THE UNIVERSITY OF BURDWAN
SYLLABUS FOR M. Sc. IN PHYSICS
EFFECTIVE FROM
2014 – 2015 SESSION

Course Structure in Physics

	Paper	Core Subjects	Marks	Credit
SEMESTER I	**MPHY0101**	Mathematical Methods I	25	2
	MPHY0102	Classical Mechanics	25	2
	MPHY0103	Quantum Mechanics I	25	2
	MPHY0104	Classical Electrodynamics I	25	2
	MPHY0105	Solid State Physics I	25	2
	MPHY0106	Electronics I	25	2
	MPHY0107	Atomic Spectroscopy	25	2
	MPHY0108	Nuclear Physics I	25	2
	MPHY0109	Practical	100	8
	TOTAL		**300**	**24**
SEMESTER II	**Paper**	**Core Subjects**	**Marks**	**Credit**
	MPHY0201	Mathematical Methods II	25	2
	MPHY0202	Relativity	25	2
	MPHY0203	Quantum Mechanics II	25	2
	MPHY0204	Classical Electrodynamics II	25	2
	MPHY0205	Solid State Physics II	25	2
	MPHY0206	Electronics II	25	2
	MPHY0207	Advanced Optics	25	2
	MPHY0208	Nuclear Physics II	25	2
	MPHY0209	Practical	100	8
	TOTAL		**300**	**24**
	Paper	**Core Subjects**	**Marks**	**Credit**
	MPHY0301	Statistical Mechanics I	25	2
	MPHY0302	Advanced Quantum Mechanics I	25	2
	MPHY0303	Group Theory	25	2
	MPHY0304	Computer Applications in Physics-I	25	2
	MPHY0305	Computer Programming Skill	15	1
	MPHY0306	Seminar Presentation	10	1

SEMESTER-III		**Major Elective Subjects**		
	MPHY0307	Radiophysics & Electronics-I	50	4
	MPHY0308	Radiophysics & Electronics-II	50	4
	MPHY0309	Laser Physics-I	50	4
	MPHY0310	Laser Physics-II	50	4
	MPHY0311	Materials Science-I	50	4
	MPHY0312	Materials Science-II	50	4
	MPHY0313	Condensed Matter Physics-I	50	4
	MPHY0314	Condensed Matter Physics-II	50	4
	MPHY0315	Nuclear & Particle Physics-I	50	4
	MPHY0316	Nuclear & Particle Physics-II	50	4
	MPHY0317	General Relativity & Astrophysics-I	50	4
	MPHY0318	General Relativity & Astrophysics -II	50	4
	Students have to choose either **MPHY0307** & **MPHY0308** or **MPHY0309** & **MPHY0310** or **MPHY0311** & **MPHY0312** or **MPHY0313** & **MPHY0314** or **MPHY0315** & **MPHY0316** or **MPHY0317** & **MPHY0318**. No. of intake will be decided by the department depending on the no. of available of seats			
	MPHY0319	Practical	75	6
	TOTAL		**300**	**24**
SEMESTER-IV	**Paper**	**Core Subjects**	**Marks**	**Credit**
	MPHY0401	Statistical Mechanics II	25	2
	MPHY0402	Advanced Quantum Mechanics II	25	2
	MPHY0403	Molecular Spectroscopy	50	4
	MPHY0404	Computer Applications in Physics-II	25	2
	MPHY0405	Nonlinear Dynamics	25	2
	MPHY0406	Project/Term Paper	15	1
	MPHY0407	Social out-reach activity	10	1
	TOTAL		175	14
		Major Elective Subject		
	MPHY0408	Practical	75	6
		Minor Elective Subjects		
	MPHY0410	Communication Technology	50	4
	MPHY0411	Laser Applications and Nonlinear Optics	50	4
	MPHY0412	Properties of Materials	50	4
	MPHY0413	Advanced Condensed Matter Physics	50	4
	MPHY0414	High Energy Physics	50	4
	MPHY0415	Cosmology	50	4
	No. of student intake will be decided by the department depending on the available seats			
	TOTAL		**300**	**24**

SEMESTER – I (TOTAL MARKS 300) (CREDIT 24)

Paper: MPHY0101

Mathematical Methods – I **[Marks 25]** **[Credit 2]**

1. (a) Functions of a complex variable. Brief review of the topics included in the honours syllabus : analytic functions, Cauchy-Riemann equations, integration in the Complex plane, Cauichy's theorem, Cauchy's integral formula. Liouville's theorem. Moretra's theorem.

   (b) Proof of Taylor and Laurent expansions. Singular Points and their classification. Branch Point and branch Cut. Riemann sheets. Residue theorem. Application of residue theorem to the evaluation of definite integrals and the summation of infinite series. Integrals involving branch point singularity.

2. Linear vector spaces, subspaces, Bases and dimension, Linear independence and orthogonality of vectors, Gram-Schmidt orthogonalisation procedure. Linear operators. Matrix representation. The algebra of matrices. Special matrices. Rank of a matrix. Elementary transformations. Elementary matrices. Equivalent matrices. Solution of linear equations. Linear transformations. Change of Basis. Eigenvalues and eigenvectors of matrices. The Cayley-Hamilton theorem. Diagonalisation of matrices. Bilinear and Quadratic forms. Principal axis transformation. Functions of matrices. Powers of a matrix. Roots of a matrix. Exponential of a matrix. Logarithm of a matrix.

Books Recommended:

M. R. Spiegel (Schaum's outline series) – Theory and Problems of Complex Variables.
George B. Arfken and Hans J. Weber (Academic Press) – Mathematical Methods for Physicists.
J. Mathews and R. I. Walker (Benjamin) – Mathematical Methods of Physics.
P. Dennery and A. Krzywicki (Harper and Row) – Mathematics for Physicists.

Paper: MPHY0102 **[Marks 25]** **[Credit 2]**

Classical Mechanics

Review of Lagrangian and Hamiltonian formalisms in different systems. Legendre transformation. Hamilton's canonical equations and their applications. Lagrangian and Hamiltonian for relativistic particles. Principle of least action.

Canonical Transformation: Equations of point and Canonical transformations; generating functions; examples of canonical transformation; Lagrange and Poisson brackets and their applications. Invariance of Poisson bracket under canonical transformation; Equations of motion in Poisson Bracket; infinitesimal canonical transformation; constants of motion and symmetry principles; generators of infinitesimal symmetry transformation; Noether's theorem; integral invariant of Poincare. Conservation theorems and angular momentum relation in Poisson brackets. Liouville's theorem.

Hamilton-Jacobi equation: Hamilton-Jacobi equation for Hamilton's principal and characteristics functions; Physical significance of these functions; Application of Hamilton-Jacobi equation in linear harmonic oscillator, particle falling under gravity etc; action and angle variables; importance of action-angle variables; Applications of action-angle variables; Passage from classical to quantum mechanics.

Rigid body motion. Heavy symmetrical top with one point fixed on the axis. Fast and sleeping top.
Deformable bodies. Strain and stress tensor. Energy of elastic deformation.

Fluid dynamics. Permanancy of vortices. Navier-Stokes theorem.

Books Recommended:

1. Classical mechanics-Goldstein
2. Introduction to advances dynamics-McCuskey
3. Mechanics- Landau and Liftshitz.
4. Classical Mechanics- K.C. Gupta
5. Classical Mechanics- Rana and Jog

Paper: MPHY0103 [Marks 25] (Credit 2]

Quantum Mechanics- I

Operator Algebra:

Vector space, concept of state vectors , principle of superposition of states, basis functions, change of basis, Ket vector and its characteristics, Bra vector and its characteristics, orthonormility, completeness condition and closure property, Hilbert space, Hermitian adjoint operator, Hermitian operator, Fundamental postulates of Quantum mechanics, eigenvalue equation, Real eigenvalues of Hermitian operator, orthogonality of eigenkets for non-degenerate eigenvalues for Hermitian operator, expectation value, projection operator, theorems of commutations of two operators, Uncertainty relation between two canonically conjugate operators using the concept of expectation value, Closure property for continuously varying Kets. Unitary operator and its characteristics, relation between wave function (Ψ) and state vector $I\Psi>$, operator representation of position and momentum, relation between $\Psi(x)$ and $\Psi(p)$. Use of operator algebra for finding the angular momentum of electron in a spherically symmetric potential. Angular wave functions of the electron in a hydrogen like atom.

Equations of motion: Time dependence of expectation values, Schrodinger, Heigenberg and Interaction pictures, equation of motion in Schrodinger picture, time translation operator, transition to Heisengenberg picture, equation of motion in Heisenberg and interaction pictures, stationary states.

Stationary states problem: (a) one dimensional problem, (b) δ function potentials and barriers, (c) three dimensional problems- spherical oscillator, Hydrogen problem.

Harmonic oscillator with operator algebra:

Creation and annihilation operators, Oscillator algebra, Hamiltonian of harmonic oscillator in terms of creation and annihilation operators, Number operator, solution of energy eigenvalues,

Selection rule, solution of wave functions, Coherent state, Coherent state as a normalized state, Coherent state is a state of minimum uncertainty product of position and momentum.

Books Recommended:

1) 'Quantum Physics' by Robert Eisberg and Robert Resnick (John Wiley and sons).
2) 'Quantum Theory' by D. Bohm (Prentice-Hall).
3) 'Quantum Mechanics: Theory and Applications' by A. K. Ghatak and S. Lokanathan (Macmillan India Ltd.).
4) 'Quantum Mechanics' by L. I. Schiff (McGraw-Hill Book, New York).
5) 'Quantum Mechanics' by Cohen and Tanandji.
6) Prabir Ghosh, Quantum mechanics, Narosa Publication

Paper: MPHY0104 [Marks 25] [Credit 2]

Classical Electrodynamics- I

Green function, Inhomogeneous wave equation: it's solution. Lineard-Wiechart potentials, Fields of a uniformly moving charge, Fields of an accelerated charge: Fields, radiation (power) and angular distribution from a charge at low velocity (non-relativistic), radiation (power) from a charge at linear motion and circular motion or orbit, angular distribution of power for linearly linearly accelerated charges, relativistic correction, Bremsstrahlung-Cerenkov radiation (qualitative treatment only). Radiation from a localised oscillating charges, near and far zone field, multipole expansion, dipole and quadrupole radiation, centre-fed linear antenna, classical theory of electron: radiation reaction from energy conversation: Lorentz theory, self force.

Books Recommended:

1. Marion- Classical Electrodynamics
2. Jackson- Classical Electrodynamics
3. Panofsky & Phillips- Classical Electrodynamics
4. Chen- Plasma Physics
5. Griffith-Electrodynamics

Paper: MPHY0105 [Marks 25] [Credit 2]

Solid State Physics- I

1. **Crystal structure and X-ray diffraction**: Lattices and Unit cells, Symmetry, Reciprocal lattice, Brillouin Zone, Simple crystal structures: FCC, BCC, HCP, NaCl, ZnS and diamond, Waves in crystals, X-ray diffraction, Laue and Bragg condition, Ewald construction, derivation of amplitude of scattered wave, atomic form factor, crystal structure factor, geometrical structure factor, X-ray, electron and neutron diffraction.

2. **Imperfection in solids**: Different types of defects and dislocation, point defects and line defects, defect concentration, disorder

3. **Crystal binding:** General considerations about bonding: ionic bonds, covalent bond, van der Walls-Fluctuating dipole forces-or molecular bonding, metallic bonding, hydrogen bonds

4. **Lattice vibrations:** Lattice dynamics, harmonic approximation, vibration of monatomic and diatomic linear lattices, dispersion relations and normal modes, quantisation of lattice vibration and phonons, anharmonic crystal interactions and thermal expansion (qualitative discussion only)

5. **Magnetic properties of solids:** Diamagnetism, paramagnetism – semiclassical treatment-paramagnetism for J=1/2, Brillouin function-van Vleck paramagnetism; ground state of an ion and Hund's rules, crystal field-quenching of orbital momentum, ferromagnetism-Weiss model, magnetic susceptibility, effect of a magnetic field, origin of the molecular field, antiferromagnetism-Weiss model, magnetic susceptibility, types of antiferromagnetic order, ferrimagnetism, ferromagnetic domains and domain walls, exchange interactions.

