M.Sc. Course in Physics

(Total Marks = 1200)

Semester System Course Structure

(Total Four Semesters and 300 marks in each Semester)

The First & Second Semesters (Unit 1-Unit 10)

(50 Marks in each Unit for Unit 1-Unit 4 and Unit 6-Unit 9; Unit 5 & Unit 10 are practical papers carrying 100 marks each. Students are divided in two groups of equal strength, Gr. A and Gr. B for Unit 5 and Unit 10 only.)

Semester – Wise Distribution of Subjects with Marks.

I. First Semester :

Course Name	Subject – Wise Marks	Total Marks	No. of Lectures
Unit 1 :	Classical Mechanics – I : 30 Statistical Mechanics – I : 20	50	52
Unit 2 :	Mathematical Methods – I : 50	50	50
Unit 3 :	Classical Electrodynamics – I : 30 Electronics – I : 20	50	50
Unit 4 :	Quantum Mechanics – I : 50	50	50
Unit 5 :	Practical : Nuclear Physics & Advanced Optics : 100 - Gr. A Students only		
	Practical : Electronics : 100 - Gr. B Students Only	100	
	Total =	**300**	

II. Second Semester :

Course Name	Subject – Wise Marks	Total Marks	No. of Lectures
Unit 6 :	Classical Mechanics – II : 30 Statistical Mechanics – II : 20	50	50
Unit 7 :	Mathematical Methods – II : 50	50	50
Unit 8 :	Classical Electrodynamics – II : 30 Electronics – II : 20	50	50
Unit 9 :	Quantum Mechanics – II : 50	50	54
Unit 10 :	Practical : Nuclear Physics & Advanced Optics : 100 - Gr. B Students only Practical : Electronics : 100 - Gr. A Students Only	100	
	Total =	**300**	

Third and Fourth Semesters
Semester – Wise Distribution of Subjects with Marks

III. Third Semester :

Course Name	Subject – Wise Marks	Total Marks	No. of Lectures
Unit 11:	Condensed Matter Physics : 54 Atomic & Molecular Spectroscopy : 36	90	100
Unit12 :	Nuclear Physics : 54 Elementary Particle Physics : 36	90	94
Unit 13 :	Quantum Mechanics : 54 Electronics : 36	90	90
Unit 14 :	Grand Viva : 30	30	
	Total =	**300**	

IV. Fourth Semester :

Course Name	Subject – Wise Marks	Total Marks
Unit 15:	Special Subject Theory Paper I : 50	50
Unit 16 :	Special Subject Theory Paper II : 50	50
Unit17 :	Elective Paper : (Advanced Study on Special Topics) : 50	50
Unit 18 :	Special Subject Practical Paper I : 50	50
Unit 19 :	Special Subject Practical Paper II : 50	50
Unit 20 :	Project Work (one) : 50 (Project Paper 40 + Viva Voce 10)	50
	Total =	**300**

Currently the following 3 specialisations are offered :

1. Electronics

2. Nuclear & Elementary Particle Physics

3. Solid State Physics.

N.K. Ghosh
Head of the Department of Physics

Syllabus for M. Sc. Physics (from 2008 onwards)

Unit 1

Full Marks : 50

Group A : Classical Mechanics I

Marks : 30 **No. of Lectures – 32**

1. Application of the Lagrange's equations of motion to solve problems of motion. (2)
2. Two Body Central Force Problem: Equivalent one body problem and effective potential; classification of orbits; differential equation for orbits; integrable power law potentials; conditions for closed and stable orbits – Bertrand's theorem, Virial Theorem , Inverse Square Law of Force : Bound state problem : Kepler problem; Kepler's laws and planetary motion; Kepler's equation; Laplace – Lenz vector. Scattering Problem : elastic scattering ; scattering cross section; centre of mass and laboratory frames; Rutherford scattering. (5)
3. Rigid Body Dynamics: Kinematics : degrees of freedom; space–fixed and body-fixed set of axes and orthogonal transformations from one set to another; Euler's angles; Euler's theorem on the motion of a rigid body; infinitesimal rotations. Equation of Motion : Angular velocity, angular momentum and kinetic energy of rotation; moments of inertia and the inertia tensor; eigenvalues of the inertia tensor and principal axes transformations; Lagrange's equations of motion for a rigid body; Euler's equations of motion. Force free motion of a rigid body; heavy symmetrical top with one point fixed; precession and nutation; Larmor precession; gyroscope asymmetrical top. (12)
4. Theory of Small Oscillations: Formulation of the problem; eigenvalue equations; frequencies of free vibrations and normal coordinates; forced vibrations and the effect of dissipative forces; simple examples. (5)

3. Hamilton's Equations of Motion : The Hamiltonian and its physical significance; Hamilton's action and the principle of least action; Hamilton's equations of motion and applications; action as a function and Maupertuis principle; conservation theorems; cyclic coordinates and Routh's procedure. (8)

Reference Books :

1. Goldstein, Poole and Safko : Classical Mechanics – Addison Wesley / Narosa
2. Landau and Lifshitz : Mechanics - Pergamon
3. Sommerfeld : Mechanics – Academic Press
4. Rana and Joag : Classical Mechanics – Tata McGraw Hill
5. Whittaker : Analytical Dynamics of Particles and Rigid Bodies - Cambridge
6. Fetter and Walecka : Theoretical Mechanics of Particles and Continua – McGraw Hill
7. Raychaudhuri : Classical Mechanics – Oxford
8. Simmons : Differential Equations
9. Bhatia : Classical Mechanics – Narosa.

Group B : Statistical Mechanics I

Marks : 20 **No. of Lectures – 20**

1. Statistical Description : Principle of equal a *priori* probability; examples of 2 and 3 level systems; random walk; Phase space; phase point; phase trajectory; statistical distribution function; ergodic hypothesis; statistical average; statistical distribution with examples from binomial, Poisson and gaussian distribution, examples of gas within a container, spin ½ particles; Stirling's approximation and central limit theorem; statistical independence and statistical fluctuations; generalized Ornstein-Zernike relation between temperature, generalized susceptibility and statistical fluctuations; examples of isothermal compressibility and number function, magnetic susceptibility and magnetic moment fluctuation, specific heat and energy fluctuation. (6)

3. States in Statistical Mechanics: Microscopic and macroscopic states; density of states; statistical weight of a macroscopic state; entropy and Boltzmann's principle; principle of increase of entropy and Boltzmann's H-theorem; examples of a free particle, perfect gas and non-interacting spin systems. Classical Liouville equation; quantum density matrix; quantum Liouville equation. (4)

4. Statistical Ensembles : Isolated closed and open systems general interactions and equilibrium between macroscopic systems; microcanonical, canonical and grand canonical ensembles; canonical ensemble and Gibbs' distribution – Boltzmann-Planck method; partition function and statistical definition of thermodynamic quantities; computation of partition functions of some standard systems; relation between density of states and partition function; spin ½ system and negative temperature; system of linear harmonic oscillators in the canonical ensemble; grand canonical ensemble and its partition function; chemical potential; dependence of different thermodynamic quantities on the number of particles; energy fluctuations in the canonical ensemble and the equivalence of the canonical and the microcanonical ensembles; density fluctuations in the grand canonical ensemble and its equivalence

to the canonical ensemble. Partition function and distribution for perfect gas; Gibbs' paradox; Free energy, entropy, equation of state and specific heat determination of perfect gas; Degeneracy temperature and application of Boltzmann distribution. (7)

5. Chemical Reaction Equilibrium: Condition of equilibrium; law of mass action; heat of reaction and change of volume in gaseous reaction; ionization equilibrium and Saha ionization formula. (3)

Reference Books :

1. Landau and Lifshitz : Statistical Mechanics – Pergamon.
2. Toda, Kubo and Saio : Statistical Physics – Springer Verlag.
3. Reif : Fundamentals of Statistical and Thermal Physics – McGraw Hill.
4. Pathria : Statistical Mechanics – Pergamon.
5. Ma : Statistical Mechanics – World Scientific.
6. Huang : Statistical Mechanics – John Wiley.

