuclear Detectors: Gas filled ionisation detectors, general features, Ionisation chamber, proportional counters, GM counters.

Scintillation Detectors: Different types of Scintillators, photo-multiplier tubes, measurements with scintillation detectors, NaI(Tl), Plastic scintillator, Scintillation spectrometer and spectrum analysis.

Semi-conductor detectors: Semi conductor properties, physics of semiconductor detectors, diffused junction, surface barrier and ion-implanted detectors, Si(Li), Ge(Li) and HPGe detectors, Semiconductor spectrometer, Pulse height analysis of spectra, SSNTD, TLD, Super heated drop detectors.

Nuclear Electronics: Pre-amplifier circuits, Voltage sensitive, Charge sensitive, Current sensitive amplifiers. Noise, linear pulse amplifier, pulse shaping, pulse stretching. Analog to digital converters(ADC). Pulse discriminators, coincidence and anti-coincidence circuits, scalers. Single and multichannel analysers. Time to amplitude converter.

Textbooks:

1. **G F Knoll,** Radiation Detection and Measurement , 3rd ed, John Wiley and Sons(2000).
2. **SS Kapoor and V S Rammurthy,** Radiation Detectors, Wiley Eastern(1986).
3. **W R Leo,** Techniques of Nuclear and Particle Physics experiments, 2nd ed, Narosa(1994).
4. **S N Ghoshal**,, Nuclear Physics, 3rd ed, S Chand(2003)
5. **C. Gruppen**, Particle Detectors, Cambridge University Press (1996)
6. **K. Kleiknecht**, Detectors for particle radiation, Cambridge University Press(1998)
7. **N Tsoulfanidis**, Measurement and Detection of Radiation,2nd ed, Taylor & Francis(1995)
8. **G Lutz,** Semiconductor Radiation Detectors : Device Physics , Springer(1999)
9. **W B Mann, R L Ayres, S B Garfinkel**, Radioactivity and its measurements, Pergamon(1980)

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Elective PHYE 3.5: Fundamentals Of Radiation Physics (02 Credits)

Unit I

Ionising radiation and their properties and sources: Review of atomic structure, atomic models, atomic number, mass number, and isotopes. Constituent of atomic nuclei, nomenclature of nuclei, relative abundance of chemical elements, stability of nuclei, binding energy, nuclear forces and nuclear models. Radioactivity, ionising radiations, waves and particles. Characteristics of radiation, energy of radiation, rate of decay, mean life, source strength. Basic properties of x-rays and gamma rays. Special units used in atomic and nuclear physics.

(**5 Hours)**

General properties of alpha, beta and gamma rays, laws of radioactivity and laws of successive transformations. Natural radioactive series, radioactive equilibrium, alpha ray spectra, beta ray spectra. Production of isotopes, rate of growth of activity, specific activity. Isotopic sources, neutron sources.

(5 Hours)

Unit II

Radiation dosimetry: Radiation quantities and units, Particle flux and fluence, energy flux and fluence, cross section, linear and mass absorption coefficient, stopping power and LET. Exposures and its measurement, absorbed dose and its relation to exposure. Electronic equilibrium, Bragg-Gray principle and air wall chamber, Kerma, Kerma rate constant. Biological effectiveness, Equivalent dose, effective dose, Ambient and directional equivalent dose. Tissue equivalence. Internal deposition: effective half-life, selectivity of organs, Beta particle dosimetry, Calculation of integral dose due to internal deposition. Dosimeters: Primary and secondary dosimeters. Pocket dosimeters, films, solid state dosimeters (TLD, RPL, etc.). Chemical and calorimetric devices.

(**12 Hours)**

Unit III

Radiation detection and measurement: Gas-filled ionisation chambers, proportional counters, GM counters general features, Characteristics of organic and inorganic counters, Resolving time, Surface barrier and ion-implanted detectors, Semiconductor spectrometers-HPGe and PHA of spectra, SSNTD, TLD, superheated drop detectors. Neutron detectors: BF3 counters, fission chambers, activation methods, Neutron time of flight method.