Books recommended:

1. F.C.Phillips: An introduction to crystallography (wiley)(3rd edition)
2. Charles A Wert and Robb M Thonson: Physics of Solids
3. J. P. Srivastava: Elements of solid state physics (Prentice Hall India; 2nd edition).
4. Christmaan-solid state physics (academic press)
5. A R Verma & O N Srivastava, Crystalolgraphic application to solid state physics

Paper: MPHY0106 **[Marks 25]** **[Credit 2]**

Electronics- I

1. Semiconductor Devices:

(a) p-n junction physics- Fabrication steps; thermal equilibrium condition; depletion capacitance; current-voltage characteristics; charge storage and transient behavior; junction breakdown; heterojunction.

(b) Characteristics of some semiconductor devices- BJT, JFET, MOS, LED, Solar cell, Tunnel diode, Gunn diode and IMPATT.

2. Active Circuits:

Transistor amplifiers- Basic design consideration; high frequency effects; video and pulse amplifier; resonance amplifier; feedback in amplifiers.

Harmonic self-oscillators - Steady state operation of self-oscillator; nonlinear equation of self oscillator; examples.

3. Op-Amp Circuits:

Characteristics of ideal and practical op-amp; Nonlinear amplifiers using op-amps- log amplifier, anti-log amplifier, regenerative comparators; Active filters; precision rectifiers; ADC and DAC circuits; Op-amp based self oscillator circuits- RC phase shift, Wien bridge, non-sinusoidal oscillators.

Voltage Regulators: Series op amp regulator, IC regulator, Switching regulators.

Books Recommended:

1. J D Ryder, Electronics Fundamental and application, PHI
2. Gaykwad, Operational Amplifier.
3. Zee, Physics of semiconductor devices.
4. Milman and Grable, Microelectronics. Tata MacGraw Hill.

5. Chattopadhyay and Jain, Analog integrated circuits
6. Chattopadhyay and rakshit, Electronic Circuit analysis

Paper: MPHY0107 **[Marks 25]** **[Credit 2]**

Atomic Spectroscopy

1. General discussion in Hydrogen spectra, Hydrogen-like systems, Spectra of monovalent atoms, quantum defect, penetrating and non-penetrating orbits, introduction to electron spin, spin-orbit interaction and fine structure, relativistic correction to spectra of hydrogen atom, Lamb shift, effect of magnetic field on the above spectra, Zeeman and Paschen-Back effect.
2. Spectra of divalent atoms: Singlet and triplet states of divalent atoms, L-S and j-j coupling, branching rule, magnetic field effects, Breit's scheme, complex spectra, equivalent electrons and Pauli exclusion principle.
3. Hyperfine structure in spectra of monovalent atoms, origin of X-rays spectra, screening constants, fine structure of X-ray levels, spin-relativity and screening doublet-laws, non-diagram lines, Auger effect.
4. Laser in Spectroscopy:
   (i) Absorption spectroscopy, (ii) excitation spectroscopy, (iii) ionization spectroscopy, (iv) saturation spectroscopy, (iv) photo acoustic spectroscopy, (v) opto-galvanic spectroscopy, Doppler-free spectroscopy, Tera Hertz spectroscopy with innovative applications.

Recommended books:
1. Introduction of atomic spectroscopy: White
2. Laser Spectroscopy: Allan Corney
3. Laser in Chemistry- D L Andrew

Paper: MPHY0108 **[Marks 25]** **[Credit 2]**

Nuclear Physics- I

1. Static and dynamic properties of nuclei: Introduction, parity and isospin of nuclei, Determination of nuclear size: mirror nuclei, muonic atoms and electron scattering methods, charge form factor. Magnetic dipole moment and electric quadrupole moment; Experimental determination. NMR.

2. Two-nucleon problem and nuclear forces: Deuteron problem; ground state and excited states, two-nucleon scattering, partial wave analysis, phase-shift, scattering length, n-p and p-p scattering, charge symmetry and charge independence of nuclear forces. Form of nucleon-nucleon potential; Exchange nature of nuclear forces, elementary discussion on Yukawa's theory.

3. Nuclear models : Introduction; Fermi gas model: Derivation of Fermi energy and ground state kinetic energy for nucleons, Spherical shell model: Extreme single particle model: Spin orbit interactions and reproduction of magic numbers; Predictions of shell model: Ground state spin parity; Magnetic dipole moment and electric quadrupole moment; Single particle model; Introduction to Collective model.

4. Nuclear reactions: Direct and compound nuclear-reactions, Reciprocity theorem; experimental verification of Bohr's independence-hypothesis, resonance reactions, Breit-Wigner one-level formula, Transfer reactions; Optical model.

5. Particle accelerators: Pelletron, tandem principle, Synchrotron and synchrocyclotron, colliding beams, threshold energy for particle production.

Books Recommended:

1. Nuclear Physics- S. N. Ghoshal (S. Chand Publications)
2. Nuclear Physics- D. C. Tayal (Himalaya Publications)
3. Introductory Nuclear Physics- K. S .Krane (Wiley India)
4. Nuclear Physics: Theory and Experimental- H. S. Hans (New Age International)
5. Nuclear Physics: Theory and Experiment- R. R. Roy and B. P. Nigam (John Wiley and Sons)

Paper: MPHY0109 [Marks 100] [Credit 8]

List of experiments

Non-Electrical:

1. Determination of mean wavelength and separation of wavelengths of sodium light by Fabry Perot interferometer
2. Determination of e/m by magnetron valve/magnetic focusing method
3. Determination of speed of ultrasonic waves in an aqueous medium
4. Measurement of thickness of a thin foil by Jamin's interferometer
5. Determination of (i) Rydberg constant, (ii) ionisation potential and (iii) quantum defect of an alkali atom.
6. Determination of Stefan's constant and hence computation of the Planck's constant
7. Determination of Hall voltage and carrier concentration of a given semiconductor
8. Study of optical characteristics of a LED and determination of band gap of the material of LED.
9. Study of dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibrations.
10. To draw the plateau curve of a GM Counter and hence to determine the statistical variation of counts of the GM Counter.
11. Determination of wavelength of sodium light using Lloyd's mirror.

Electrical & Electronics

1. Study the current mirror biasing and V_{BE} multiplier based voltage reference
2. Study the transistor amplifier in common emitter (CE) mode
3. To draw the LDR characteristics at different intensities and to find out the value & the dark resistance of the LDR
4. Study on op-amp based linear and nonlinear amplifier
5. Studies on regulated and unregulated DC power supply
6. Study the input and output voltage characteristics of Schmitt trigger circuit
7. Studies on characteristics of different gates

8. To Construct and test the operation Preamphasis & deemphasis circuits by plotting frequency response using Op-amp.
9. To Study the amplitude modulation technique and determine the modulation index
10. To study the transfer characteristics of different networks and to study the phase transfer characteristics of a given two-port network (RC) by using CRO.

All the students will be divided into two groups i.e. Non-electrical and Electrical & Electronics and that will be decided by the Department

SEMESTER – II (TOTAL MARKS 300) (CREDIT 24)

Paper: MPHY0201 [Marks 25] [Credit 2]

Mathematical Methods- II

1. Integral transforms. Fourier transforms. Inverse Fourier transforms. Fourier transform of derivatives. Covolution theorem. Momentum representation. Laplace transforms. Inverse Laplace transforms. Laplace transform of derivatives. Derivative of a transform. Integration of transforms. Laplace Covolution theorem. Solution of ordinary and partial differential equations by Fourier and Laplace transform methods.

2. Green's functions for ordinary and partial differential equations of mathematical physics. Integral equations. Fredholm and volterra equations of the first and second kinds. Solution of integral equations using Integral transforms, Generating functions, Neumann series, Separable (degenerate) kernels. Hilbert – Schmidt theory.

3. Tensor analysis, Coordinate transformations, scalars, Covariant and Contravariant tensors. Addition, Subtraction, Outer product, Inner product and Contraction. Symmetric and antisymmetric tensors. Quotient law. Metric tensor. Conjugate tensor. Length and angle between vectors. Associated tensors. Raising and lowering of indices. Tensor calculus. Differentiation of a tensor. The Christoffel symbols and their transformation laws. Covariant derivative of tensors.

Books Recommended

George B. Arfken and Hans J. Weber (Academic Press) – Mathematical Methods for Physicists.
J. Mathews and R. I. Walker (Benjamin) – Mathematical Methods of Physics.
P. Dennery and A. Krzywicki (Harper and Row) – Mathematics for Physicists.
W. Joshi (Wiley Esstern) – Matrices and Tensors

Paper: MPHY0202 [Marks 25] [Credit 2]

Relativity

1. **Brief review** of Minkowski's Four Dimensional Space-time.

2. **Tensor calculus and curved space:**

Idea of parallel transport and covariant derivatives, Geodesics, Curvature tensor and its properties, Bianchi Identities, Ricci tensor, Einstein tensor.

3. **Einstein's equation of Gravity:**

Principles of equivalence, Principle of general covariance, Metric tensors and Newtonian Gravitational potential, Logical steps leading to Einstein's equations of gravitation, Linearised equation for weak fields.

4. **Applications of general relativity:**

Schwarzschild's exterior solution, singularity, event horizon and concept of black holes, Birkhoff's theorem, Observational tests of Einstein's theory – Precession of Perihelion of the planet Mercury, Bending of light rays in a gravitation field, Gravitational Red shift.

5. **Stellar Structure and Evolution:**

Star formation, Stellar Magnitudes, Classification of stars, H-D classification, Hertzsprung-Russel (H-R) diagram, Celestial coordinate systems, Virial theorem, Equations of stellar structure and evolution.
Pre-main sequence evolution, Jeans criteria for star formation, fragmentation, Polytropic Models: Lane-Emden equation, Post main sequence stage.

6. **Nuclear Astrophysics:**

Thermonuclear reactions in stars, pp chains and CNO cycle, Helium burning and subsequent thermonuclear reactions, nucleosynthesis beyond iron, r- and s- processes.

7. **Gravitational Collapse & Relativistic Astrophysics:**

Introduction, Newtonian theory of stellar equilibrium, White Dwarfs, Chandrasekhar Mass Limit (no derivation), Neutron Stars, Tolman-Oppenheimer-Volkoff (TOV) equation (derivation is not required) and its consequences,. Pulsars.
Black holes, Dutt-Oppenheimer-Snyder (DOS) equation and its consequences (derivation is not required), Kerr black hole (no derivation), event horizon, Penrose process, No Hair Theorem, Kerr-Newmann metric (no derivation).
Qualitative discussions on: Quasars, Brown dwarfs, Red Giant Stars, Nova, Supernova

8. **Cosmology:**

Cosmological Principles, Weyl postulate, Hubble's law. Robertson-Walker metric (derivation is not required), Cosmological parameters, Static Universe, Expanding universe, Open and Closed universe.

Books Recommended:

1. Textbook of astronomy an astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2. Theoritical Astrophysics (Vols.I,II,III) – T. Padmanavan (CUP)
3. Introduction to Cosmology – J.V.Narlikar (Cambridge University Poress)
4. General Relativity, Astrophysics and Cosmology – A.K.Raychaudhuri, S.Banerji and A.Banerjee (Springer-Verla, 1992)
5. General Relativity and Cosmology – S. Banerji and A. Banerjee (Elsevier, 2007)
6. The Structure of the Universe – J.V.Narlikar (OUP, 1978)
7. General Relativity and Cosmology (MacMillion, 1978).- J. V. Narlikar
8.Theory of Relativity (Wiley, 1972). - S. Weinberg

9. Introduction to Theory of Relativity (Prentice-Hall, 1969). - P. G. Bergmann
10. Introduction to Special Theory of Relativity.- R. Resnick
11. The Special Theory of Relativity (Prentice Hall of India, 2002) S. Banerji and A. Banerjee
12. Introduction to the Theory of Relativity. - W.G.V. Rosser

Paper: MPHY0203 [Marks 25] [Credit 2]

Quantum Mechanics- II

Approximation methods: Time independent perturbation theory for non-degenerate and degenerate states (derivation of first order corrections of energy eigenvalues and wave functions and derivation of Second order correction of energy eigenvalues), Application of time independent perturbation theory - Anharmonic oscillator, Stark effect in hydrogen atom, Ground state energy of Helium atom. Variational method: Concept of method of variation and its application for finding the ground state of Helium atom. WKB method: Connection formulae, Application. Time-dependent perturbation theory: Harmonic perturbation, Fermi's golden rule, Sudden approximation.