Unit 2

Full Marks : 50

Mathematical Methods I **No. of Lectures – 50**

1. Analysis: Point set, neighbourhood, isolated point, limit point etc. Convergence of a sequence, infinite series, absolute convergence and conditioned convergence, test of convergence (ratio test, Cauchy's root test, Raabe's test) (2)

2. Function of Complex Variables : Limit , continuity, differentiability, analyticity, necessary and sufficient condition for analytic function, Cauchy Riemann conditions; Fluid flow analogy, multivalueness of functions, singularities, branch points and cuts, Riemann sheets. (5)

3. Integrals : Jordan curve; rectifiable arc and its length; contours; Riemann's definition of integration and the integrability of a function; Primitive function, Darboux inequality, simply and multiply connected domains, Cauchy's theorem, Cauchy's integral formula; derivatives of an analytic function; Liouville's theorem ; indefinite integrals; Morera's theorem, Taylor's theorem and Laurent's Theorem; zeros and singularities of a function; essential singularity; limiting points of zeroes and poles; Weierstrass's theorem; the point at infinity, (8)

   Calculus of Residues: Residue and evaluation of residue; Cauchy's residue theorem; evaluation of definite integrals by the method of contour integration (including integration around branch cuts): evaluation of principal values of improper integrals; summation and inversion of series; partial fraction representation of meromorphic functions; infinite product representation of entire functions (Mittag Leffler Expansion). (7)

4. Analytic Continuation: Definition and some elementary theorems; Schwarz reflection principle; power series method of analytic continuation, Gamma and Beta functions – definitions and properties, Asymptotic Expansion: Definition and some illustrations; saddle point expansion method. (7)

5. Linear Ordinary Differential Equations (Second Order): Linear independence of solution number of solutions and the Wronskian; Wronskian method of obtaining the

second solution. Classification of singularities of differential equation: Ordinary points; regular and irregular singularities; series solutions about ordinary and regular singular points; convergence and analyticity properties of series solutions – Fuch's theorem; Frobenius' method of obtaining the second solution ,Self adjoint operator; the Sturm – Liouville problem. (7)

6. Series solution of differential equation and Special Functions : Hypergeometric and confluent hypergeometric functions; Legendre functions (including associated Legendre functions and spherical harmonics)' Bessel functions (including spherical Bessel functions); Hankel function and modified Bessel functions. Hermite and Laguerre functions (including associated Laguerre functions). analogy with Sturm Liouville problem; generating functions; recursion relations; orthonormality; integral representation and analytic properties ; asymptotic behaviour; graphical representation. (14)

Reference Books :

1. Mathews and Walker : Mathematical Methods of Physics – Benjamin
2. Arfken and Weber : Mathematical Methods for Physicists – Academic Press
3. Morse and Feshbach : Methods of Theoretical Physics – McGraw Hill
4. Pipes and Harvill : Applied Mathematics for Physicists and Engineers – McGraw Hill Kogakusha
5. Harper : Introduction to Mathematical Physics – Prentice Hall
6. Chattopadhayay : Mathematical Methods of Physics – New Age International
7. Courant and Hibert : Methods of Mathematical Physics – John Wiley
8. Smirnov : Course on Higher Mathematics – Pergamon
9. Lang : Linear Algebra – Addison Wesley
10. Finkbeiner : Matrices and Linear Transformations - Taraporevala
11. Whittaker and Watson : A Course in Modern Analysis - Cambridge
12. Copson : Theory of Functions of a Complex Variable – Oxford
13. Tichmarsh : Theory of Functions - Oxford

Unit 3

Full Marks : 50

Group A : Classical Electrodynamics I

Marks : 30 **No. of Lectures – 30**

1. Electrostatics : Coulomb's law; electrostatic field and electrostatic potential; Gauss's law; Laplace and Poisson equations; surface distribution of charges; dipoles and discontinuities in electric fields and potentials; volume distribution of dipole moments; electrostatic energy; multipole expansion of the electrostatistic potential. (7)
2. Dielectrics and Electrostatistics of Microscopic Media : The displacement vector; electric field in a material medium; electric susceptibility and molecular polarisability; electrostatic energy in dielectric media and volume force on dielectrics; boundary conditions. Basic concepts on alternating fields applied to dielectric. Dielectric losses. (8)
3. Boundary Value Problems in Electrostatics : General methods for the solution of the potential problem; Green's theorem; uniqueness theorem. Solutions of the Laplace equation in rectangular cartesian, spherical polar and cylindrical coordinates; various boundary value problems [e.g., potential of a point charge, point charge in front of a dielectric sphere, dielectric sphere in a uniform field, a charged ring, a line charge in front of a dielectric cylinder etc.]. (7)
4. Magnetostatics: Biot Savart's law; Ampere's law; magnetic scalar and vector potentials; uniqueness of the vector potential; permeable media-magnetic susceptibility and boundary conditions; magnetic fields of localised current distributions; magnetic moment; force, torque and magnetic induction of a localised current distribution in an external magnetic field; magnetic volume force. Uniformly magnetised sphere; magnetised sphere in external field; permanent magnets; field inside and outside a bar magnet; magnetic shielding; spherical shell of permeable material in a uniform field. Atmospheric electrodynamics. (8)

Reference Books :

1. Jackson : Classical Electrodynamics – John Wiley

2. Panofsky and Phillips : Classical Electricity and Magnetism – Addison Wesley
3. Griffiths : Introduction to Electrodynamics – Prentice Hall India
4. Schwinger : Classical Electrodynamics – Perseus Books
5. Stratton : Electromagnetic Theory – McGraw Hill
6. Landau & Lifshitz : Classical Theory of Fields - Pergamon
7. Landau & Lifshitz : Electrodynamics of Continuous Media - Pergamon
8. Chandrasekhar : Plasma Physics – Chicago University Press.
9. Volland: Atmospheric Electrodynamics- C R C Press

Group B : Electronics I

Marks : 20 **No. of Lectures – 20**

1. Power Circuits : Regulated power supply; basic concepts; practical monolithic circuit. Thyristor; SCR construction, operation and characteristics; equivalent circuit of SCR; SCR rectifier; other applications; Diac; Triac, UJT & Relaxation Oscillator (4)
2. Waveform Generators : Tuned oscillators and crystal oscillators, Pulse generation and shaping by astable, monostable and bistable multivibrators; Schmitt trigers; time base generators; (4)
3. Integrated Circuits : Fabrication techniques of IC components and devices; LSI, VLSI. (2)
4. Operational Amplifiers : Basic operational amplifier; characteristics; operational feedback; virtual ground; adder; integrator; differentiator; subtracting amplifier; constant amplitude phase shifter; RC active filters; instrumentation amplifiers.
   Non-ideal Op-Amps : Effects of i) finite loop gain, ii) finite input resistance, iii) non-zero output resistance and iv) off-set and drift; common mode rejection ratio. (6)
5. Amplitude Modulation and Detection : sideband power relation; typical amplitude modulation circuit; detection of ampitude modulated waves; envelope; average detection; elimination of clipping distortion; AVC circuit; block diagrams of AM transmitter and superheterodyne receiver. (4)

Reference Books :

1. Van der Ziel : Solid State Physical Electronics – Prentice Hall India
2. Millman and Taub : Digital and Switching Waveforms – McGraw Hill Kogakusha
3. Taub and Schilling : Digital Integrated Electronics – McGraw Hill Kogakusha
4. Millman and Halkias : Integrated Electronics – McGraw Hill Kogakusha
5. Tobey, Graeme and Huelsman : Operational Amplifiers – McGraw Hill Kogakusha
6. Gaekwad : Op-Amps and Linear Integrated Circuits – Prentice Hall India.
7. Jordan & Balmain: Radiation & Radiating Systrems- Prentice Hall India.