(**10 Hours)**

TEXT BOOKS:

1. **Glasstone S,** \`Source book on Atomic Energy' (East West Press, New Delhi)
2. **Knoll G F**, Radiaiton Detection and Measurements' (Wiley, New York, 1989)
3. **Greening J R, Bristol, Adam Hilger**, \`Fundamentals of Radiation Dosimetry' Medical Physics Hand Book 6, 1981
4. **Attix F H**, \`Radiation Dosimetry' Vol. I, II and III (Academic Press, NY, 1968)

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1. Hardcore Lab PHYP 3.6: General Physics Lab III (2 Credits)

2. Softcore Lab PHYSP 3.7.1: Condensed Matter Physics Lab I (2credits)

3. Softcore Lab PHYSP 3.7.2: Nuclear Physics Lab I (2credits)

Hardcore PHYH 4.1: Experimental Techniques (04 Credits)-Modified- To Be Implemented from JAN 2016.

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 thermometers,.

(**13Hours)**

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.

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.

(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)

Charged Particle Accelerator techniques:
DC accelerators-
General set up of an accelerator installation, Cock-Croft Walton accelerator, Van de Graff accelerator, Tandem Van de Graff accelerator, Pelletron.
AC accelerators-
Construction and working principles of Linear accelerator, Cyclotron, Sector focused cyclotron, Synchrocyclotron, principle of phase stability, Microtron, Betatron, Electron and Proton Synchrotron, Particle smashers (Colliders)qualitative idea only.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)

References:

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.Merrit 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 Reinhggand Glang**, "Hand book 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.

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Softcore PHYS 4.2.1: Condensed Matter Physics - II(4 Credits)

Unit I

Impurity semiconductors: Thermal ionization of impurities, impurity states and band model, statistics of impurity semiconductors; case of incomplete ionization of impurity levels (very low temperature).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, Gunn diode, semiconductor lasers, field effect transistor, the semiconductor lamp and other devices, Integrated circuits and microelectronics (qualitative),MOSFET, quantum Hall effect, heterojunctions, quantum wells and superlattices(qualitative) **(13Hours)**

Unit II

Photovoltaic converters:

Interaction of solar radiations with semiconductors, photovoltaic effect, types of solar cell, equivalent circuit diagram of a solar cell, determination of series resistance (Rs) and shunt resistance (Rsh), ideal properties of semiconductor for use its solar cell, carrier generation and recombination, dark and illuminated characteristics of solar cell, solar cell output parameters: RL, Voc, Isc, Pm, FF, efficiency, performance dependence of a solar cell on band gap energy, diffusion length and carrier life time, Types of heterojunction, construction of energy band diagram of heterojunctions, origin of capacitance in a heterojunction, expression for junction capacitance, Mott – Schottky relation.

(13 Hours)

Unit III: Materials and Solar cell Technology

Single, poly – and amorphous silicon, GaAs, CdS, Cu2S, CuInSe2, CdTe etc.technologies for fabrication of single and polycrystalline silicon solar cells, amorphous silicon solar cells and tandem cells, solar cell modules, photovoltaic systems, space quality solar cells.

Photochemical Converters

Semiconductor – electrolyte interface, photoelectrochemical solar cells,conversion efficiency in relation to material properties, photoelectrolysis cell, driving force of photoelectrolysis, alkaline fuel cell, semiconductor- septum storage cell,

Thermoelectric effects, 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.

(13 Hours)

Unit IV

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, magnetic properties of two electron system, Ground state of the Heisenberg ferromagnet, low temperature behaviour of Heisenberg ferromagnet. Ferromagnetic spin waves, Magnon dispersion relation, quantization of spin waves, thermal excitation of magnons, Bloch $T^{3/2}$ law, Ferromagnetic domains. Block wall.

High temperature properties, Corrections to Curie Law, Analysis of the critical point. Mean field theory, effect of dipolar interactions, domains, demagnetisation factors.

Ferrimagnetism: Structure of ferrites, saturation magnetisation, Curie temperature and susceptibility of ferrimagnets

Antiferromagnetism: Molecular field theory, two sub lattice model, Neel temperature. Magnetic susceptibility parallel and perpendicular to the applied magnetic field**.** **(13 Hours)**

Unit V

Properties of Ferrites: Intrinsic and Extrinsic Properties of Ferrites Magnetic Properties Under Consideration, Mixed Ferrites for Property Optimization, Temperature Dependence of Initial Permeability, Time Dependence Initial Permeability (Disaccomodation), Chemistry Dependence Low Field Losses (Loss Factor),Chemistry Considerations for Hard Ferrites Saturation Induction Microwave Ferrites and Garnets Ferrites for Memory and Recording Applications.