Generalised angular momentum- Infinitesimal rotation, Generator of rotation, Commutation rules, Matrix representation of angular momentum operators, Spin, Pauli spin matrices, Rotation of spin states, Coupling of two angular momentum operators, Clebsch Gordon co-efficients, Applications.

Symmetries- Symmetries, Invariance principle and Conservation laws, Space translation, Time translation, Space rotation, Irreducible spherical tensor operators, Wigner-Eckert theorem and its applications, Space inversion, Time reversal.

Scattering theory- Scattering of a particle by a fixed centre of force, scattering amplitude, differential and total cross sections. Method of partial waves, phase shifts, optical theorem. Scattering by a hard sphere and potential well. Integral equation for potential scattering. Green's function. Born approximation. Yukawa and Coulomb potential.

Books Recommended:

1) 'Quantum Physics' by Robert Eisberg and Robert Resnick (John Wiley and sons).
2) 'Quantum Theory' by D. Bohm (Prentice-Hall).
3) 'Quantum Mechanics: Theory and Applications' by A. K. Ghatak and S. Lokanathan (Macmillan India Ltd.).
4) 'Quantum Mechanics' by L. I. Schiff (McGraw-Hill Book, New York).
5) 'Quantum Mechanics' by Cohen and Tanandji.
6) Prabir Ghosh, Quantum mechanics, Narosa Publication

Paper: MPHY0204 [Marks 25] [Credit 2]

Classical Electrodynamics- II

Dispersion: Dispersion and absorption: Lorentz electromagnetic theory. Kramers-Kronig relation.

Magnetohydrodynamics: Magnetohydrodynamic (MHD) equations, magnetic, viscosity, pressure, Reynold number, etc. MHD waves. Alfven waves and velocity, Hartmann flow and Hartmann number

Plasma Physics: (a) Orbit theory of drift motions in a plasma. Pinch effect. Instability in pinched plasma column. Plasma oscillations, short wavelength of plasma oscillation and Debye screening length

(b) Propagation of EM waves through plasma. Effect of external magnetic field on wave propagations: ordinary and extraordinary rays.

Waveguide: Wave guides and resonant cavities: Basic concept of wave guides, TE & TM modes, Rectangular waveguide, circular waveguide, resonat cavities, rectangular cavity resonator-TE, TM modes. Power loss in a cavity-Q of a cavity.

Books Recommended:

1. Marion- Classical Electrodynamics
2. Jackson- Classical Electrodynamics
3. Panofsky & Phillips- Classical Electrodynamics
4. Chen- Plasma Physics
5. Griffith-Electrodynamics

Paper: MPHY0205 [Marks 25] [Credit 2]

Solid State Physics-II

1. Quantized free electron theory. Fermi energy, wave vector, velocity and temperature, density of states. Electronic specific heats. Pauli spin paramagnetism. Sommerfeld's model for metallic conduction. AC conductivity and optical properties, plasma oscillations. Hall effects.

2. Intrinsic and extrinsic semiconductors. carrier concentration and Fermi levels of intrinsic and extrinsic semi-conductors Bandgap. Direct and indirect gap semiconductors. Hydrogenic model of impurity levels.

3. Energy bands in solids. The Bloch theorem. Bloch functions. Review of the Kroning-penney model. Brillouin zones. Number of states in the band. Band gap in the nearly free electron model. The tight binding model. The fermi surface. Electron dynamics in an electric field. The effective mass. Concept of hole. (elementary treatment)

4. Superconductivity, Survey of important experimental results. Critical temperature. Meissner effect. Type 1 and type ii superconductors. Thermodynamics of superconducting transition. London equation. London penetration depth. Energy gap. Basic ideas of BCS theory. Josephson junction and some applications; High-Tc superconductors.

5. Dielectric and optical properties of solids: Dielectric constant and polarizability, sources of polarizability, dipolar polarization in soilds, ionic polarizability, electronic polarizability, piezoelectricity, ferroelectricity.

Books recommended:

1. John Singleton: Band theory and Electronic properties of Solids (Oxford University Press; Oxford Master Series in Condensed Matter Physics).
2. Ibach & Luth: Solid State Physics
3. M. Ali Omar: Elementary solid state physics (Addison-wesley)
4. C. Kittel: Solid-state physics (Wiley eastern)(5th edition).

Paper: MPHY0206 **[Marks 25]** **[Credit 2]**

Electronics-II

Passive Networks: Four-terminal two-port network – parameters for symmetrical and unsymmetrical networks; image, iterative and characteristic impedances; propagation function; lattice network; Bisection theorem and its application.
L-C filters-LPF, HPF, BPF and BRF type constant-k prototype filters; m-derived filters (principle only), Attenuators,

High Frequency Transmission Line: Distributed parameters; primary and secondary line constants; Telegraphers' equation; Reflection co-efficient and VSWR; Input impedance of loss-less line; Distortion of em wave in a practical line.

Elements of Communication Electronics: Principles of analog modulation- linear and exponential types; comparison among different techniques; power, bandwidth and noise immunity consideration; Generation of transmitted carrier and suppressed carrier type AM signals; principles of FM and PM signal generation.

Principles of detection of different types of modulated signals (TC and SC types).

Modulation techniques in some practical communication systems: AM and FM radio, VSB AM and QAM technique in TV broadcasting.

Digital Circuits: Logic functions; Logic simplification using Karnaugh maps; SOP and POS design of logic circuits; MUX as universal building block.
RCA, CLA and BCD adder circuits; ADD-SHIFT and array multiplier circuits.
RS, JK and MS-JK flip-flops; registers and counters (principle only).

Books Recommended:

1. R P Jain, Modern digital electronics, Tata mac'Hill.
2. J.D.Ryder, Networks line and fields.
3. Frazier, Telecommunications
4. Roddy and Coolen, Electronic Communication systems. PHI.

Paper: MPHY0207 **[Marks 25]** **[Credit 2]**

Advanced Optics

1. Basic Laser Theory: Historical background of laser, Einstein coefficients and stimulated light amplification: population inversion, creation of population inversion in three level & four level lasers.

2. Basic Laser Systems: Gas Laser: CO_2 laser, Solid State Laser: Host material, Nd:YAG laser, Liquid laser: Dye laser, Semiconductor laser.

3. Laser Beam Propagation: Laser beam propagation, properties of Gaussian beam, resonator, stability, various types of resonators, resonator for high gain and high energy lasers, Gaussian beam focusing

4. Nonlinear Optics: Origin of nonlinearity, susceptibility tensor, phase matching, second harmonic generation, methods of enhancement, frequency mixing processes.

5. Holography: Importance of coherence, Principle of holography and characteristics, Recording and reconstruction, classification of hologram and application, non-destructive testing,

6. Transient effect: Principle of Q-switching, different methods of Q-switching, electro-optic Q-switching, Pockels cell

7. Fibre optics: Importance of light in communication, problem in free space propagation of laser beam, propagation through optical fibres, various types of fibres, Attenuation in fibres: material loss, wave guide dispersion, micro-bending scattering, couplers & connectors.

8. Detection of optical radiation:
Human eye, thermal detector (bolometer, pyro-electric), photon detector (photoconductive detector, photo voltaic detector and photoemissive detector), p-i-n photodiode, APD photodiode.

Books recommended:
1. Principles of lasers- O Svelto
2. Solid State Laser Engineering- W Koechner
3. Laser- B A Labgyel
4. Gas laser- A J Boom
5. Methods of Experimental Physics Vol. 15B ed. By C L Tang
6. Industrial Application of Lasers – J F Ready
7. Handbook of Nonlinear Optics- R L Sautherland
8. Laser and electrooptics- C C Davis

Paper: MPHY0208 [Marks 25] [Credit 2]

Nuclear Physics- II

1. Beta and Gamma decay: Fermi's theory of beta decay, allowed and forbidden transitions, selection rules, non-conservation of parity in beta decay, Wu's experiment; direct evidence for the neutrino, gamma–decay and selection rules.

2. Interaction of radiation with matter and detectors: Mechanism, Bohr's Ionization formula, Radiation detectors – Multi wire proportional counter, Scintillation counter; Cerenkov detector; solid state detectors.

3. Reactor Physics : Slowing down of neutrons in a moderator, average log decrement of energy; slowing down power and moderating ratio, slowing down density; Fermi age equations, Four-factor formula; buckling and critical size of reactors.

4. High energy physics : Types of interaction in nature-typical strengths and time-scales, conservation laws, charge-conjugation, Parity and Time reversal, CPT theorem, Gell-Mann-Nishijima formula, intrinsic parity of pions, resonances, Relativistic kinematics; Symmetry classification of elementary particles, quark hypothesis, charm, beauty and truth, gluons, quark-confinement, asymptotic freedom.

Books Recommended:

1. Nuclear Physics- S. N. Ghoshal (S. Chand Publications)
2. Nuclear Physics- D. C. Tayal (Himalaya Publications)
3. Introductory Nuclear Physics- K. S .Krane (Wiley India)
4. Nuclear Physics: Theory and Experimental- H. S. Hans (New Age International)
5. Nuclear Physics: Theory and Experiment- R. R. Roy and B. P. Nigam (John Wiley and Sons)

Paper: MPHY0209 [Marks 100] [Credit 8]

LIST OF EXPERIMENTS:

Non-Electrical:

1. Determination of mean wavelength and separation of wavelengths of sodium light by Fabry Perot interferometer
2. Determination of e/m by magnetron valve/magnetic focusing method
3. Determination of speed of ultrasonic waves in an aqueous medium
4. Measurement of thickness of a thin foil by Jamin's interferometer
5. Determination of (i) Rydberg constant, (ii) ionisation potential and (iii) quantum defect of an alkali atom.
6. Determination of Stefan's constant and hence computation of the Planck's constant
7. Determination of Hall voltage and carrier concentration of a given semiconductor
8. Study of optical characteristics of a LED and determination of band gap of the material of LED.
9. Study of dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibrations.
10. To draw the plateau curve of a GM Counter and hence to determine the statistical variation of counts of the GM Counter.
11. Determination of wavelength of sodium light using Lloyd's mirror.

Electrical & Electronics

1. Study the current mirror biasing and V_{BE} multiplier based voltage reference
2. Study the transistor amplifier in common emitter (CE) mode
3. To draw the LDR characteristics at different intensities and to find out the value & the dark resistance of the LDR
4. Study on op-amp based linear and nonlinear amplifier
5. Studies on regulated and unregulated DC power supply
6. Study the input and output voltage characteristics of Schmitt trigger circuit
7. Studies on characteristics of different gates
8. To Construct and test the operation Preamphasis & deemphasis circuits by plotting frequency response using Op-amp.
9. To Study the amplitude modulation technique and determine the modulation index
10. To study the transfer characteristics of different networks and to study the phase transfer characteristics of a given two-port network (RC) by using CRO.

All the students will be divided into two groups i.e. Non-electrical and Electrical & Electronics
Those students who have done Non-electrical experiments in Semester-I will have to opt Electrical & Electronics experiments in semester -II and vice-versa

SEMESTER – III (TOTAL MARKS 300) (CREDIT 24)

Paper: MPHY0301 **[Marks 25]** **[Credit 2]**

Statistical Mechanics- I

1. Scope and aim of statistical mechanics. Transition from thermodynamics to statistical mechanics. Review of the ideas of phase space, phase points, Ensemble, Density of phase points. Liouville's equation and Liouville's theorem.
2. Stationary ensembles: Micro canonical, canonical and grand canonical ensembles. Partition function formulation. Fluctuation in energy and particle. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators. Para magnetism, concept of negative temperature.
3. Density matrix: Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches, Properties. Pure and Mixed states.

   Density matrix for stationary ensembles. Application to a free particle in a box, an electron in a magnetic field. Density matrix for a beam of spin ½ particles. Construction of the density matrix for different states (pure and mixture) and calculation of the polarization vector.
4. Distribution functions. Bose-Einstein and Fermi-Dirac statistics. General equations of state for ideal quantum systems.