Unit 4

Full Marks : 50

Quantum Mechanics I **No. of Lectures – 50**

1. Linear Vector Space Formulation:

   a) Principle of superposition; analysis of phenomena illustrating this principle, Linear Vector Space : Linear independence; complete set; scalar product; dual space; orthogonalisation; linear operators; hermitean and unitary operators; eigenvectors and eigenvalues; basic features of spectra of hermitean operators, States and Observables of a System as Vectors and Operators and related discussion; Commutation rules and commutator algebra; compatible observations; compatible observations; uncertainty relations; method of quantisation of classical systems, Representation of Vectors and Operators in Discrete Basis – matrix representation; change of basis; coordinate representation of states and operators, momentum eigenfunctions – box and δ - function normalisation; momentum representation; Fourier transformation; wave packets; energy representation, Linear Harmonic Oscillator ; Eigenvalue problem by operator method; Discussion on solution of the Schroedinger eigenvalue equation in coordinate representation ; momentum wave function; coherent states, Mixed State : density matrix and its properties; examples; use of density matrix in calculating average values. (20)

2. Equation of Motion: Stationary states and time independent Schroedinger equation. Stationary state problem: Bound and unbound states, reflection and transmission, delta function well and barrier, array of delta function barriers (Dirac comb), Time dependence of expectation values; Schroedinger, Heisenberg and Dirac (interaction) pictures; equation of motion in Schroedinger picture; time translation operator; transition to Heisenberg picture; equations of motion in the Heisenberg and interaction pictures; stationary states, Linear Harmonic Oscillator with Heisenberg equation of motion, use of the dynamical equation of quantum mechanics to describe a physical system-the ammonia molecule for example, Time dependent Schroedinger

equation for a single particle system; probability density and current; initial value problem; Green's function; propagator concept; free particle moving in one dimension; Gaussian wave packet and its spreading. Classical limit, Ehrenfest theorem, the WKB approximation. (20)

3. Angular momentum as generator of rotation, commutation rules, eigenvalues and matrix representation, orbital angular momentum and eigenfunction. Spin angular momentum, algebra of Pauli spin matrices, spin half particle in a magnetic field. Addition of angular momenta; Clebsch Gordan coefficients, Tensor operators, Wigner – Eckart theorem (statement only) (10)

Reference Books :

1. David Griffiths: Introduction to Quantum Mechanics, Pearson Education
2. Schiff : Quantum Mechanics – McGraw Hill Kogakusha
3. Merzbacher : Quantum Mechanics – John Wiley
4. Sakurai : Modern Quantum Mechanics – Addison Wesley
5. R. P. Feynman: Lectures on Physics, Vol. 3, Narosa
6. Schwabl: Quantum Mechanics, Narosa
7. Bransden and Joachain : Introduction to Quantum Mechanics - Longmans
8. Landau and lifshitz : Quantum Mechanics - Pergamon
9. Davydov : Quantum Mechanics – Pergamon
10. Gasiorowicz: Quantum Physics, John Wiley

Unit 5 & 10

(Practical)

Full Marks : 100 **Time : 6 Hours**

Nuclear Physics and Advanced Optics

List of Experiments:

1. a) Determination of the Plateau region of a GM tube.
   b) Analysis of statistical fluctuations at low and high count rates.
2. Determination of half-life of Indium.
3. Study of gamma absorption in Aluminium and Lead using a GM tube and determination of the mass absorption coefficient.
4. Study of beta absorption in Aluminium using a GM tube and determination of range and energy of beta particles.
5. a) Calibration of a Michelson interferometer using Na-D lines as standard.
   b) Measurement of $d\lambda$ between Na-D lines.
   c) Determination of refractive index/thickness of a thin sheet of a transparent material.
6. Study of spectra of Hydrogen atom using a constant deviation spectrograph, to identify the Rydberg series and to construct its energy level diagram.
7. Study of the molecular spectra of I_2 in absorption and determination of the dissociation energy.
8. Study of the Zeeman splitting of Na-D lines using a constant deviation spectroscope and Fabry-Perot etalon.

Unit 5 & 10

(Practical)

Full Marks : 100 **Time : 6 Hours**

Electronics

List of Experiments :

1. Construction of a power supply with semiconductor devices, zener diodes and using an emitter follower and to study its performance – ripple factor, line and load regulations.
2. Construction of a single stage common emitter voltage amplifier, measurement of its gain, input and output impedances and the determination of the gain-bandwidth product using R-C coupling.
3. Experiments on Diac, Triac, SCR and UJT
4. Design and construction of astable multivibrator and the study of its characteristics and performance.
5. Experiments on Modulation and demodulation
6. Study of characteristics of FET and MOSFET and use of these as source followers.
7. To test the performance of digital gates using ICs
8. Study of OPAMP (IC 741) characteristics and its use as an inverting amplifier, non-inverting amplifier, adder and differential amplifier.

Unit 6

Full Marks : 50

Group A : Classical Mechanics II

Marks : 30 **No. of Lectures – 30**

1. Canonical Transformations : Equations of canonical transformation; generating functions; examples of canonical transformations; integral invariants of Poincare; Lagrange and Poisson brackets as canonical invariants; equations of motion in Poisson bracket notation; infinitesimal contact transformations; constants of motion and symmetry principles; generators of infinitesimal symmetry transformations; Noether's theorem; Liouville's theorem. (8)

2. Hamilton – Jacobi theory; Hamilton's principal and characteristic function; Hamilton – Jacobi equations for these two functions; separation of variables in the Hamilton – Jacobi method (e.g. simple harmonic motion, Kepler problem etc.), Hamilton – Jacobi theory, geometrical optics and wave mechanics. (7)

3. Mechanics of Continuous Media : Transition form discrete to continuous systems; the Lagrangian formulation; stress energy tensor and conservation theorems; Hamiltonian formulation; Poisson brackets and momentum representation; examples (6)

4. Non-linear Dynamics and Chaos : Non-linear Equations : Autonomous systems; critical points; stability; Liapunov direct method; periodic solutions; Poincare – Bendixon theorem; Lienard theorem. Non-Linear Oscillation and Chaos: Perturbations and the Kolmogorov – Arnold – Moser theorem (no derivation); Non-linear oscillations; Volterra's problem; limit cycles. Chaos – Poincare maps; Logistic equations; attractors; elementary ideas about chaos; (9)

Reference Books :

1. Goldstein, Poole and Safko : Classical Mechanics – Addison Wesley / Narosa.
2. Landau and Lifshitz : Mechanics – Pergamon.
3. Sommerfeld : Mechanics – Academic Press.
4. Rana and Joag : Classical Mechanics – Tata McGraw Hill.
5. Whittaker : Analytical Dynamics of Particles and Rigid Bodies – Cambridge.
6. Fetter and Walecka : Theoretical Mechanics of Particles and Continua – McGraw Hill.
7. Raychaudhuri : Classical Mechanics – Oxford.
8. Simmons: Differential Equations.
9. Bhatia: Classical Mechanics – Narosa.

Group B : Statistical Mechanics II

Marks : 20 **No. of Lectures – 20**

1. Real Gas: Free energy; virial equation of state; second virial coefficient and Joule-Thomson expansion; inversion temperature; model calculation and van der Waal's equation of state. (2)
2. Strong Electrolyte: Debye length; Debye – Hueckel theory, screened Coulomb potential; equation of state and osmotic pressure. (3)
3. Quantum Statistics : Fermi and Bose distributions; quantum gas not in equilibrium; quantum gases of elementary particles; number density and chemical potential; energy density, equation of state and different thermodynamic quantities; relativistic quantum gas; black body radiation and Planck's law; degenerate Bose gas; lattice specific heat and phonons; Bose condensation and super fluidity; quantum liquid with Bose-type spectrum – example of *liquid He*; degenerate Fermi gas; degeneracy pressure; specific heat of degenerate Fermi gas; Riemann's $\xi(z)$ and integrals of quantum statistics : relativistic degenerate electron gas; high temperature dense matter; white dwarfs and neutron stars. (12)
4. Phase Transitions: Liquid–gas, order-disorder, ferroelectric, ferromagnetic transitions, critical points; Ehrenfest's classification; order parameter; continuous and discontinuous transitions; Landau's theory of continuous transitions; continuity of entropy; discontinuity of specific heat; singularities of order parameter and partition function; generalized susceptibility; mean field theory; critical exponents; scaling and fluctuations of order parameter. (3)

Reference Books :

1. Landau and Lifshitz : Statistical Mechanics – Pergamon
2. Toda, Kubo and Saito : Statistical Physics – Springer Verlag
3. Reif : Fundamentals of Statistical and Thermal Physics – McGraw Hill
4. Pathria : Statistical Mechanics – Pergamon
5. Ma : Statistical Mechanics – World Scientific
6. Huang : Statistical Mechanics – John Wiley

Unit 7

Full Marks : 50

Mathematical Methods II **No. of Lectures – 50**

1. Integral Transforms : Definitions; complex Fourier transform – analytic properties; Parseval's theorem and convolution theorem; complex Laplace transforms; applications. (3)

2. Boundary Value Problems and Green's Functions : Classification of second order partial differential equations-elliptic, parabolic and hyperbolic equation; Method of characteristics. Inhomogeneous differential equation ; homogeneous differential equation, different type of boundary conditions (Dirichlet, Neuman and Cauchy Problem), Methods of solution of second order partial differential equations: Separation of variables, eigenfunction expansion, integral transform method.