AC Properties of Ferrites: Introduction AC Hysteresis Loops Eddy Current Losses Permeability Disaccomamodation Core Loss Microwave Properties Microwave Processional Modes Logic and Switching Properties of Ferrites.

(13 Hours)

Text books:

10. **Charles Kittel**, Introduction to Solid State Physics (V edition), Wiley,1976.
11. **A.J. Dekker**, Solid State Physics, Prentice Hall, (1957).
12. **N.W.Ashcroft and N.D.Mermin**, Solid State Physics, Saunders college publishing (1976).
13. **J.S. Blakemore**, Solid State Physics,(II edition), Cambridge University Press,(1974).

Reference books:

14. **Harald bath and Hans Luth** ,Solid State Physics, Springer International Student editon, Narosa Publishing House, (1991).
15. **M.A. Omar**, Elementary Solid State Physics, Addison Wesley, New Delhi,(2000).
16. **S.O. Pillai**, Solid State Physics, New Age International Publication,(2002).
17. **M.A.Wahab**, Solid State Physics, Narosa Publishing House, New Delhi,(1999).
18. **H.C.Gupta**, Solid State Physics, Vikas Publishing House, New Delhi,(2002).

Solar energy conversion: The solar cell, by Richard C. Neville.

10. Photoelectrochemical solar cells – Suresh Chandra
11. Solar energy conversion – A. E. Dixon and J. D. Leslie.
12. Solar cells – Martin A.Green
13. Heterojunction and metal – semiconductor junctions – A.G. Milnes and D. L. Feucht.
14. Solid state electronic devices - B.G. Streetman.

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

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 interferenence, SQUIDS, High T_c superconductors (qualitative).

Superfluidity

Introduction-discovery, superfluidity in Helium; two fluid model. Bose-Einstein condensation, Landau's theory, First and second sound, third and fourth sound; Hydrodynamics of superfluid flow; quantization of vortex lines. Liquid Helium-3

(13Hours)

Unit II

Disordered systems

Disorder in condensed matter substitution, positional and topographical disorder; Short- and long-range order; Atomic correlation function and structural descriptions of glasses and liquids; Anderson model; mobility edge; Minimum Metallic Conductivity, applications of Amorphous semiconductors, glasses, polymers, liquid crystals, ceramics(Qualitative) and mechanism of conduction.

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 close-packed structures. Experimental method of detecting dislocations and stacking faults, Electron Microscopy: Kinematical theory of diffraction contrast and lattice imaging.

(13Hours)

Unit III

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.

Solar Energy: Different Types of Solar Cells:

Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current, Brief description of single crystal silicon and organic and Polymer Solar Cells, Elementary Ideas of Advanced Solar Cells e.g. Tandem Solar cells, Solid Liquid Junction Solar Cells, Nature of Semiconductor, Principles of Photo-electrochemical Solar Cells.

(13 Hours)

Unit IV & Unit V

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.

(8Hours)

Nanoparticles: Synthesis and Properties:

Method of Synthesis: RF Plasma Chemical Methods, Thermolysis, Pulsed Laser Methods,Metal Nanoclusters, Magic Numbers,Modeling of Nanoparticles, Bulk to Nano Transitions.

Carbon Nanostructures:

Nature of Carbon Clusters, Discovery of C60, Structure of C60 and its Crystal, Superconductivity in C60, Carbon Nanotubes: Synthesis, Structure, Electrical and Mechanical Properties.

Graphene: Discovery, Synthesis and Structural Characterization through TEM, electronic ,electrical and mechanical properties of graphine . Applications of graphine.

Quantum Wells, Wires and Dots:

Preparation of Quantum Nanostructures, Size Effects, Conduction Electrons and Dimensionality, Properties Dependent on Density of States.

Analytical Techniques for Nano Structures/ Particles:

Scanning Probe Microscopes (SPM), Diffraction Techniques, Spectroscopic Techniques, Magnetic Measurements.