Books Recommended:

1. R. K. Pathria, Statistical Mechanics
2. K. Huang, Introduction to Statistical Mechanics
3. Silvio R. A. Salinas, Introduction to Statistical Mechanics.
4. F. Reif, Fundamentals of Statistical and Thermal Physics.
5. Kadanoff, Statistical Mechanics. World Scientific.
6. R. Kubo, Statistical Mechanics. (Collection of problems)

Paper: MPHY0302 **[Marks 25]** **[Credit 2]**

Advanced Quantum Mechanics- I

1. The Klein Gordon (KG) equation. Covariant notations. Free particle energy, negative energy and negative probability densit, KG equation in em field.

2. The Dirac equation. Properties of the Dirac matrices. The Dirac particle in an external electromagnetic field. The non-relativistic limit of the Dirac equation and the magnetic moment of the electron.

3. Covariant form of the Dirac equation. Lorentz covariance of the Dirac equation. Boost as hyper rotation, boost, rotation, parity and time reversal operation on the Dirac wave function.

4. Conjugate Dirac spinor and its Lorentz transformation. The γ^5 matrix and its properties. Bilinear covariants and their properties.

5. Boosting the wave function from the rest frame. Plane wave solutions of the Dirac equation and their properties. Energy and spin projection operators.

6. Dirac's hole theory and charge conjugation. Feynman-Stuckelberg interpretation of antiparticles.

7. Foldy-Wuthuysen transformations: free particle transformation, the transformation, to the hamiltonian with an electromagnetic field, relativistic correction to mass, spin-orbit interaction, Darwin term, Zitterbewegung

8. The Hydrogen atom problem: the Dirac theory with central force, the Coulomb potential, the energy eigenvalues, spin-orbit splitting, ground state wave function.

Books Recommended:

1. Relativistic Quantum Mechanics – J.D.Bjorken and S.D.Drell, McGraw-Hill, New York (1964).
2. Relativistic Quantum Mechanics- Walter Greiner, Springer-Verlag (1990)
3. Advanced Quantum Mechanics – J.J.Sakurai, Addison-Wesley Publishing Company, Inc. (1967).
4. Relativistic Quantum Mechanics and Quantum Fields – T-Y Wu and W-Y Pauchy Hwang, Allied Publishers Limited (2001).

Paper: MPHY0303 [Marks 25] [Credit 2]

GROUP THEORY

1. *ABSTRACT GROUP THEORY*:

Definition. Group postulates. Finite and infinite groups, order of a group, Rearrangement theorem. Group multiplication table. Subgroups and Cosets. Lagrange's theorem. Order of an element. Conjugate elements and classes. Cyclic and other distinct groups. Permutation groups. Invariant subgroups, factor groups. Generators. Isomorphism and homomorphism. Illustrations with point symmetry groups

2. *Representation theory*.

Definition of representation. Faithful and unfaithful representations. Reducible and irreducible representations. Schur's lemmas, Great orthogonality theorem and its geometrical interpretation. Character. First and second orthogonality theorems of characters and its geometrical interpretation. Regular representation, celebrated theorem and its implication. Construction of character tables of simple groups.

3. *Continuous group*

Infinite groups. Discrete and continuous groups. Lie groups. Axial rotation group SO(2). Rotation group SO(3). Special Unitary groups SU(2) and SU(3) and their application in Physics.

4. *Application in Physics*

Group of Schroedinger equation and degeneracy. Reduction due to symmetry. Application in Spectroscopy. Determination of molecular point groups for simple systems.

Books Recommended:

1. M. Hammermesh. 'Group Theory'. Addison-Wesley
2. M. Tinkham. 'Group Theory and Quantum Mechanics;. McGraw-Hill.
3. G. G. Hall. 'Applied Group Theory'. Longmans, Green.
4. A. W. Joshi. 'Group Theory'. Wiley Eastern Ltd..
5. F. A. Cotton. 'Chemical Application to Group Theory'. Wiley Eastern Limited.
6. N. Deo : Group Theory (Tata McGraw Hill)

Paper: MPHY0304 [Marks 25] [Credit 2]

Computer Applications in Physics-I

1. **Computer fundamentals**:

   Functional units-CPU, Memory, I/O units; Information representation- integral and real number representation; Character representation: Alphanumeric codes; BCD, Gray, ASCII codes; Error detection and error correcting codes; Hamming codes; CRC codes.

2. Computer Software and Operating Systems:

System software and application software; Translator programs; Loaders and linkers; Operating systems- classification; Elements of DOS and Windows- basic commands.

3. Elements of C Programming Language:

Algorithms and flowchart; Structure of a high level language program; Features of C language; constants and variables; expressions; Input and output statements; conditional statements and loop statements; arrays; functions; character strings; structures; pointer data type; list and trees.

Books Recommended:

1. Tanenbaum, Operating system. Prentice Hall.
2. Gottfried, Programming with C. Schaum series.
3. Balaguruswamy, ANSI C. TMH.

Paper: MPHY0305 [Marks 15] [Credit 1]
General Computer Internal Assessment through assignment

Paper: MPHY0306 [Marks 10] [Credit 1]
Seminar presentation (internal assessment)

(seminar topic to be chosen by the student from core subject)

Major Electives

Paper: MPHY0307 **[Marks 50]** **[Credit 4]**

Radiophysics & Electronics-I

1. Microwave Devices: Problems of microwave generation in conventional oscillators.
2. Vacuum tube devices : Klystron and Reflex Klystron , Magnetrons, Slow wave structure and Travelling wave tubes,
3. Solid state devices : Gunn diode, Impatt, Trapatt ,transistors, GaAs-InP FET, HEMT.
4. Optical Devices: Laser and Laser resonator, LEDs, Photodiodes, Photo conductor.
5. Microwave measurements (Frequency, power, impedance).
6. Optical modulator: Electro optics modulation (amplitude and phase).
7. Optical coupler: Coupling of light from one fiber to other with the use of evanescent wave
8. Analysis of networks and systems: Sample data system. Z- transform, Fourier and Laplace transforms.
9. Microwave Transmission lines and Waveguides: Transmission lines, Standing wave ratio, Quarter wave transformer, Smith Chart, Stub matching. Wave guides coaxial, rectangular and cylindrical; Waveguide attenuation, Resonators.
10. Antenna theory: Antennas-dipole, Antenna arrays, reflectors, steering strip, microstrip and coplanar structure.
11. Feed back control systems: Feed back system, stability, performance criteria, servo systems, automatic control principle.

Books Recommended

1. P. Bhattacharya - Semiconductor opto electronics devices.
2. R E Collin - Foundations of Microwave engineering.
3. S.Y.Liao – Microwave Devices on circuits.
1. J. Ryder – Networks, Lines and Field.
2. A. Papoulis – Signal Analysis
3. Electronic and Radio Engineering – F. E Terman.
4. Microwaves – K . C. Gupta.
5. Optoelectronics and Fibre Optic Communication –C. Sarkar.
6. Photonics – A. Yariv and P. Yeh.

Paper: MPHY0308 **[Marks 50]** **[Credit 4]**

Radiophysics & Electronics -II

1. IC Technology : Hybrid and monolithic IC; Semiconductor processing diffusion, implanation, oxidation, epitaxy, lithography; Si IC technology-MOS and Bipolar; Packaging and testing.

2. Analog Integrated Circuits. Differential amplifier, OP-AMP comparator; continuous time filters, switched capacitance implementation of sample data filters; analog multiplexers, PLL and frequency synthesizer.

3. Digital Integrated Circuits: Logic families – TTL, ECL, MOS, MESFET; design of combinational and sequential circuits – MUX, decoder/ encoder, registers, counters, gate arrays; programmable logic devices – PAL, GAL, PLA, Programmable gate arrays.

4. Special purpose ICs: ICs for analog communication; Digital signal processing ICs; Basic concepts of MIC, MMIC and OELC; GaAs technology;

5. Memories: Sequential and Random access memories; RAM bipolar and MOS static and dynamic memories; programmable memories PROM, EPROM, EEPROM.

6. Microprocessor and their applications: Architecture of 8 bit (8085) and 16 bit (8086) microprocessors; addressing modes and assembly language programming of 8085 and 8086. 8086 machine cycles and their timing diagrams; Interfacing concepts memory and I/O interfacing; Interrupts and interrupt controllers; microprocessor based system design; comparison of different microprocessors.

7. Fundamentals of speech synthesis and recognition, Image processing and biomedical signal processing.

Books Recommended:

1. Geiger, Allen and Strader – *VLSI – Design Techniques for Analog and Digital Circuits*.
2. Gray and Meyer – *Analysis and Design of Analog Integrated Circuits*.
3. A P Mathur – *Microprocessors.*
4. R S Gaonkar – *Microprocessor Architecture, Programming and Applications with 8085/ 8085A* (2nd Ed.).
5. D V Hall – *Microprocessor and Interfacing*.
6. Lin and Gibson – *Microprocessor*.
7. S Soelof – *Applications of Analog Integrated Circuits*.

Paper: MPHY0309 [Marks 50] [Credit 4]

Laser Physics -I

1. Basic Laser Principle: Summary of black body radiation, Quantum theory for evaluation of the transition rates and Einstein coefficients-allowed and forbidden levels-metastable state; population inversion; rate equations for three level and four level lasers, threshold of power calculation, various broadening mechanism, homogeneous and inhomogeneous broadening

2. Basic Laser System: Basic concept of construction of laser system, various pumping system, pumping cavities for solid state laser system, characteristics of host materials and doped ions.

3. Optical beam propagation: Paraxial ray analysis, wave analysis of beams and resonators, propagation and properties of Gaussian beam, Gaussian beam in lens like medium, ABCD law-Gaussian beam focusing

4. Resonators: Stability of resonators-'g' parameter, various types of resonators, evaluation of beam waist of such combination, design aspect of resonator for various types of lasers, unstable resonator and their application. Rabi oscillation and frequency

5. Q-switching: Giant pulse theory, different Q-switching techniques: mechanical Q-switching, electrooptic Q-switching Pockel and Kerr effect), acoustooptic Q-switching, dye Q-switching, Raman-Nath effect.

6. Ultrafast Phenomenon: Principle of generation of ultrafast pulses, basic concepts for measurement of fast processes, Streak techbique, Stroboscopy, sampling technique, nonlinear optical methods for measuring ultrashort pulses

7. Different laser systems:

Gas Laser: (i) molecular gas lasers- CO_2 laser & N_2 laser; (ii) ionic gas laser – Ar^+ laser
(iii) gas dynamic laser; (iv) high pressure pulsed gas laser
Solid State Laser: (i) Nd:YAG laser, (ii) Nd:Glass laser, comparison of performances
(iii) Tunable solid state laser: Ti:sapphire laser; Alexandrite laser
Chemical Laser: HF laser, HCl laser
Excimer laser; Fibre laser**,** Free electron laser; semiconductor laser

Books Recommended:

1. Principles of lasers- O Svelto
2. Solid State Laser Engineering- W Koechner
3. Quantum Electronics- A Yariv
4. The Physics and Technology of Laser Resonator- D R Hall & P E Jackson
5. Introduction to optical electronics- K A Jones
6. Laser- B A Langyel
7. Gas laser- A J Boom

Paper: MPHY0310 [Marks 50] [Credit 4]

Laser Physics -II

1. Laser Safety:

Various hazards due to laser radiation-eye, skin, chemical etc., safety measures and standard

2. Nonlinear Optics:

Introduction, nonlinearities of the polarization, generation of second harmonic, D.C., sum and difference frequency generation, anharmonic oscillator model, Miller's rule, crystal symmetry, coupled amplitude equation, Manley-Rowe relation

3. Phase Matching:

Basic idea of phase matching, quasi-phase matching method, various methods of phase matching (angle, temperature, birefringence etc.) critical and noncritical phase matching, collinear and non-collinear phase matching, expression of angle band-width ($\Delta\theta$) and wavelength band-width ($\Delta\lambda$) in phase matched second harmonic generation, idea of tangential and dispersion phase matching

4. Second Harmonic Generation:

Basic equation, conversion efficiency and parameters affecting doubling efficiency, various methods of enhancing conversion efficiency, second harmonic generation with Gaussian beam, intra-cavity second harmonic generation

5. Higher Order Nonlinear Processes:

Four wave mixing processes-third harmonic generation, resonance enhancement of nonlinear susceptibilities, different phase matching techniques, generation of tunable deep UV and IR radiation, stimulated Raman scattering, inverse Raman scattering, anti-stokes coherent Raman scattering, application in spectroscopy

6. Chemical Application:

Selective excitation reaction, different separation processes, principle of isotope separation, uranium enrichment, Ultrashort pulses in chemical reaction

7. Laser speckle:

Spatial frequency filtering- principle and its application

10. Laser in medical science:

Laser tissue interaction, physical effects on human skin of laser beam reflection, absorption, scattering, different interaction mechanism, different surgical treatment. Effects of ultrashort pulses

Books Recommended:

1. Methods of Experimental Physics Vol. 15B ed. By C L Tang
2. Industrial Application of Lasers – J F Ready
3. Solid State Laser Engineering- W Koechner
4. The Principle of Nonlinear Optics- Y R Shen
5. Handbook of Nonlinear Optics- R L Sautherland
6. Laser and electrooptics- C C Davis

Paper: MPHY0311 **[Marks 50]** **[Credit 4]**

Materials science-I

Applied crystallography in materials science

Noncrystalline and semicrystalline states, Lattice. Crystal systems, unit cells. Indices of lattice directions and planes. Coordinates of position in the unit cell, Zones and zone axes. Crystal geometry. Symmetry classes and point groups, space groups. Glide planes and screw axes, space group notations, Equivalent points. Systematic absences, Determination of crystal symmetry from systematic absences. Stereographic projections. Standard projection of crystals.