   Green's Functions – definition and properties (for self adjoint differential operators only); computation of Green's function – direct computation, eigenfunction expansion, integral transform method. Standard equations like Laplace and Poisson equations, diffusion equation, Helmholtz equation, wave equation etc. (10)

3. Tensors : Coordinate transformation, Jacobian determinant, definition of tensors; contravariant, convariant and mixed tensors; tensor algebra, Riemannian Geometry, signature requirement, metric tensor associated tensors, parallel transport, covariant differentiation, Christoffel symbols; Geodesics, Riemann – Christoffel curvature tensors, Bianchi identity, Ricci tensor, vanishing of the curvature tensor as a condition of flatness. Gradient, divergence, curl and Laplacian in terms of tensors. (10)

4. Special Theory of Relativity: Relativistic Mechanics : Lorentz transformations and classifications; transformation of velocities; 4-vectors; 4 dimensional velocity and acceleration, Principle of least action; energy and momentum; 4-momentum and 4-force; covariant equations of motion; energy-momentum tensor and conservation

laws; decay of particles; transformation of cross sections; elastic collision of particles; angular momentum. (8)

Electromagnetism : 4 vector potential, invariance of electric charge, electromagnetic field tensors, Covariance of Maxwell's equations, transformation of electromagnetic fields, invariants. Energy momentum-stress tensor of electromagnetic fields and Lorentz force. Covariant Lagrangian formulation of particle mechanics in presence of electromagnetic fields. (8)

4. Introduction to General Relativity : Need for a non-euclidian geometry to represent gravitation, Principle of general covariance and equivalence; Einstein's field equations; Einstein-Hillbert action, Linearized equation for a weak field. Schwarzschild solution; Birkoff's theorem, Crucial tests : Bending of light, Perihelion motion of Mercury, Gravitational red shift. (6)

Cosmology: observational evidence (Hubble expansion, Abundance of lighter elements, cosmic microwave background radiation), Observable quantities like red shift (z), apparent magnitude (m), angular diameter (θ) and source counts (N). Cosmological principle, Elementary discussion of standard cosmology, FRW model. (5)

Reference Books :

1. Sokolnikoff : Tensor Analysis – Wiley Toppan
2. Lass : Vector and Tensors – McGraw Hill Kogakusha
3. Joshi : Matrices and Tensors – New Age International
4. Landau and Lifshitz : Classical Theory of Fields - Pergamon
5. Adler, Bazin and Schiffer : Introduction to General Relativity – McGraw Hill Kogakusha
6. Bergmann : Theory of Relativity – Prentice Hall.
7. Churchill : Complex Variables and Applications – McGraw Hill Kogakusha
8. Sneddon : Special Functions of Mathematical Physics and Chemistry - Longmans
9. Senddon : Introduction to the Theory of Partial Differential Equations – McGraw Hill Kogakusha
10. Hildebrand : Advanced Calculus for Applications – Prentice Hall.

Unit 8

Classical electrodynamics II

Full Marks 30 **No of lectures 30**

1. Non-stationary system:

a) Faraday's law; energy in the magnetic field; displacement current; Maxwell's equations; Faraday's law in moving medium; Maxwell's equations in moving medium; Lorentz force; conservation of momentum and energy – Poynting's theorem; Maxwell stress tensor; scalar and vector potentials; gauge transformations – Lorentz gauge and Coulomb gauge; the inhomogeneous wave equation; Green's function for the wave equation; retarded and advanced solutions. (5)

b) Fields and radiation of a localised oscillating source; multipole expansion of the scalar and vector potentials; radiation fields; electric and magnetic dipole and electric quadrupole fields; Hertz potential. (5)

c) Lienerd – Wiechert potentials and the fields of a uniformly moving charge; convection potential and virtual photons. (4)

d) Radiation from an Accelerated Charge : Fields of an accelerated charge; angular and frequency distributions of the emitted radiation; special cases of acceleration-parallel and perpendicular (circular orbit) to velocity; Larmor's formula and its relativistic generalisation; bremsstrahlung; Cerenkov radiation; radiation reaction; electromagnetic mass. (7)

e) Scattering : Radiation damping; scattering by a free electron; scattering and absorption of radiation by a harmonically bound electron; scattering from a system of charges – coherent and incoherent Bragg diffraction. (5)

2. Magnetohydrodynamics and Plasma Physics: Conducting fluid in a magnetic field; freezing in of lines of force; MHD equations; magnetic pressure; pinch effect; Alfven waves; plasma oscillations; screened potential and Debye length. (4)

Reference Books :

1. Jackson : Classical Electrodynamics – John Wiley
2. Panofsky and Phillips : Classical Electricity and Magnetism – Addison Wesley
3. Griffiths : Introduction to Electrodynamics – Prentice Hall India
4. Schwinger : Classical Electrodynamics – Perseus Books
5. Stratton : Electromagnetic Theory – McGraw Hill
6. Landau & Lifshitz : Classical Theory of Fields - Pergamon
7. Landau & Lifshitz : Electrodynamics of Continuous Media - Pergamon
8. Chandrasekhar : Plasma Physics – Chicago University Press.

Group B : Electronics II

Full Marks 20 **Lectures 20**

1. Network Analysis : constant *k* and *m* derived low pass; band pass and band elimination filters (4)
2. MOSFET; principle of operation; CMOS, VMOS biasing and equivalent circuit; source follower; FET parameters; low frequency CS and CD amplifiers. Qualitative ideas about LED, semiconductor LASER, and P-i-N Photo detector (4)
3. Noise: Different sources of noise; signal to noise ratio; definition and calculation of noise figure. (3)
4. Frequency Modulation and Detection : Frequency spectrum; bandwidth; reactance tube and p-n junction methods of generation of FM waves; Armstrong system; demodulation by staggered, tuned and Foster Seely discriminator circuits. Concept of Pulse Modulation. (5)
5. Television : Basic principles; TV systems and standards; scanning and display systems; TV cameras – image orthicon, vidicon; picture tubes (B/W and colour); composite video signal (including colour signal); black & white and colour receivers (block diagrams); ideas of common video and sound circuits; synchronising circuits; vertical and horizontal deflection circuits; bandwidth requirements and TV transmission channels; basic idea of colour television system. (4)

Reference Books :

9. Van der Ziel : Solid State Physical Electronics – Prentice Hall India
9. Millman and Taub : Digital and Switching Waveforms – McGraw Hill Kogakusha
9. Taub and Schilling : Digital Integrated Electronics – McGraw Hill Kogakusha
9. Millman and Halkias : Integrated Electronics – McGraw Hill Kogakusha
9. Ryder: Networks, Lines and Fields—Prentice Hall India
9. Jordan and Balmain : Radiation and Radiating Systems – Prentice Hall India
9. Grob: Basic Television- McGraw Hill Kogakusha
9. Sarkar: Microwave Propagation and Technique –S. Chand