Bulk Nanostructure Materials:

Methods of Synthesis, Solid Disorders Nanostructures, Mechanical Properties, Nanostructure Multilayers,

Metal Nanocluster, Composite Glasses, Porous Silicon. **(18Hours)**

Textbooks:

1..Charles Kittel, Introduction to Solid State Physics (7^{th} 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.Ziman, Principles of the theory of solids. Cambridge University Press, 29-Nov-1979

4. Harold Bath and Hans Luth ,Solid State Physics, Springer International Student editon, Narosa Publishing House, (1991).
5. M.A. Omar, Elementary Solid State Physics, Addison Wesley, New Delhi,(2000).
6. S.O. Pillai, Solid State Physics, New Age International Publication,(2002).
7. M.A.Wahab, Solid State Physics, Narosa Publishing House, New Delhi,(1999).
8. H.C.Gupta, Solid State Physics, Vikas Publishing House, New Delhi,(2002).
9. John P. McKelvey, Introduction to Solid State and Semiconductor Physics. Krieger Pub. Co., 1966
10. K.P.Jain, Physics of low dimensional semiconductors, Narosa (1997).
11. John H.Davies, Physics of low dimensional semiconductors, Cambridge University Press(1997)
12. R. Zallen: The Physics of Amorphous Solids; 2004 WIELY VCH Verlag GmbH & Co KGaH.Wienhein.
13. N.F. Mott and E.A. Davies: Electronic Processes in Non-crystalline Materials; 2nd edn. (Oxford University Press, New York, 1979).
14. H.P. Klug and L.E. Alexander: X-ray Diffraction Procedures; (Wiley, New York 1954) Revised 1974

15. B.D.Culity:X-ray and neutron diffraction. Oxford Press (1972)
16. S.Chandra Superionic conductors; North-Holland, 1981.
17. Verma and Srivastava, Crystallography and solid state physics; Wiley, 1982.
19. A.K. Vasudevan, and J.J. Petrovic Material science and Engineering; Thermal Spray 2001: New Surfaces for a New Millennium (Proceedings of Itsc 2001)
20 Chatercterzation of materials: J.B.Wachitman, Zwi.H.KAlman. Journal of Materials Science Letters 21 May 1993, Volume 12, Issue 9, pp 681-683
21. Materials science and Engineering -An Introduction : William Callister, John Wiley & Sons, 2007
22. Powder X-ray diffraction: L.V.Azaroff, Martin Julian Buerger ,McGraw-Hill, 1958.
23 Solar Cell Devices-Physics :Fonash Academic Press Inc; 2nd Revised edition edition (28 May 2010)
24. Phoptoelectrochemical Solar Cells: Suresh Chandra, Physica status solidi (a) 1982 WILEY-VCH Verlag GmbH & Co. KGaA
25. Quantum Dots : Jacak, Hawrylak and Wojs Springer; Softcover reprint of the original 1st ed. 1998 edition (June 4, 2012)
26. Handbook of Nanostructured Materials and Nanotechnology : Nalva (editor), Academic Press, 2002
27. Nano Technology/ Principles and Practices: S.K. Kulkarni, Springer International Publishing 3rd Edition. Springer, 2015
28. Carbon Nanotubes: Silvana Fiorito Pan, Stanford Publishing (31 May 2008).
29. Nanotechlongy: Richard Booker and Earl Boysen, John Wiley & Sons, 2011.

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Softcore PHYS 4.2.2: Nuclear Physics-II (4 Credits)

Unit I & II

Nuclear Forces: Charge Symmetry, spin dependence, tensor character, exchange character, pseudoscalar meson theory. General survey of non-central forces.

Nucleon-Nucleon Forces: Charge independence, isospin formalism, conversion of isotopic spin, charge independent, Exchange operations and exchange forces.

Nuclear Models:

Nuclear Shell model: Motion in a mean potential, square well and oscillator potential well, spin orbit potential, extreme single particle model, L-S coupling and j-j coupling, magnetic and quardupole moments.

Fermi Gas Model: Kinetic energy in the ground state, asymmetry energy, nuclear evaporation.

Optical Model: Optical model and its applications.

Collective model: Nuclear rotational motion. Rotational energy spectrum and nuclear wave functions. Nuclear moments. Collective excitations.

(25 Hours)

Unit III& IV

Deuteron and the Nuclear Force: Properties of deuteron,Theory of the ground state of Deuteron,excited states of deuteron, wave equation for a central force relation between the range and depth of potentials,Deuteron as mixture of s and d states,admixtures of deuteron wave functions,magnetic moment of deuteron.

n-p and p-p scattering:Low energy n-p scattering formalism, partial wave analysis, energy dependence of phase shifts for short range scattering potential. S-wave scattering for spindependence, S-wave scattering amplitude and scattering length.

Effective range theory, cross section for a square well of finite width,coherent scattering for hydrogen molecules and the sign of scattering lengths, Cross sections for ortho, para hydrogen, comparison with experiments. The optical theorem, low-energy scattering of protons by protons, Mott's modification of Rutherford's formula, Experimental results, High energy n-p and p-p scattering, experimental results.