Introduction to materials

Classification of materials: Crystalline & amorphous materials, high T_c superconductors, alloys & composites, semiconductors, solar energy materials, luminescent and optoelectronic materials, Polymer, Liquid crystals and quasi crystals, Ceramics.

Preparation techniques of materials

Preparation of materials by different techniques: Single crystal growth, zone refining, epitaxial growth. Melt-spinning and quenching methods, sol-gel, polymer processing. Preparation of ceramic materials; Fabrication, control and growth modes of organic and inorganic thin films: different technique of thin film preparations: Basic principles.

Synthesis of nanomaterials

Top down and bottom up approaches of synthesis of nano-structured materials, nanorods, nanotubes/wire and quantum dots. Fullereness and tubules, Single wall and multiwall nanotubes.

Phase transition in materials

Solid solutions, Phases, Thermodynamics of solutions, Phase rule, Binary phase diagrams, Binary isomorphous systems, Binary eutectic systems, ternary phase diagrams, kinetics of solid reactions. Order disorder phenomenon in binary alloys, long range order, super lattice, short range order.

Books Recommended:

1. Materials science and Engineering by *V. Raghavan*, Prentice-Hall Pvt. Ltd.
2. Thin Solid Films by *K. L Chopra*
3. Elements of X-ray diffraction by *B. D. Cullity*, Addison-Wesley Publishing Co.
4. Elements of crystallography by *M. A. Azaroff*
5. Engineering Materials by *Kenneth G. Budinski*, Prentice-Hall of India Pvt. Ltd.

Paper: MPHY0312 [Marks 50] [Credit 4]

Materials Science-II

X-ray scattering from crystalline, nanocrystalline and noncrystalline materials

Continuous spectrum and characteristic spectrum, Duane-Hunt law. X-ray energy level schemes, diagram and non-diagram lines, Absorption of X-rays and theory of filters.

X-ray scattering: General description of scattering process, coherent and incoherent scattering, total scattering from a spherically symmetric electron cloud, Atomic scattering factor. Coherent and incoherent scattering from hydrogen atom, scattering from many electron atom (outline). Perfect crystal theory: Intensity form a small single crystal, integrated intensity from a small perfect crystal (no deduction), integrated reflection from Mosaic and powder crystal.

Lattice Imperfections

Point defect and line defect. Dislocations, Burger vectors. Alloys and solid solutions, composition. Surface energy for solids.

Microstructure characterization by direct & indirect methods

Diffraction techniques: interpretation of x-ray powder diffraction patterns, Identification & quantitative estimation of unknown samples by X-ray powder diffraction technique. Theory and method of particle size analysis.

Scanning electron microscopy (SEM), Transmission electron microscopy (TEM). Energy-dispersive and wavelength dispersive spectrometry. Electron and neutron diffraction.

Computational methods in Materials Physics

Density Functional Theory: Basics of DFT, Comparison with conventional wave function approach, Hohenberg-Kohn Theorem; Kohn-Sham Equation; Thomas-Fermi approximation and beyond; Practical DFT in a many body calculation and its reliability.
Quantum mechanical modeling of materials: Atomic Pseudopotentials, Basis Sets: Plane Waves and Augmented Basis sets. Plane Wave based DFT calculations.
Simplied Approaches to the electronic problem: Tight binding methods; Atomistic modeling of materials: Many body Classical potentials, Classical force fields.

Books Recommended:

1. X-ray diffraction by *B. E. Warren*, Addison-Wesley Publishing Co.
2. An Introduction to Metallurgy by *Sir Alan Cottrell*, University Press
3. The Structure & Properties of Materials (Volume II) by *J. H. Brophy, R. M. Rose and J. Wulff*, Wiley Eastern Ltd.
4. Structure of Metals, *C. S. Barrett & T. B. Massalski*, McGraw-Hill Book Company.

Paper: MPHY0313 [Marks 50] [Credit 4]

Condensed Matter Physics-I

Band theory and Dynamics of an Electron in a Crystal:

Electrons in periodic potential and single particle Schrödinger equation for all electrons; Bloch electrons and band structure**; O**rthogonalized plane wave (OPW) method – Idea of pseudo-potential; Phillops-Kleiman's cancellation. Band electrons in a magnetic field, Landau levels, it's degeneracy, filling factor and idea of quantum Hall effect; density of states; Fermi surface and its experimental determination, Pauli spin paramagnetism, Landau Diamagnetism, the de Haas-van Alphen effect; Azbel-Kaner Cyclotron resonance.

Many body techniques:

The basic Hamiltonian, Jelium Model, Hatree and Hatree-Fock equation, interacting electron gas, Hatree-Fock approximations for the electron gas, Excahnge hole, exchange energy, Density Functional Theory, Static screening, Thomas Fermi approximation, Plasma Oscillations, Bohm Pines theory-Random Phase Approximation, plasma oscillations, dielectric function of an electron gas, Linhard dielectric function.

Phenomenology of Ferromagnetism, Antiferromagnetism and Ferrimagnetism:

Ferromagnets, Antiferromagnets, Ferrites, two sublattice model, Curie temperature and susceptibility, super exchange, magnetic bubbles. Zero-point sublattice magnetization, Thermal behaviour of sub-lattice magnetization.

Electron Paramagnetic Resonance (EPR):

Phenomenon of magnetic resonance, Bloch equation, Adiabatic fast passage and slow passage solution, Rate of absorption, Saturation, linewidth, Spin lattice relaxation, Spin-Spin relaxation, Exchange interaction, EPR set up.

Nuclear Magnetic Resonance (NMR) :

Nuclear moments-Overview, Nuclear induction and absorption experiment, Rate of absorption, Line width, Motional narrowing in liquids, Chemical shift, High resolution spectroscopy, Knight shift

Mössbauer Spectroscopy and Hyperfine interactions:

Problems of nuclear γ-ray resonance absorption and Mössbauer's discovery, Recoil-less fraction and its temperature dependence, Mössbauer source for iron rich samples, Isomer shift, Application of Mössbauer effect to solid state physics, Quadrupole interaction, EFG tensor, Splitting of nuclear levels of iron. Application of Mössbauer spectroscopy in magnetic nanocrystalline ferrites.

Books recommended:

1. Introduction to Solid State Physics: C. Kittel
2. Solid State Physics: Askroft and Mermin
3. Theory of Superconductivity, J. Robert Schrieffer,
4. Introduction to Superconductivity, 2nd Edition, by *Michael Tinkham*
5. J.M. Ziman: Principles of the theory of solids
6. Electron Paramagnetic Resonance: Pake

Paper: MPHY0314 [Marks 50] [Credit 4]

Condensed Matter Physics -II

Band theory and Dynamics of an Electron in a Crystal: Electrons in periodic potential and single particle Schrödinger equation for all electrons; Bloch electrons and band structure; **O**rthogonalized plane wave (OPW) method – Idea of pseudo-potential; Phillops-Kleiman's cancellation. Band electrons in a magnetic field, Landau levels, it's degeneracy, filling factor and idea of quantum Hall effect; density of states; Fermi surface and its experimental determination, Pauli spin paramagnetism, Landau Diamagnetism, the de Haas-van Alphen effect; Azbel-Kaner Cyclotron resonance.

Many body techniques: The basic Hamiltonian, Jelium Model, Hatree and Hatree-Fock equation, interacting electron gas, Hatree-Fock approximations for the electron gas, Excahnge hole, exchange energy, Density Functional Theory, Static screening, Thomas Fermi approximation, Plasma Oscillations, Bohm Pines theory-Random Phase Approximation, plasma oscillations, dielectric function of an electron gas, Linhard dielectric function.

Phenomenology of Ferromagnetism, Antiferromagnetism and Ferrimagnetism – Ferromagnets, Antiferromagnets, Ferrites, two sublattice model, Curie temperature and susceptibility, super exchange, magnetic bubbles. Zero-point sublattice magnetization, Thermal behaviour of sub-lattice magnetization.

Electron Paramagnetic Resonance (EPR) - Phenomenon of magnetic resonance, Bloch equation, Adiabatic fast passage and slow passage solution, Rate of absorption, Saturation, linewidth, Spin lattice relaxation, Spin-Spin relaxation, Exchange interaction, EPR set up.

Nuclear Magnetic Resonance (NMR) - Nuclear moments-Overview, Nuclear induction and absorption experiment, Rate of absorption, Line width, Motional narrowing in liquids, Chemical shift, High resolution spectroscopy, Knight shift

Mössbauer Spectroscopy and Hyperfine interactions – Problems of nuclear γ-ray resonance absorption and Mössbauer's discovery, Recoil-less fraction and its temperature dependence, Mössbauer source for iron rich samples, Isomer shift, Application of Mössbauer effect to solid state physics, Quadrupole interaction, EFG tensor, Splitting of nuclear levels of iron. Application of Mössbauer spectroscopy in magnetic nanocrystalline ferrites.

Books recommended:

1. Introduction to Solid State Physics: C. Kittel
2. Solid State Physics: Askroft and Mermin
3. Theory of Superconductivity, J. Robert Schrieffer,
4. Introduction to Superconductivity, 2nd Edition, by *Michael Tinkham*
5. J.M. Ziman: Principles of the theory of solids
6. Electron Paramagnetic Resonance: Pake

Paper: MPHY0315 [Marks 50] [Credit 4]

Nuclear & Particle Physics -I

1. Two-nucleon bound state problem, deuteron ground state, singlet state, spin-dependence of nuclear force, magnetic dipole and electric quadrupole moments of deuteron, D-state admixture, tensor interaction, concept of isospin, generalized Pauli principle and its consequence, exchange nature of nucleon-nucleon interaction – its experimental signatures, photo-disintegration of deuteron. Meson theory of nucleon-nucleon interaction – Yukawa's potential from time-independent Klein-Gordon equation with a source term.

2. Nuclear many-body problem, Hartree-Fock (HF) theory – derivation of HF equation, symmetries of HF orbits, angular momentum projection to get the physical nuclear state of the nucleus from the intrinsic state, energy of the projected state.
Concept of quasiparticles. Second quantization formalism in nuclear physics, Wick's theorem, normal ordered products and contractions, pairing density and pairing potential, BCS quasiparticle transformations, HF-BCS theory, consequences of the fermionic properties of the quasiparticles. BCS ground state.

3. Importance of electron scattering in probing the structures of nucleon and nucleus, elastic electron scattering on proton, Lorentz-invariant transition four- current, form factors and anomalous magnetic moment of proton, electric and magnetic form factors in the Breit frame of reference.
Inelastic scattering of unpolarized electron on unpolarized nucleus – Coulomb and magnetic form factors of the nucleus, the differential scattering cross-section in terms of the form factors.

4. Shell model-nucleons in a harmonic oscillator potential, radial density distribution, estimate of oscillator frequency, spin-orbit potential, Predictions of spin, magnetic and electric quadrupole

moment of nuclei, Nordheim's rules; residual interaction and configuration mixing, Evaluation of matrix elements of one and two body operators, antisymmetrization of wave functions, cfp, single particle model, seniority and reduced iso-spin; many particle shell model.