Unit 9

Full Marks : 50

Quantum Mechanics II **No. of Lectures – 54**

9. Symmetries :

a) Symmetry operations as unitary and anti-unitary transformations; continuous symmetries and groups; generators; conservation laws from invariance principles Discrete Symmetries : space reflection, inversion and parity; intrinsic parity; time reversal; Wigner's definition; Kramer's degeneracy. (6)

b) Space translations; time displacements. Application of symmetry arguments to derivation of selection rules and degeneracy. Break up of $\Lambda^0 \rightarrow p + \pi^-$ illustrating the use of conservation of angular momentum (6)

2. Three Dimensional Potential Problems : Central potential; separation of variables; eigenfunctions and eigenvalues; angular part solution; radial pat solution; rigid rotator; free particle; spherical oscillator; hydrogen problem; charged particle in a magnetic field – Landau levels. (7)

3. Scattering Theory : Scattering amplitude; differential and total cross-sections; spherically symmetric potentials – partial wave analysis; elastic and absorption cross-sections; phase shift – its evaluation, Born approximation; simple examples; hard sphere scattering; Integral equation for scattering; (10)

9. Approximation Methods :

a) Variational method for stationary state problems : simple applications. (4)

b) Degenerate and non-degenerate stationary state perturbation Theory: Examples and applications; (6)

9. Time dependent Perturbation theory: Transition amplitude, constant and harmonic perturbations; Fermi's golden rule; simple examples; time energy uncertainly. (6)

e) Adiabatic and sudden approximations disturbed harmonic oscillator. (4)

5. Path integral formulation of quantum mechanics (elementary level), Geometric phase, Aharonv-Bohm effect (5)

Reference Books :

1. David Griffiths: Introduction to Quantum Mechanics, Pearson Education.
2. Schiff : Quantum Mechanics – McGraw Hill Kogakusha.
3. Merzbacher : Quantum Mechanics – John Wiley.
4. Sakurai : Modern Quantum Mechanics – Addison Wesley.
5. R P Feynman: lectures on Physics Vol. 3, Narosa.
6. Schwabl: Quantum Mechanics , Narosa.
7. Bransden and Joachain : Introduction to Quantum Mechanics – Longmans.
8. Landau and lifshitz : Quantum Mechanics – Pergamon.
9. Davydov : Quantum Mechanics – Pergamon.
10. Gasiorowicz: Quantum Physics, John Wiley.

Unit 11

Full Marks : 90

Group A : Condensed Matter Physics
Marks : 54 **No. of Lectures : 64**

1. Structure of Solids : Crystalline and Amorphous States :

   a) Crystal Structure: Periodic arrays of atoms; crystal symmetry; fundamental types of lattices; simple crystal structures.

   b) Crystal diffraction : Bragg's law; experimental diffraction methods; Laue derivation of amplitude of scattered wave; Laue diffraction; reciprocal lattices; Brillouin zones; geometrical structure; atomic form factor.

   c) Imperfections in solids; point defects and line defects; defect concentration; disorder. (10)

2. Lattice Stability and dynamics :

   a) Crystal Binding: various mechanisms of bindings in solids; cohesive energy; criteria of structural stability.

   b) Lattice Vibrations: harmonic approximation; vibration of monoatomic and diatomic linear lattices; dispersion relations and normal modes; quantisation of lattice vibration and phonons; determination of force constants from experimental dispersion relations; anharmonic crystal interactions and thermal expansion (qualitative discussion only). (8)

3. Electron States and Band Theory : Free electron theory; periodic boundary condition; electron in periodic potential; Bloch theorem; Kroening Penney model; formation of energy bands; nearly free electron and tight binding approximations; concepts of hole and effective mass; density of states; energy bands in reduced zones; Fermi surface; explanation of electronic behaviour of metals, semiconductors and insulations. (8)

4. Transport Properties : Boltzmann transport equation; electrical conductivity of metals and alloys; thermal conductivity of metals and insulators; Wiedemann – Franz's law; isothermal Hall effect;

   de Hass van Alphen effect; cyclotron resonance.

Superconductivity: Experimental facts and qualitative explanations; thermodynamics and electrodynamics of superconducting transitions; penetration depth; type I and type II superconductors; flux quantisation; Josephson effect, (10)

5. Semiconductors : Intrinsic and extrinsic semiconductors; carrier mobility; lifetime and diffusion of minority carriers. (4)

6. Magnetic Properties of Solids : Dia-and paramagnetism of solids; ferromagnetism; exchange interactions; magnetic anisotrophy and energy; domains; thickness and energy of domain walls.

   Antiferromagnetism; ferrimagnetism; solids in alternating magnetic fields, relaxation mechanism; elementary discussion on magnetic resonance; nuclear magnetic resonance and simple applications (12)

7. Optical and Dielectric Properties of Solids : Luminiscence; decay machanisms; thermoluminiscence; thalium activated alkali halides; colour centres; excitons; photoconductivity; dielectric solid in static and alternating electric fields; losses; relaxation times; Ferroelectricity – different models and thermodynamic treatment of phase change.

   Thermo-electricity; electrets. (12)

Reference Books :

1. Aschroft and Mermin : Solid State Physics – Saunders
2. Kittel : Introduction to Solid State Physics – John Wiley
3. Azaroff : Introduction to Solids – Tata McGraw Hill
4. Dekker : Solid State Physics - Macmillan
5. Epifonov : Solid State Physics – MIR
6. Bhattacharyya : Solid State Physics – Calcutta Book House
7. Srivastava : Elements of Solid State Physics – Prentice Hall India
8. Pillai : Solid State Physics – New Age International
9. Keer : Principles of Solid State – Wiley Eastern

Group B : Atomic and Molecular Spectroscopy

Marks : 36 **No. of Lectures – 36**

1. Atomic Spectroscopy :

a) One Electron Atom : Hydrogen spectrum; spectral series limit and term values; Ritz combination principle; summary of Bohr-Sommerfeld model; semi-classical treatments of relativistic corrections and spin – orbit interaction; Thomas correction; non-relativistic limit of Dirac equation; existence of intrinsic spin and anomalous magnetic moment; Dirac – Coulomb problem; relativistic spin-orbit and Darwin terms; correction to Bohr – Sommerfeld term values; fine structure constant; Lamb – Ratherford splitting; evaluation of integrals $<1/r^k>_{nl}$; features of alkali spectrum; doublet structure; Born – Heisenberg approximation; induced dipole field; quantum defects – Rydberg and Ritz terms; X-ray spectrum and screening. (5)

b) Semi-classical treatment of emission and absorption of radiation by atomic systems; Einstein's *A* and *B* coefficients; selection rules. (2)

c) Many Electron Atoms : Schroedinger equation for many electron system; central field approximation; product function and Hartee equation; Pauli exclusion principle; Slater determinant; Hartree Fock approximation; exchange integral; Koopman's theorem, Aufbau principle and the periodic table, Electronic configuration; multiplicity of terms; Russel – Saunders coupling; Hund's rule; Lande's interval rule; j – j coupling; Lande's *g* factor, Thomas – Fermi approximation. (7)

d) Atoms in External Electric and Magnetic Fields: Zeeman and Paschen Back effects; Stark effect in hydrogen. Electron – Nucleus Interaction : Effect of nuclear spin; hyperfine structure of atomic spectrum; ^{133}Cs clock. (3)

2. Molecular Structure and Spectra :

a) Adiabatic approximation and separation of electronic and nuclear motions; Hund-Mulliken and exchange integral; covalent bond of homonuclear molecules; hybridization and directed valence bond of carbon. (3)

b) Electronic terms in molecules; relation between atomic and molecular terms. Vibrational and rotational structures of singlet terms in diatomic molecules; anharmonicity and rotation – vibration coupling; angular part of a singlet wave function for a diatomic molecule; multiplet structures in diatomic molecules and Hund's schemes; symmetry of molecules; $\wedge$ doubling. (5)

c) Rotational Energy Levels : Quantisation of rotation of a rigid body; rotational spectrum and bond length measurements; rotation – vibration spectrum; Deslander's formula and electronic spectrum; Frank – Condon principle; Condon parabola; Fortrat diagram – *P*, *Q* and *R* branches; band head; fine structure.