(25 Hours)

Unit V

Nuclear Reactions: Cross section for scattering and reactions, compound Nucleus, Breit-Wigner Formula, Continuum theory, Statistical theory of nuclear reactions. Evaporation probability and cross sections for specific reactions.

Direct reactions,Resonance reactions, Kinematics of pickup and stripping reactions,theory of stripping and pickup reactions.

(14 Hours)

Textbooks:

1. **I Kaplan,** Nuclear Physics, Addison-Wesley(1962)
2. **R R Roy and B P Nigam**, Nuclear Physics, New Age(1967).
3. **S N Ghoshal**, Nuclear Physics, 3r ed, S Chand(2003)
4. **M A Preston**, Physics of the Nucleus, Addison Wesley,
5. **E Segre**, Nuclei and Particles, Benjamin(1977)
6. **R D Evans**, The Atomic Nucleus, McGraw Hill(1955)
7. **G R Satchler**, Introduction to Nuclear Reactions, Macmillan(1980)
8. **D F Jackson**, Nuclear Reactions, Metheun(1970)
9. **J M Pearson**, Nuclear Physics: Energy and Matter, Adam Hilger(1986)
10. **M A Preston and R K Bhadhuri**, Structure of the Nucleus, Addison Wesley(1975)
11. **A Bohr and B Mottelson**, Nuclear Structure I, Benjamin(1969)
12. **A Bohr and B Mottelson**, Nuclear Structure II, Benjamin(1975)

13. **G E Brown**, The Unified theory of Nuclear Models and Forces, North-Holland(1967)
14. **S B Patel**, Nuclear Physics, New Age(1991)
15. **J B Blatt and V F Weisskopf,** Theoretical Nuclear Physics,

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Softcore PHYS 4.3.2: Nuclear Physics III (04 Credits)

Unit I

Nuclear Fission and Fusion:

Fission processes,Spontaneous fission,Emission cross section,Nature of the fragments,Bohr-Wheeler theory of nuclear fission,statistical model of fission, photo fission, photo nuclear reactions, condition for fusion, magnetic confinement**.** **(10 Hours)**

Unit Neutron Physics: Radioactive 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, targets for production of neutrons, collimation and shielding, fast neutron dosimetry.

(15 Hours)

Unit III & IV

Reactor Physics: Slowing down of neutrons, moderators, condition for controlled chain reaction in a homogeneous reactors , effect of reflector critical size

Criticality Condition: Four factor formula:Neutron transport equation, Diffusion theory of neutrons,one group critical equations.The Fermi age diffusion method and multi group diffusion theory.

Homogeneous reactor systems: Infinite multiplication factor- calculation of critical size, Heterogeneous reactor systems. Calculation of thermal utilisation. Calculation of optimum lattice. Fast reactors, Breeder reactors, Multi-group equations. Evaluation of buckling, Core composition and critical mass.

(25 Hours)

Unit V

Nuclear Fuels: The fuel cycle, production of reactor fuels: Sources of Uranium, production of Uranium and its compounds: Thorium and Plutonium. Properties of Fuel Materials: Uranium and its compounds, Plutonium and Thorium Fuel Materials.

(**14 Hours)**

Textbooks:

1. **P M Zweifel,** Reactor Physics, McGraw Hill(1973)
2. **W M Stacey,** Nuclear Reactor Physics, Wiley(2001)
3. **J J Duderstadt and L J Hamilton**, Nuclear Reactor Analysis, Wiley (1976)
4. **J R Lamarsh and A J Baratta**, Introduction to Nuclear Engineering,3rd ed,Prentice Hall(2001)
5. **J R Lamarsh,** Introduction to Nuclear Reactor Theory, Amer.Nuc.Soc(2002)
6. **S N Ghoshal**, Nuclear Physics, 3rd ed, S Chand(2003)
7. **G Bell, S Glasstone**, Nuclear Reactor Theory, Robert E. Krieger Publishing(1985)
8. **S Glasstone and M C Edlund,** The Elements of Nuclear Reactor Theory, Reinhold(1952)

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Softcore Lab PHYSP 4.4.1: Condensed Matter Physics Lab II (2credits)
Softcore Lab PHYSP 4.4.2: Nuclear Physics Lab II (2credits)
PHY 4.5: Project work