5. Collective model-Collective Hamiltonian, vibrational spectra, Ellipsoidally deformed nuclei, total deformation parameter and non- axiality parameter, Moment of inertia –rigid and irrotational values. Rotational models of even-even and odd A nuclei. High Spin states, qualitative explanation, VMI; coriolis anti-pairing, Cranking formula for the moment of inertia of deformable nucleus, Bohr-Wheeler's theory of nuclear fission. Fission isomers.

Paper: MPHY0316 [Marks 50] [Credit 4]

Nuclear & Particle Physics -II

1. Two-nucleon scattering-partial wave analysis, effective range theory, coherent scattering, spin-flip and polarization, High energy scattering. (10 lectures)

2. Nuclear reactions-reaction and scattering cross sections, compound nuclear reactions, resonance reactions, Breit-Weigner dispersion formula, experimental determination of resonance widths and shapes, Direct nuclear reaction; statistical theory, PWBA and DWBA calculations; transfer reactions, Optical model, spectroscopic factors. (12 lectures)
Heavy ion reactions-salient features at low, intermediate and high energies, classical dynamical model, heavy ion fusion, fusion excitation function, deep inelastic collision. (8 Lectures)

3. Nuclear measurement techniques: Detectors and electronics for high resolution gamma and charged particle spectroscopy; Fast neutron, detection Neutrino detection, Drift chambers, RICH, calorimeter (10 lectures)

4. Biological effects of radiation: Physical and chemical damage; dose, dose rate; damage of tissue levels, Radiation shielding and its safety, Nuclear Medicine; Projection Imaging, with internal and external radiation, computed Tomography, Magnetic Resource Imaging Principles, Radiation therapy. (5 lectures)

Books Recommended:

1. Nuclear Physics: L.R.B Elton
2. Nuclear reactions: Blatt and Weisskopf
3. Nuclear Theory- Roy and Nigam
4. Nuclear Physics- B. Cohen
5. Nuclear Physics- Preston and Bhaduri
6. Nuclear structure- Bohr and Mottelson
7. Nuclear structure- M. K. Pal
8. Techniques in experimental nuclear physics- Leo
9. Techniques in experimental nuclear physics- Knoll
10. Techniques in experimental nuclear physics-S. S. Kapur

Paper: MPHY0317 **[Marks 50]** **[Credit 4]**

General Relativity & Astrophysics-I

Review of Mechanics of Continuous Media:

Equation of continuity, 4-D formulation, comoving coordinate system, Energy momentum tensor of continuous media,

2. Space-Time Geometry:
A critical review of space, time and gravity, Euclidean and non-Euclidean space-time, Parallel transport in flat and curved Space, affine connection, Covariant derivatives, covariant derivative of vectors, covariant derivative of tensors, metric tensors, Geodesics, Geodesics on spherical surface, Riemann Christoffel tensor, Ricci tensor, Bianchi Identities, Einstein tensor, necessary and sufficient condition for flatness of space-time, Newtonian gravity in metric tensor form.

3. Einstein's Gravity:
Inconsistencies of Newtonian gravitation with Special Theory of Relativity, Need for a curved space-time, Principle of equivalence, Inertial and gravitational mass, connection between Inertia and gravitation, Principle of general covariance, heuristic derivation of Einstein's law of gravitation, weak field approximation of Einstein's gravity.

4. Solutions of Einstein's Field Equations and Static Black Holes:

Schwarzschild solution, exterior solution, isotropic coordinates, singularity, Schwarzschild radius and event horizon, Schwarzschild interior solution, Schwarzschild solution in other coordinate systems, Birkhoff's theorem. Conflict between Minkowski metric and equivalence principle, Circular geodesic of a particle in Schwarzschild space – time, minimum radius, motion of a test particle, trajectories of photons. Precession of Perihelion of Mercury, Bending of light rays in a gravitation field, gravitational red shift, Radar echo delay, Analogues of Keplar's laws, Charged black hole (R – N metric).

5. Rotating Black Holes:

Kerr black hole (derivation is not required), distinguished surfaces of Kerr black hole, event horizon, infinite red shift surface, ergosphere, energy extraction from a black hole- Penrose mechanism, irreducible mass, Kerr – Newmann metric (derivation is not required), No hair theorem, Cosmic censorship hypothesis.

Black hole physics: Laws of black hole thermodynamics, surface gravity, detection of black holes, elementary discussion on Hawking radiation.

6. Gravitational waves & Gravitational Lensing:
Introduction, plane waves, radiation of gravitational waves, detection of waves. Theory of gravitational lensing, magnification and amplification of images.

Measurement Techniques: Principles of Telescope operation, Basic Antenna theory, equations, range etc., Types of Antenna (dipole antenna, horn antenna etc.)

Paper: MPHY0318 **[Marks 50]** **[Credit 4]**

General Relativity & Astrophysics-II

Introduction: Astronomy and Astrophysics, Celestial coordinate system (Sun – Earth system, Galactic system), Classification of stars, basic parameters. Stellar magnitudes, H D classification of stars,

Dynamical Equations for Stellar Structure: Star formation, Saha Equation of ionization and its consequences in astrophysics, Hertzsprung-Russel (H-R) diagram, gravitational energy. Virial theorem for stars and galaxies, basic equations for stellar structure, energy transport inside stars, Convective and Radiative stars, Radiation density, radiative energy transfer in stellar interior, convection inside stars, Schwarzschild stability condition, luminosity – mass, luminosity – temperature relations, Eddington luminosity limit

Models of Stars: Three phases of stars' life, Pre-main sequence evolution, dynamical equation, Jeans criteria for star formation, Jean's mass, fragmentation and adiabatic contraction, main sequence stage, Lane-Emden equation and models of stars, simple stellar models: Eddington's model and Homologous model, Pre-main sequence contraction: Hayashi and Henyey tracks.

Nuclear Astrophysics: Thermonuclear reactions inside stellar interior, p–p chain reaction, C-N-O cycle, subsequent thermonuclear reactions, nucleosynthesis and formation of iron group of elements, formation of heavy elements beyond iron, r- and s- and p- processes Solar neutrino problem

Stellar Objects & Stellar Explosions: Qualitative discussions on: Galaxies, Nabulae, Quasars, Brown dwarfs, Red Giant Stars, Nova, Supernova.

Relativistic Astrophysics: Post Main sequence stage and gravitational collapse, **White Dwarfs**, stability condition, Electron degeneracy and equation of States, derivation of Chandrasekhar Mass Limit, Mass-Radius relation of WD. **Neutron Stars**, Spherically symmetric distribution of perfect fluid in equilibrium. Derivation of Tolman-Oppenheimer-Volkoff (TOV) equation, Newtonian limit, Mass-Radius relations of Neutron Stars. **Pulsars**: period, magnetic fields, rotational energy, synchrotron radiation (qualitative), emission mechanism, age, dispersive measure, brief discussion on Magnetars, Gamma ray bursts.
Black holes: Schwarzschild black hole, Collapse in a spherically symmetric space-time, Dutt-Oppenheimer-Snyder (DOS) equations, concept of a black hole, singularity and event horizon, White Holes.

Accretion disks: Formation of accretion disks, differentially rotation systems in Astrophysics, Disk dynamics, Steady Disks, Disk formation in close binary systems through mass transfer, Roche Lobe, Accretion onto compact objects (Black Holes and Neutron Stars).

Plasma Astrophysics: Elements of Plasma Astrophysics, basic equations of fluid mechanics, Jeans instability, basic equations of magneto hydrodynamics, Particle acceleration in astrophysics.

W.G.V.Rosser – Introduction to the Theory of Relativity.
S. Banerji and A. Banerjee – The Special Theory of Relativity (Prentice Hall of India, 2002)
R. Resnick – Introduction to Special Theory of Relativity.
P. G. Bergmann- Introduction to Theory of Relativity (Pren tice-Hall, 1969).

J. V. Narlikar- General Relativity and Cosmology (MacMillion, 1978).
S. Banerji and A. Banerjee General Relativity and Cosmology – (Elsevier, 2007)
A.K.Raychaudhuri, S.Banerji and A.Banerjee General Relativity, Astrophysics and Cosmology – (Springer-Verla, 1992)
J.V.Narlikar - The Structure of the Universe – (OUP, 1978)
J. V. Narlikar –Introduction to Cosmology (Cambridge Univ, Press, 2003).
S. Weinberg- Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity (Wiley, 1972).
V.B.Bhatia - Textbook of astronomy an astrophysics with elements of cosmology, Narosa publishing house, (2001).
T. Padmanavan - Theoritical Astrophysics (Vols.I,II,III) – (CUP)
E.W.Kolb and M.S.Turner - The Early Universe –(Addison-Wesley Reading, 1990)

Paper: MPHY0319 [Marks 75] [Credit 6]

Advanced Practical

List of Experiments

Group A:

1. Determination of temporal coherency of a coherent (laser) light and compare it with incoherent light (sodium)
2. Study of magneto-optic effect (Faraday effect)
3. Study of electro-optic effect (Pockel effect)
4. Stydy of Zeeman effect
5. Study of characterization of antenna
6. Design of active filters (a) band-pass filter, (b) all pass filter
7. Studies of nonlinear electronic circuits and design of chaotic electronic oscillator
8. Studies on LED modulation characteristics

Group B:

1. Band-gap determination from thermal variation of resistivity
2. Measurement of magnetic susceptibility using Quincks method
3. Study of ESR
4. Study of gamma ray spectrum of radioactive nuclides with NaI (Tl) scintillators & SCA
5. Study of beta-ray absorption & determination of end point energy of the beta-ray spectra of the given source by the Feather's method
6. Study of gamma-ray absorption & determination of gamma ray energy
7. Determination of particle size of an unknown powder specimen using Scherrer equation from supplied XRD pattern
8. Phase identification of an unknown sample from its X-ray diffraction pattern

All the students will be divided into two groups i.e. Group A & Group B and that will be decided by the Department

SEMESTER IV (Total 300 Marks) (CREDIT 24)

Paper: MPHY0401 **[Marks 25]** **[Credit 2]**

Statistical Mechanics- II

1. Ideal quantum systems:
   a. Properties of ideal Bose gas: Bose-Einstein condensation: Transition in liquid He^4, Superfluidity in He^4. Photon gas: Planck's radiation law. Phonon gas: Debye's theory of specific heat of solids.
   b. Properties of ideal Fermi gas: Review of the thermal and electrical properties of an ideal electron gas. Landau levels, Landau diamagnetism. White dwarf and Neutron stars.
2. Strongly interacting systems:

   Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian.

   Exact solution of one-dimensional Ising system (Matrix methods). Bragg-William's approximation (Mean field theory) and the Bethe-Peierls approximation.
3. Phase transition: General remarks. Phase transition and critical phenomena. Critical indices. Landau's order parameter theory of phase transition.
4. Fluctuations. Thermodynamic fluctuations. Spatial correlations in a fluid. Brownian motion: Einstein-Smoluchowski's theory.

Books Recommended

1. Sanchez Bowley, Introductory Statistical Mechanics, Oxford University Press
2. R. K. Pathria, Statistical Mechanics
3. K. Huang, Introduction to Statistical Mechanics
4. Silvio R. A. Salinas, Introduction to Statistical Mechanics.
5. F. Reif, Fundamentals of Statistical and Thermal Physics.
6. Kadanoff, Statistical Mechanics. World Scientific.
7. R. Kubo, Statistical Mechanics. (Collection of problems)

Paper: MPHY0402 **[Marks 25]** **[Credit 2]**

Advanced Quantum Mechanics- II

1. Concepts of fields. Lagrangian dynamics of Classical fields. Derivation of the Euler-Lagrange equation from Hasmilton's variational principle. Lagrangians and equations of motion of fundamental fields.

2. Noether's theorem. Invariances. Conserved currents and charges. Energy-momentum tensors and energy of fields.

3. Canonical quantization and particle interpretation of the real Klein-Gordon field. Fock space of bosons. Energy of the real Klein Gordon field. Normal ordering.

4. Introduction of antiparticle. Charge of quantum complex Klein-Gordon field.

5. Canonical quantization and energy of the Dirac field. Anti-commutators. Pauli principle. Equal time anti-commutator between the Dirac field and the canonically conjugate momentum field.