Fluorescence and phosphorescence; photodissociation; Raman spectrum. (6)

3. LASER :Basic principle of laser; interaction of atomic system and radiation – density matrix of 2-level systems; atomic susceptibility; line shape; saturation; spontaneous and induced transitions; gain coefficient; homogeneous and inhomogeneous broadening; beam stability; optical resonators and resonance frequency; oscillation condition; threshold inversion; oscillation frequency; power output, Specific Laser Systems : Ruby laser; Nd-glass laser; Nd^{3+} : YAG laser; He-Ne laser; CO_2 laser; semiconductor diode laser; quantum well laser; free electron laser. (5)

Reference Books :

1. Bransden and Joachain : Physics of Atoms and molecules – Longmans.
2. Condon and Odabasi : Atomic Structure – Cambridge.
3. Condon and Shortley : Theory of Atomic Spectra – Cambridge.
4. Bethe and Salpeter: Quantum Mechanics of One and Two Electron Atoms – Springer Verlag.
5. Slater : Quantum theory of Molecules and Atomic Structure, Vols. I and II – McGraw Hill.
6. Slater : Quantum Theory of Molecules and Solids, Vol. I – McGraw Hill.
7. Landau and Lifshitz : Quantum Mechanics – Non-relativistic theory –Pergamon.
8. Berestetskii, Lifshitz and Pitaevski : Relativistic Quantum Theory – Pergamon.
9. Davydov : Quantum Mechanics – Pergamon.
10. Yariv : Quantum Electronics – John Wiley.
11. Ghatak : Laser Physics – Tata McGraw Hill.
12. Lengyel : Lasers – Wiley Interscience.
13. Svelto : Principles of Laser – Plenum Press.

Unit 12

Full Marks : 90

Group A : Nuclear Physics
Marks : 54 **No. of Lectures – 54**

1. Nuclear Systematics :
   a) Mass; charge; binding energy; separation energy. (2)
   b) Nuclear Size : electron scattering and form factors charge density radius and potential radius, Woods-Saxon potential, experimental methods of determination (4)
   c) Static Electric and Magnetic Moments of a Nucleus; magnetic dipole and electric quadrupole moments; Schmidt limits; anomalous magnetic moments of nucleons and qualitative discussions about their origin; (3)
2. Two Nucleon System :
   a) Bound State Problem : Relative stability of the *n-n*, *n-p*, and *p-p* systems; gross properties of the deuteron; deuteron problem with a spherical well – ground and excited states; electric quadrupole and magnetic moments of the deuteron – experimental values and the presence of non-central forces. (5)
   b) Scattering Problem : *n-p* scattering at low energies; partial wave analysis; effective range formula and scattering length – shape independent approximation; modification of effective range for deuteron bound state; scattering by hard sphere and finite square-well potential. (5)

      p-p scattering at low energies; identity of particles – antisymmetrisation of wavefunction; comparison with *n-p* scattering; interference between nuclear and Coulomb forces; effective range. (3)

      nn scattering; charge-independence and charge symmetry, isotope spin and isobaric analog states – mirror nuclei, exchange forces and saturation, repulsive core. (3)
3. a) Structure of Complex Nuclei : Nuclei with Mass Number lying between 3 and 5 – qualitative discussions about ground state and stability; Many body theory – two and

three nucleon cases considering one-nucleon and two-nucleon symmetric operator; the need for nuclear models. (3)

b) Liquid Drop Model: properties of the model; the semi-empirical mass formula and its application to considerations of nuclear stability, Degenerate Fermi Gas Model – applications. (4)

c) Shell Model: Evidence of shell structure; magic numbers; effective single particle potentials – square-well, harmonic oscillator, Wood-Saxon with spin orbit interaction; extreme single particle model – its successes and failures in predicting ground state spin, parity and electro-magnetic moments. (5)

d) Collective Model : Evidence of collective motion; nature of vibrational and rotational spectra – qualitative discussion in term of phonons and rigid rotators, illustrated with examples. (12)

4. Nuclear Reactions: Classification; conservation principles; kinematics and Q-values; exo-ergic and endo-ergic reactions; threshold energy, Experimental set ups; cross-sections-elastic, inelastic, reaction, total; principle of detailed balance;

Compound Nuclear Reactions : characteristics; resonance and compound nucleus formation; one level Breit – Wigner formula;

Direct Reactions: characteristics; types of direct reactions with examples – elastic, inelastic, transfer, stripping, pick-up, knock-on and break-up reactions (qualitative discussion with example). (7)

5. Nuclear Disintegrations :

a) Nuclear Emission: Penetration of potential barrier; nature of barrier for neutrons, protons and alpha particles; Gamow's theory of alpha disintegration and calculation of reduced widths and decay half -lives. (3)

b) Nuclear Fission: Liquid drop model and nuclear stability; spontaneous and induced fissions; elementary discussion of Bohr-Wheeler theory; barrier penetration and decay rates in fission; mass distribution of decay products; fission isomers (4)

Reference Books :

1. M. K.Pal : Theory of Nuclear structure (EWA press)
2. Cohen : Concepts of Nuclear Physics – Tata McGraw Hill
3. Bethe and Morrison : Elementary Nuclear Theory – John Wiley
4. Wong : Introductory Nuclear Physics – Prentice Hall
5. Elton : Introductory Nuclear Theory – Wiley Inter-science
6. Fermi : Nuclear Physics – Chicago University Press
7. Blatt and Weiskopff : Theoretical Nuclear Physics – Dover
8. Evans : The Atomic Nucleus – McGraw Hill.
9. Roy and Nigam : Nuclear Physics –New Age International
10. S. N. Ghoshal : Nuclear Physics-S Chand Publication
11. Preston :Physics of the Nucleus: Addision Wesley

Group B : Elementary Particles and Interactions

Marks : 36 **No. of Lectures – 40**

1. **Introduction** : Implications of Relativity : Particle creation and annihilation; relativistic wave equations (no derivation); antiparticles, spin etc. Types of Interaction in Nature – strong, electromagnetic, weak and gravitational; existence of first three types of interaction in nuclear phenomena; possible exchange mechanisms; Yukawa's prediction; typical strengths, coupling constants, lifetimes, reaction cross-sections. Discovery of the positron, muon, pion, neutrino and other particles (including strange particles, heavier hadrons and leptons); modern methods of producing particles. (5)

2. Relativistic Kinematics and Phase Space; centre of mass and laboratory frames of reference; colliding beams; Lorentz invariants and Mandelstamm variables; energy, momentum and angular momentum conservation; collision and decay kinematics; threshold energies for particle production; phase space; cross-section and decay formulae. (5)

3. Symmetries, Conservation laws and Quantum Numbers : General features of conservation laws – conservation laws and invariance; quantum numbers; space reflection invariance and parity; intrinsic parity; charge conjugation and charge parity; charge independence and isospin conservation – branching ratios in reactions and decay processes; pion-nucleon scattering amplitudes; time reversal invariance and the principle of detailed balance; CPT theorem (statement only) and its consequences; electric charge, isospin and G-parity; strangeness; Gell-Mann Nishijima formula; charm, beauty and truth; baryon number, lepton number and muon number conservation; hypercharge; universal symmetries and restricted symmetries. (8)

4. Particles and Resonances : Classification into hardrons and leptons, baryons and mesons, Properties of Charged Pions amd Muons – decay modes; measurement of charge, spin, parity, charge parity and G-parity; lifetime of pions and muons, General

Experimental Methods of determination of mass, spin, parity and other quantum numbers of other particles (Principles only). (6)

5. Strong Interactions and Hadrons :

a) Hadron Structure : Quark model (group theoretical discussion not needed); experimental evidence (detailed mathematics not needed); quark structure of baryons and mesons; prediction of Ω^- ; mass formula and mixing; baryon and meson resonances – orbital excitation model; quarkonium; consequences of the quark model – spin, mass, magnetic moment of hadrons; Zweig's rule; Pauli principle and the colour of quarks, Strong Interaction : Nature of strong interaction; gluons as mediators in quark-quark interaction. (6)