6. Coulomb gauge quantization and energy of the Electromagnetic field.

7. A comparison between non-covariant and covariant quantization of the electromagnetic field. Features of covariant quantizations : Derivation of equal-time commutators between the components of fields and canonically conjugate momentum fields, (Derivation of energy operator not needed) special properties of time-like photons. Gupta-Bleuler formalism.

8. Basic ideas of the path integral formalism in quantum mechanics and quantum field theory.

9.Interacting fields (mainly electromagnetic interaction). Lagrangian and equations of motion of a system of interacting electrons and photons. Covariant perturbation theory. Derivation of the s-matrix operator. Time-ordering. Application to Compton scattering. Wick's theorem (statement only). Enumeration of terms of s-matrix element and corresponding Feynman diagrams. Statement of Feynman rules of graphs in quantum electrodynamics. Vacuum polarization diagram in Hydrogen atom, Charge renormalization and Lamb shift. (Detailed derivations of integrals not needed). Drawing of diagrams and statement of anomalous magnetic moment of electron.

Books recommended:

1. Relativistic Quantum Fields - J. D. Bjorken and S. D. Drell, McGraw-Hill (1965)
2. Quantum Field Theory - Lewis H Ryder, Cambridge University Press (1985)
3. Quantum Field Theory - Claude Itzyksen and Jean-Bernard Zuber, McGraw Book Co. (1985)
4. Quantum Field Theory in a nutshell - A. Zee, Princeton University Press (2003).
5. A First Book of Quantum Field Theory – A. Lahiri and P. B. Pal, Narosa Publishing House (2001).

Paper: MPHY0403 **[Marks 50]** **[Credit 4]**

Molecular Spectroscopy

1. Born-Oppenheimer approximation and separation of electronic and nuclear motions in molecules. Band structures of molecular spectra.

2. Microwave and far infrared spectroscopy : Energy levels of diatomic molecules under rigid rotator and non-rigid rotator models. Selection rules. Spectral structure. Structure determination. Isotope effect. Rotational spectra of polyatomic molecules. Stark effect.

3. Infrared spectra : Energy levels of diatomic molecules under simple harmonic and anharmonic (no deduction necessary for this one) models. Selection rules and spectral structures. Morse potential energy curves. Dissociation energies. Isotope effect. Rotational – vibrational coupling. Parallel and perpendicular modes. Symmetry properties of molecular wave functions and nuclear spins.

4. Raman spectroscopy. Rotational, Vibrational, Rotational-Vibrational Raman spectra. Stokes and anti stokes Raman lines. Selection Rules. Spectral structures. Nuclear spin and its effect on Raman spectra.

5. Vibrational spectra of poly atomic molecules. Normal modes. Selection rules for Raman and infrared spectra. Complementarity of Raman and infrared specra. Normal modes of CO_2 molecule. Normal modes of other simple triatomic molecules.

6. Electronic spectra of diatomic molecules:
   (a) Vibrational band structure. Progressions and sequences. Isotope shifts. Deslandres tables. Molecular constants in the ground and excited electronic states and crude idea of molecular bonding.

   (b) Rotational structure of electronic spectra. P-, Q- and R- branches. Band head formation and shading of bands.

   (c) Intensity distribution in the vibrational structure of electronic spectra and Franck-Condon principle. Hund's coupling. Experimental determination of dissociation energy.

   (d) Hydrogen molecule ion and molecular orbitals. Valence Bond approach in hydrogen molecule. Coulomb and exchange integrals. Electronic structures of simple molecules. Chemical bonding. Hybridizations.

   (e) Basic aspects of photo physical processes: radiative and non-radiative transitions; fluorescence and phosphorescence; Kasha's rules. Nuclear Magnetic resonance spectroscopy. Electron spin resonance spectroscopy. Fourier transform spectroscopy. Photo acoustic spectroscopy. Photo electron spectroscopy. Mossbauer spectroscopy.

   (f) Application of group theory to spectroscopy.

Books Recommended:

1. G. Herzberg. 'Molecular Spectroscopy (Diatomic Molecules)' Van-Nostrand.
2. G. M. Barrow. 'Molecular Spectroscopy'. McGraw-Hill.
3. J.Michael Hollas. ' Modern spectroscopy'. John-Wiley & sons.
4. C. L. Banwell and E. M. McCash. 'Fundamentals of Molecular Spectroscopy' Tata- McGraw-Hill..
5. G.Aruldhas 'Molecular Spectroscopy'.
6. Bransden and Joachin. 'Atoms and Molecules'
7. F.A.Cotton. 'Chemical application to Group theory'.

Paper: MPHY0404 **[Marks 25]** **[Credit 2]**

Computer Applications in Physics- II

1. CPU- programmers model; instruction set and addressing modes of a generic CPU; RISC and SISC; Storage System- primary and secondary memory; semiconductor, magnetic and optical memory; cache memory; virtual memory; memory management; IO Units – keyboard, mouse, VDU, printers; (principle of operation only). Computer Networks- motivation, classification, topology, technology (qualitative description); Internet- structure, TCP/IP protocol, internet services; Introduction to WWW.

2. Representation of integers and real numbers; Accuracy, range, overflow and underflow of number representation; error propagation and instability.

Solution of polynomial equations- bisection, Newton-Raphson algorithm.

Solution of system of simultaneous equations- Gauss elimination, Gauss-Seidel, LU decomposition algorithms. Interpolation- Newton interpolation formula. Numerical integration – trapezoidal formula, Simpson's formula, Romberg formula. Numerical solution of differential equations- Euler, Runge-Kutta formula. Numerical solution of partial differential equations- description of algorithms only. Monte Carlo technique of numerical integration.

Books Recommended:

1. Sastry, Introductory Methods of Numerical Analysis. PHI
2. Kyayszig, Advance Engineering Mathematics. John Willey, 9th Ed.
3. Tanenbaum, Computer Network, Prentice Hall.

Paper: MPHY0405 [Marks 25] [Credit 2]

Nonlinear Dynamics

1. Dynamical System, constants of motion, phase space, fixed points. Nonlinear dynamical systems in Physics, biology, engineering, etc. Dynamical equations and Stability for linear systems. Flow defined by nonlinear systems of ODEs, linearization and stable manifold theorem. Hartman-Grobman theorem. Stability and Lyapunov functions. Planar flows: saddle point, nodes, foci, centers and nonhyperbolic critical points. Bifurcation theory: saddle-node, pitch-fork, Hopf, period doubling, homoclinic bifurcations. Applications in: Laser model, population dynamics.

2. Limit cycle oscillations and Chaos: Concept of limit cycle, Poincare-Bendixon theorem; role of nonlinearity: From harmonic oscillator to Van der Pol oscillator, Chaos, Lorenz equation and Rossler equation. Applications in: Chaos in electronic oscillators, chaos in Laser system.

3. Discrete time nonlinear systems: logistic map, sine circle map, linear stability analysis and the existence of 2-cycles; numerical analysis of the logistic map; universality and the Feigenbaum numbers; bifurcation and chaos, intermittency, crises; Applications in: population dynamics, discrete phase-locked loop system, power electronics.

4. Dispersion, Dissipation and nonlinearity, Korteweg–de Vries (KdV) equation, solitory waves and soliton interaction, Application of KdV equation, Nonlinear phenomena in optical Kerr material, self phase modulation, group velocity dispersion, temporal soliton, nonlinear Schoedinger equation. Squeezed state of light formation: coherent state amplitude squeezed state, phase squeezed state of light.

Books Recommended:

1. Stephen Wiggins, "Introduction to Applied Nonlinear Dynamical Systems and Chaos", Springer-Verlag, Second Edition.
2. Steven Strogatz. "Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering", Levant Publishers, 1994.
3. Edward Ott**,** Chaos in Dynamical Systems**,** Cambridge University Press.
4. Dominic Jordan, Peter Smith, "Nonlinear Ordinary Differential Equations: An Introduction for Scientists and Engineers" (Oxford Texts in Applied and Engineering Mathematics)

5. J K Bhattacharyya, Nonlinear Dynamics
6. Ajoy Ghatak & K Thyaragrajan, Introduction to Fiber Optics (Cambridge University Press).
7. G P Agrawal, Application to Non Linear Fiber Optics (Academic Press).

Paper: MPHY0406 **[Marks 15]** **[Credit 1]**

Project/Term Paper

Paper: MPHY0408 **[Marks 10]** **[Credit 1]**

Social out-reach activity

Major Elective

Paper: MPHY0409 **[Marks 75]** **[Credit 6]**

Advanced Practical

List of Experiments

Group A:

1. Determination of temporal coherency of a coherent (laser) light and compare it with incoherent light (sodium)
2. Study of magneto-optic effect (Faraday effect)
3. Study of electro-optic effect (Pockel effect)
4. Stydy of Zeeman effect
5. Study of characterization of antenna
6. Design of active filters (a) band-pass filter, (b) all pass filter
7. Studies of nonlinear electronic circuits and design of chaotic electronic oscillator
8. Studies on LED modulation characteristics

Group B:

1. Band-gap determination from thermal variation of resistivity
2. Measurement of magnetic susceptibility using Quincks method
3. Study of ESR
4. Study of gamma ray spectrum of radioactive nuclides with NaI (Tl) scintillators & SCA
5. Study of beta-ray absorption & determination of end point energy of the beta-ray spectra of the given source by the Feather's method
6. Study of gamma-ray absorption & determination of gamma ray energy
7. Determination of particle size of an unknown powder specimen using Scherrer equation from supplied XRD pattern
8. Phase identification of an unknown sample from its X-ray diffraction pattern

All the students will be divided into two groups i.e. Group A & Group B

Those students who have done Group A experiments in Semester-III will have to opt Group B experiments in Semester-IV and vice versa

Minor Electives

Paper: MPHY0411 **[Marks 50]** **[Credit 4]**

Communication Technology

Review of CW Modulation Technique:
Linear modulation DSB, SSB, VSB, QAM techniques, Exponential modulation FM and PM; AM and FM modulators and demodulators.

Pulse Modulation and Demodulation Techniques:
Sampling the rein PAM, PWM, PPM, Pulse code modulation – coding technique modulation and demodulation.

Digital Modulation Techniques:
ASK, FSK, PSK, DPSK, QPSK, MSK, Principle, modulators and demodulators.

Effect of Noise on Communication System:
Characteristics of additive noise; Performance of AM, FM and PCM receivers in the face of noise; Multi-path effect.

Elements of Information Theory:
Information, average information, information rate, Effect of coding on average information per bit; Shanon's theorem; Channel capacity, an optimum modulation system.

TV Systems:
Color TV standards – NTSC, PAL, SECAM; Transmission format of intensity and color signal; Transmitter and receiver systems of broadcast TV; Advanced TV; Cable TV.

RADAR System: Basic pulsed radar system – modulators, duplexer indicators, radar antenna CW radar; MTI radar FM radar; chirped pulse radar.

Optical Communication: Fibre optic communication systems; Power budget equation; Multiplexing; Quantum limit; Incoherent reception; signal-to-noise ratio calculation; Basics of coherent techniques in FOC.

Satellite Communication:
Orbits, Station keeping; Satellite attitude; Path loss calculation; Link calculation; Multiple access techniques; Transponders; Effects of nonlinearity of transponders.

Specialised Communication Systems:
Mobile Communication – Concepts of cell and frequency reuse description of cellular communication standards; Pagers. Computer communication – Types of networks; Circuit message and packet switched networks; Features of network, design and examples of ARPANET, LAN, ISDN, Medium access techniques – TDMA, FDMA, ALOHA, Slotted ALOHA, CSMA/CD; Basics of protocol.

Books Recommended

1. A B Carlson – *Communication Systems.*
2. D Roddy and J Coolen – *Electronic Communications.*
3. Franz and Jain – *Optical Communication Systems.*
4. A M Dhake – *Television and Video Engineering*.

5. Gulati – *Monochrome and Color TV*.
6. Kennedy and Davis – *Electronic Communication Systems*.
7. Taub and Schilling – *Principle of Communication Systems*.

Paper: MPHY0412 [Marks 50] [Credit 4]

Laser Applications and Nonlinear Optics

1. Upconversion and down conversion:
Sum frequency generation, limitation to upconversion, introductory theory, infrared detection, effect of phase matching, noise properties, image conversion, experimental status, difference frequency generation, effect of phase matching, evaluation of $\Delta\theta$ and $\Delta\lambda$

2. Optical communication:
Optical fibre waveguide, modes in optical fibre, pulse distortion and information rate in optical fibres, distortion in single mpde fibre, fibre losses, coupling of source with fibre, modulation, PCM, multiplexing, WDM, TDM, solitons.

3. Nonlinear materials:
UV-VIS-NIR crystals, assessment of nonlinear crystals (Kurtz powder method, Maker fringe method), chalcopyrites, derivation and characteristics.

4. Methods of semiconductor crystal growth:
Outline of crystal growth method, liquid phase epitaxy, vapour phase epitaxy, metal organic chemical vapour deposition, chemical beam epitaxy, molecular beam epitaxy.

5. Laser instrumentation:
Principle of measurement with laser beam, distance measurement, rotation, fluid velocity measurement, laser range finder

6. Remote monitoring:
Advantages of remote monitoring of the atmosphere by laser, principles of remote monitoring, different lidar systems, sources of noise and its remedial measures, Raman back scattered lidar

7. Material processing:
Laser in drilling, cutting, welding, marking, annealing

8. Optical bistability & phase conjugation:
Principle of optical bistability, different optical logic gates, optical phase conjugation, production of phase conjugated beam, self focusing, optical computing.

9. Laser cooling & BE Condensation: Principle of laser cooling & trapping, optical molasses, cooling below doppler limit, magnetic trapping, applications

Books Recommended:
1. Methods of Experimental Physics Vol. 15B ed. By C L Tang
2. Industrial Application of Lasers – J F Ready
3. Laser remote Sensing:- R M Measures

4. Optical bistability- H M Gibbs
5. Handbook of Nonlinear Optics- R L Sautherland
6. Laser and electrooptics- C C Davis

Paper: MPHY0413 [Marks 50] [Credit 4]

Properties of Materials

Optical and dielectric properties of materials

Theory of electronic polarization and optical absorption, ionic polarization, orientational polarization. Optical phonon model in an ionic crystal; Interaction of electromagnetic waves with optical modes, polariton, Dispersion curves of transverse optical (TO) phonon and optical photon in a diatomic ionic crystal, LST relation; Metal-insulator transition. Optical properties of metals & nonmetals- Luminescence, photoconductivity.

Electrical properties of materials

Resistivity variation in metals and semiconductors, electrical conduction in ionic ceramics. Band gap determination in semiconductors using electrical and optical methods. Tensor Properties of Materials; Tensor representation of electrical conductivity.

Magneto-resistance and its application

Ordinary and anisotropic magneto-resistance, mechanism; Giant magneto-resistance (GMR): basic properties, mechanism, spin valves and spin switches; Colossal magneto-resistance (CMR): basic properties and phase diagram, comparison with GMR Theoretical understanding, Double exchange mechanism, crystal field splitting and Jahn-Teller distortion.

Mechanical Properties of metals and ceramics

Concepts of stress & strain, stress-strain behavior, anelasticity, Plastic deformation, Hardness-Knoop & Vicker's hardness test.

Thermal properties of metals & alloys

Temperature effects on the intensities of Bragg reflections. Influence of temperature on diffraction of X-rays: Normal coordinates of lattice vibration and X-ray scattering from a vibrating lattice and origin of thermal diffuse spots. First order TDS. Debye-Waller factor' Debye's method of calculating isotropic temperature factor for a cubic crystal. DTA, TGA, DSC (Outline only).

Annealing processes, Heat treatment of steels, mechanism of hardening. Quenching, thermal stresses.

Structure - Property correlation, application aspects of material

Correlation of structure with physical properties of materials, application prospects of materials in different areas. Functional and smart materials.

BOOKS RECOMMENDED

1. Introduction to Ceramics by *W. D. Kingery, H. K. Bowen and D. R. Uhlmann*, John Wiley & Sons
2. Diffraction analysis of the microstructure of materials by *E. J. Mittemeijere and P. Scardi*, Springer
3. Materials Science & Engineering by *William D. Callister*, John Wiley & Sons, Inc.

4. Modern techniques of surface science by *D. P. Woodruff & T. A. Delchar*, Cambridge University Press
5. X-ray spectroscopy by *B. K. Agarwal*, Springer-Verlag.

Paper: MPHY0414 [Marks 50] [Credit 4]

Advanced Condensed Matter Physics

General magnetism: Magnetic susceptibility tensor, quadratic representation, correlation of principal susceptibilities with crystallographic axes in different crystal systems using magnetic ellipsoid, correlation of magnetic anisotropy of molecules and ions in a unit cell with those of crystals, measurements of principal anisotropies of crystals belonging to different systems, Derivation of quantum mechanical expression of diamagnetic susceptibility, structural information from measurement of magnetic anisotropy.

Paramagnetism: Van Vleck expressions of susceptibility, crystal field theory, free ion and Crystal field Hamiltonians, Steven's operators, Operator equivalent method, splitting of 3d ions in octahedral and tetrahedral field, Crystal field splitting of Ce^{3+} in ethyl sulfate and derivation of susceptibility of Ce^{3+} ethyl sulfate lattice, Kramer's theorem, J-T effect.

Superconductivity: Ginzburg-Landau theory of Superconductivity, Gl Equations. Fluxoid quantisation. BCS theory - Cooper pairing: instability of the Fermi sea, BCS Hamiltonian and its diagonalization by Bogoliubov-Valatin transformation, ground state energy, gap equation, critical temperature, isotope effect. Josephson junction and Josephson effect, Applications – Detailed description of SQUID. Coexistence of superconductivity and magnetism. High T_c superconductors.

Ordered magnetic Systems – Origin of Ferromagnetism - Heitler London Calculation, Spin Hamiltonian. Heisenberg Model – Indirect Exchange and Superexchange, Ground state. Spin waves and magnons, Spin waves in Antiferromagnets. Band model of ferromagnetism – Temperature behaviour of a ferromagnet in the band model.

Neutron Diffraction in magnetic systems – Basic theory and Applications.

Magnetic domains and interactions – Dipole Interactions, Demagnetizing fields and Origin of domains. Magnetocrystalline anisotropy and its origin, Domain Walls

Magnetic Phase Transitions – Mean Field theory, Landau and Lanadau-Ginzburg theories, Critical behaviour.

Optical properties of solids – Kramers-Kronig relations. Semiconductors - Direct and indirect interband transitions; Excitons - Mott-Wannier excitations, Frenkel Excitons, Electron-Hole Liquid. Insulators – Polarization – Ferroelectrics, Berry phase theory of polarization, Clausius – Mossotti relation, Polaritons, Polarons.

Books recommended:

1. Solid State Physics: Mattis
2. Solid State Physics: C. Kittel
3. Magnetism in Condensed Matter: Stephen Blundell
4. Ferrites: J. Smith & P.J. Wijn

5. Introduction to Magnetic Materials: B. D. Cullity
6. M.P. Marder – Condensed Matter Physics
7. Physics of Magnetism – S. Chikazumi.
8. Quantum theory of Solids – C. Kittel.

Paper: MPHY0415 **[Marks 50]** **[Credit 4]**

High Energy Physics

1. Basic objectives of high energy physics. Brief overview of four fundamental interactions and their characteristics, elementary particles and their characteristics.

2. Static model ($SU(3)_f$) of quarks. Baryon and meson supermultiplets. Spin-flavour state functions of baryon decouplets, baryon octets and meson nonets. Colour wave functions. Magnetic moments of baryons. Principles of discoveries of heavy flavours: Charm, bottom and top.(Detailed experimental techniques not needed). Summary of quantum numbers of all quark flavours. Vector mesons and their decays. Zweig rule.

3. Gauge theories of fundamental interactions. Internal symmetries. Global and local gauge invariances. U(1) and $SU(3)_c$ symmetries. Comparison between Quantum Electrodynamics and Quantum Chromodynamics. Running coupling constants (derivations not required). Ultraviolet breakdown. Asymptotic freedom. Infrared slavery.

4. High energy electron-proton scattering. Bjorken variable. Elastic, deep-inelastic régimes. Derivation of inclusive scattering cross section in terms of structure functions. Bjorken scaling. Scaling violation. Concepts of Mandelstam variables. Compton scattering and gluon emission scattering amplitudes and cross-sections in terms of Mandelstam variables. Altarelli-Parisi evolution equation.

5. Weak interaction. Analogy with electromagnetic interaction. Four-fermion point interaction of Fermi. Weak interaction amplitude in terms of bilinear covariants. Parity violation. τ-θ paradox, Wu's experiment. Goldhaber's experiment to determine the neutrino helicity, two-component theory of neutrino. Correlation data. V-A form of weak interaction amplitude. Parity violations in Λ^0, K^0 decays. Strangeness oscillation. Regeneration phenomenon. CP violation in K^0 decay. CPT theorem (statement only). Strangeness-conserving and strangeness-violating weak interactions. Cabbibo theory.

6. Gauge theory of weak interaction. Spontaneous symmetry breaking and Higgs mechanism. Electroweak unification. Glashow-Weinberg-Salam model of electroweak symmetry breaking. $W^{\pm}$, Z^0 masses. Basic ideas of a Grand Unified Theory, SU(5) theory and its predictions. Inclusion of gravity. Planck scale. Brief chronology of events in the early universe.

7. Neutrino mass and neutrino oscillation. Derivation of intensity of ν_e - ν_μ . Atmospheric, solar and Supernova neutrinos. Solar neutrino problem.

Books recommended:

1. Introduction to high energy physics- D H Perkins, Addison Wesley, Reading, Mass (1982)

2. Quarks and Leptons: An introductory course in modern partoicle physics-F Halzen and A D Martin, John Weiley & Sons (10983)
3. The ideas of Particle Physics:An introduction for Scientists - G.D.Coughlan, J.E.Dodd and B.M.Gripaios, Cambridge University Press(1984).
4. Facts and Mysteries in elementary particle physics- Martinus Veltman, World Scientific (2003)

Paper: MPHY0416 [Marks 50] [Credit 4]

Cosmology

Introduction:

Large scale structure of the universe, Cosmological scales, Weyl postulates, Cosmological Principles, Static Universe model – Einstein Model, de-Sitter Model, Properties of Einstein and de-Sitter universes, cosmological constant and its significance, Mach principle (elementary discussions), Discussion on Newtonian cosmology, red shift.

Non static model of the universe:

Friedmann model of the universe, Field equations, Energy tensors of the universe, Friedmann-Robertson-Walker metric (derivation is not required), Cosmological parameters, Static Universe vs Expanding universe, Hubble' law, scale factor, present day scale factor, Models of F-R-W universes (k=0,+1,-1), volume of the universe, Open and Closed universes, Cosmological red shift, Hubble time and age of the universe, cosmological models with Λ-term, Particle Horizon and Event Horizon, Olber's Paradox.

Early Universe:

Big Bang, Early universe, Thermal history, Entropy – Temperature and Time – Temperature relations, photons, primodial neutrinos, neutrino decoupling, decoupling of matter and radiation, electrons, positrons, protons, neutrons, synthesis of lighter nuclei, primordial nucleosynthesis, radiation dominated and matter dominated universe, Qualitative discussions on very early universe, vacuum energy, false vacuum energy, Grand Unified Theory (GUT),

Problems of Standard Cosmology:

Some problems of Standard Cosmology. Flatness problem, Horizon problem, Entropy problem, and Monopole problem, Elementary discussion on inflationary universe.

Observational Cosmology:

Red shift – magnitude relation, Hubble diagram using type I_a supernova, number counts of extra galactic objects. Cosmic Microwave Background Radiation, brief reviews on: counts of galaxies, counts of radio sources, age of the universe.

Dark Energy and Dark matter:

Elementary analysis on Dark Energy and Dark Matter, evidences in support of Dark Energy and Dark Matter. Origin and nature of Dark Energy, galaxy rotation curves.

Singularity in Cosmological Models:

A brief discussion on Raychaudhuri equation and Hawking – Penrose singularity theorem.

Books Recommended

W.G.V.Rosser – Introduction to the Theory of Relativity.
S. Banerji and A. Banerjee – The Special Theory of Relativity (Prentice Hall of India, 2002)
R. Resnick – Introduction to Special Theory of Relativity.
P. G. Bergmann- Introduction to Theory of Relativity (Pren tice-Hall, 1969).
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