6. Weak Interactions : Phenomenology – conservation laws and selection rules in weak decays, Nuclear Beta Decay : Fermi theory and Kurie plot; log *ft* values classification and selection rules; decay rates in electron capture, Muon Decay : Different types of neutrinos; experimental verification, Parity Violation : Decay of K^+, the tau-theta puzzle; nuclear beta decay of ^{60}Co; role of neutrino in parity non-conservation; V-A interaction, Neutral *K* decays – CP eigenstates; regeneration phenomena; CP violation experiment and consequences; Strangeness oscillation, Z, W^- and W^+ as mediators of weak interaction; discovery and properties of these particles. (6)

7. Electromagnetic Interactions :

Conservation Principles; the photon as the mediator; the electromagnetic field as a gauge field; the QED Lagrangian; brief discussion on experimentally verifiable predictions of the QED. (2)

Nuclear Gamma Emission: Multipole transitions and selection rules; lifetimes; internal conversion. (2)

Reference Books :

1. Griffiths : Introduction of Elementary Particles – John Wiley
2. Perkins : Introduction to Elementary Particle Physics – Addison Wesley/Cambridge
3. S. N. Ghoshal : Nuclear Physics-S Chand Publication
4. Hughes : Elementary Particles – Cambridge
5. Blatt and Weiskopff : Theoretical Nuclear Physics – Dover.

Unit 13

Full Marks : 90

Group A : Quantum Mechanics
Marks : 54 **No. of Lectures – 54**

1. Advanced Scattering Theory :

a) Formal Theory of Scattering : Potential scattering; Green's functions; Lippmann Schwinger equations; in and out states; S and T Matrices; cross section and decay formulae; decomposition of S matrix into angular momentum states for spherically symmetric potentials and connection with phase shifts.

Coulomb scattering; spherical and polar coordinates; Rutherfords formula; form factor.

Scattering of identical particles; effect of polarisation; collision between identical charged particles; Mott's formula. (12)

2. Relativistic Formulation of Quantum Mechanics of Single Particles :

a) Quantum Mechanics and Relativity; historical background; relativistic notation (2)

b) Klein – Gordon equation : continuity equation and indefinite norm; free particle solutions; negative energy – momentum solutions and their interpretation, non-relativistic reduction and the interpretation of the Klein – Gordon equation (also in presence of weak slowly varying electromagnetic fields); spin of the K – G particle; invariance properties. (6)

d) Dirac equation; the Dirac Hamiltonian for free particles; symmetric form of Dirac equation; gamma matrices – their different representations and properties; the conjugate Dirac equation; continuity equation; non-relativistic correspondence; spin; helicity and magnetic moment of the Dirac particle.

Lorentz covariance for the Dirac particle; space reflection; parity; bilinear covariants;

Free particle solutions and their interpretation; wave packets; Klein paradox and zitterbewegung; negative energy solutions and hole theory; positron; charge conjugation; time reversal and other symmetries.

Particles of zero mass; two component theory; the neutrino and its helicity. (12)

3. Quantum Mechanics of Fields and Many Particle Systems (Second Quantisation);

a) Identical Particles; Bosons and Fermions; symmetric and antisymmetric many body wavefunctions.

Method of Second Quantisation :Lagrangian formalism; Noether's theorem; invariance under transformations and operator requirements; quantisaton of a field obeying Schroedinger's equation; quantum conditions for boson and fermion fields; occupation number representation and Fock space; method of writing one and two body operators in the second quantised notation. (7)

b) Quantisation of Klein-Gordon Field : single component free Hermitean scalar field; plane wave and spherical wave decompositions; energy, momentum and displacement operators; symmetry of states; non-hermitean scalar field; charge operator; particles and antiparticles. (4)

c) Quantisation of Dirac Field : Plane wave representation; quantum conditions; energy and momentum operators; positivity of energy; current and charge operators-symmetrisation. (5)

d) Quantisation of the Electromagnetic Field : Maxwell's equations and the electromagnetic field tensor; quantisation in the radiation gauge; transverse photon. (4)

e) Interacting Fields : Brief discussion; quantised electromagnetic field interacting with a classical source. (2)

Reference Books :

1. Schiff : Quantum Mechanics – McGraw Hill Kogakusha
2. Merzbacher : Quantum Mechanics – John Wiley
3. Davydov : Quantum Mechanics - Pergamon

4. Baym : Lecture Notes on Quantum Mechanics – Benjamin
5. Schweber : Relativistic Quantum Field Theory – Harper and Row
6. Bjorken and Drell : Relativistic Quantum Mechanics – McGraw Hill
7. Bjorken and Drell : Relativistic Quantum Fields – McGraw Hill
8. Muirhead : Physics of Elementary Particle –Pergamon
9. Greiner : Relativistic Quantum Mechanics – Springer.
10. Ghatak and Lokanathan : Quantum Mechanics, Theory & Applications – Macmillan.

Group B : Electronics
Marks : 36 **No. of Lectures – 36**

1. Digital Circuits and Systems : Exclusive OR gate, half adder; full adder, decoder, encoder; bistable latch, flip-flops; SR, JK, Master slave; shift registers; counters; digital to analog converter; summing and R-2R ladder type, analog to digital converter; counting and tracking; ROM; RAM. (10)
2. Elements of Microprocessors : Basic concepts; block diagram of 8085; instruction set; memory interfacing; timing diagram; idea of assembly language programming. (10)
3. Transmission Lines, Waveguides and Microwaves : Parallel wire and coaxial lines; transmission line equation; characteristic impedance; propagation constant; lossy lines; high frequency transmission lines; travelling wave interpretation; VSWR : open and short circuit impedance; principle of stub line matching; directional coupler.

   Parallel plane waveguide; rectangular waveguide; waveguide modes; resonant cavities; microwave oscillators; reflex klystron; magnetron. (10)
4. Antenna and Rader Systems :
   a) Antenna : Basic consideratons; antenna gain; resistance, bandwidth and beamwidth. (4)
   b) Radio method Detection and Ranging; pulse radar; range equation; transmitting and detection systems – block diagrams; duplexer; radar wave propagation; radar targets; radar cross section. (2)

Reference :

1. Millman and Grabel : Microelectronics – McGraw Hill.
2. Millman : Microelectronics – McGraw Hill.
3. Ryder : Networks, Lines and Fields – Prentice Hall India.
4. Malvino and Leach : Digital Principles and Applications – Tata McGraw Hill.
5. Terman : Electronic and Radio Engineering – McGraw Hill.
6. Jordan and Balmain : Radiation and Radiating Systems – Prentice Hall India.

7. Grob : Basic Television – McGraw Hill Kogakusha.
8. Kraus : Antenna – McGraw Hill.
9. Reich, Ordnung and Skalnick : Microwave Principles – Affiliated East West Press.
10. Sarkar : Microwave Propagation and Technique – S. Chand.
11. Ram : Fundamentals of Microprocessors and Microcomputers – D. Rai and Sons.
12. Rafiquazzaman : Microprocessors – Prentice Hall India.
13. Malvino : Digital Computer Electronics – Tata McGraw Hill.

Unit 14

Grand Viva

Full marks : 30

Grand Viva to be conducted by the Department. At least one external examiner should be appointed for the Grand-Viva. Students may be asked questions from any part of the syllabus covering Unit-11 to Unit 13. However, any relevant question outside the before mentioned syllabus may also be asked.

Unit 15

Electronics Special
Paper I
Full Marks : 50

No. of Lectures – 50

Group A : Semiconductor Devices

1. Tunnel Diode : Effects of high doping; degenerate semiconductors, energy band diagrams of a tunnel diode in equilibrium and under different types of biasing conditions; current-voltage characteristics; tunneling current; excess current and thermal current; equivalent circuit and input impedance. (6)

2. Solar Cells, Photo detectors and light emitting diodes : Advantages of using solar energy, principle of operation of a p-n junction solar cell; equivalent circuit; energy band diagram; I-V characteristics; open-circuit voltage, short-circuit current; fill factor, efficiency; solutions of continuity equation, spectral response, limitations of a solar cell and methods of improvement of its performance, construction and principle of operation of photodiode detectors. Direct and indirect band gap semiconductors, LED materials, construction and principle of operation of LED (6)

3. IMPATT Diode and Gunn diode: Principle of operation of an IMPATT diode; injection phase delay and transit time effect; small signal analysis; equivalent circuit of the avalanche region; impedances of the avalanche region and the drift regions. Principle of operation of a Gunn diode. (7)

4. Quantum Semiconductor Structures : Ideal low-dimensional systems, free electrons in three dimensions, ideal two-dimensional electron gas, ideal zero and one-dimensional electron gases, quantum wells, wires and dots. Ideal hetero-junction. Super lattices and multi-quantum-wells, doping super lattices. (6)

Group B : Quantum and Opto-electronics, Networking

1. Semiconductor Physics : Anisotropy of physical properties of single crystals; relaxation time; magnetic-resistance; Hall effect; thermoelectric power; photoconductivity;. (6)

2. Quantum Electronics : Spontaneous and stimulated emission of radiation; Einstein's coefficients; LASER rate equation and lasing condition; He-Ne and Carbon dioxide LASERS; Q-switching; semiconductor lasers in IR and visible ranges. (8)

3. Opto-electronics : Classification and fabrication principles of optical fibres; single mode and graded index fibres; WKB analysis; transmission losses; fibre characteristics; basic principles of optical fibre communications. Digital optics and optical computation (idea only). (6)

4. Computer Networking : Principle of computer networks; circuit switching; message switching; packet switching; protocols; CSMA, ALOHA, SLOTTED ALOHA; seven layer protocol; network topologies; star; ring; bus; tree; local area network; internet. (5)

Reference Books :

1. Sze : Physics of Semiconductor Devices – Wiley Interscience.
2. Grove : Physics and Technology of Semiconductor Devices – Prentice Hall India.
3. Streetman : Solid State Electronic Devices – Prentice Hall India.
4. Smith : Semiconductors – Cambridge.
5. Dekker : Solid State Physics – Macmillan.
6. Holland : Vacuum Deposition of Thin Films – Chapman and Hall.
7. Chopra : Thin Films – McGraw Hill.
8. Lengyel : Introduction to Laser Physics – Wiley Inter-science.
9. Ghatak : Laser Physics – Tata McGraw Hill.
10. Kao : Optical Fibre Systems – Technology and Design – Tata McGraw Hill.

11. Gower : Optical Communication Systems – Prentice Hall India.
12. Keiser : Optical Fibre Communications – Tata McGraw Hill.
13. Senior : Optical Fibre Communication – Prentice Hall India.
14. Gandhi : Theory and Practice of Microelectronics – John Wiley.
15. Bornham and Vvedensky (Editors) : Low-Dimensional Semiconductor Structures – Cambridge University Press.
16. Mitin, Kochelap and Stroscio : Quantum Heterostructures – Cambridge University Press.
17. Hovel : Solar Cells (Semiconductors & Semimetals, Vol.II) – Academic Press.
18. Green : Solar Cells - Operating Principles, Technology and System Application – Prentice Hall.

Unit 15

Nuclear and Elementary Particle Physics Special

Paper I

Full Marks : 50 **No. of Lectures – 56**

1. Two Body Interactions :

a) Scattering: Spin dependence of the interaction - singlet and triplet scattering lengths; coherent scattering from ortho and para-hydrogen; singlet state of the deutron; high energy np, pp, nn scattering; Serber force and Jastrow's idea of repulsive core, exchange forces and saturation. (6)

b) Deutron problem: Electric quadrupole and magnetic moments of the deutron – detailed analysis with intrinsic wave function; Tensor force and the Rarita – Schwinger equations. (4)

c) Pion-Nucleon Interaction : Scattering of particles with zero with spin; density matrix; polarization; pion-nucleon interaction – baryon resonance with strangeness; spin dependence in π-N scattering. (5)

2. Nuclear Shell model : Residual interaction – single particle model and individual particle model; justification of Nordheim's rule; configuration mixing; anti-symmetrization of wave functions – two and three nucleons in unfilled shell; coefficients of fractional parentage.

Pairing interaction and its effects.

Electromagnetic transition in the Shell model. (9)

3. Collective Model : Collective modes of motion – vibrational and rotational modes; Hamiltonian for collective model of a deformed nucleus and its separation into vibrational and rotational parts; β and γ-vibrations; rotation – vibration coupling; collective spectra of nuclei; back-bending; electromagnetic moments and transition rates in the collective model. (9)

4. Unified Model : Coupling of collective and individual particle modes; rotation – particle coupling – strong, weak and intermediate. Deformed core and Nilsson model. (5)

5. Neutron Physics and Reactor physics: Neutron sources and detectors, interaction of neutrons with matter, moderation of neutron , diffusion equation, Fermi age equation, thermal nuclear reactors, Four factor formula, critical criterion of a thermal reactor, spherical reactor. (8)

6. Interaction of charged particles with matter- ionization formula, range-energy relation ship, charged particle detectors, energy measurement and identification of charged particles (3)

   Interaction of electromagnetic radiation with matter, E-type and M-type multiple transitions, rate, selection rules, single particle transition (5)

   Internal conversion, coefficient and rate, internal pair creation, angular correction.

7. Nuclear Matter: Brueckners' theory , its success, modern developments. (2)

Reference :

1. Bethe and Morrison : Elementary Nuclear Theory – John Wiley
2. Sachs : Nuclear Theory – Addison Wesley
3. Preston : Physics of the Nucleus – Addison Wesley
4. Preston and Bhadury : Structure of the Nucleus – Addison Wesley
5. Pal : Theory of Nuclerar Structure – East West Affiliated Press
6. Bohr and Mottelson : Nuclear Structure, Vols. I and II - Benjamin
7. Greiner and Meruhn : Nuclear Models – Springer Verlag
8. de Shalit and Talmi : Nuclear Shell Theory – Academic Press
9. de Shalit and Feshbach : Theoretical Nuclear Physics, Vol. I – Academic Press.

Unit 15

Solid State Physics Special

Paper I

Full Marks : 50 **No. of Lectures – 54**

I) Group Theory -

1. Fundamental Ideas : Elementary concepts of group; symmetry transformations as elements of a group; multiplication table; group representation; reducible and irreducible representations; character table. (5)

2. Crystal Symmetry : Concepts of a point group; translational symmetry and space group (elementary ideas only); effect of symmetry on physical properties. (3)

II) Electron States in Solids :

1. Crystalline Solids : Pseudopotential approach; APW; OPW . (4)

2. Non-crystalline Solids : Electronic density of states; Green's function for single and two impurity states using tight-binding Hamiltonian; idea of Anderson localization; scattering diagrams; average t-matrix approximation and CPA. Vibration states and low temperature properties of non-crystalline solids. (3)

III) Lattice Dynamics :

1. Born – Oppenheimer approximation and separation of nuclear and electron motions; internuclear potentials; lattice Hamiltonian, harmonic approximation, cubic and quartic terms; force constants and their symmetries. (2)

2. Normal Modes and Frequencies : Examples of 1-d and 2-d lattices with nearest neighbour harmonic interaction; density of states for these cases; frequency spectra and their singularities; Kohn anomalies in phonon dispersion relation. (3)

3. Effects of Defects in Lattice Vibration : Rayleigh's theorem; local (defect) modes; qualitative change in frequency spectrum. (2)

4. Electron – Phonon Interaction : Interaction Hamiltonian in second quantised form; qualitative discussions on electron phonon interactions. (1)

IV) Magnetism :

1. Susceptibility of Non-interacting Systems; Landau diamagnetism and de Hass van Alphen effect; ideas of measurement of Fermi surface. (2)

2. Paramagnetism : Paramagnetic ion in crystalline electric field; paramagnetism of transition-metal ions and rare earth ions (van Vleck); Pauli spin paramagnetism. (2)

3. Idea of a Spin-Hamiltonian : dipole-dipole interaction; direct exchange, super exchange and double exchange; RKKY interaction. (2)

   Spin waves; spin wave dispersion for ferro – and anti-ferromagnetic ordering of spins on a chain; Holstein – Primakoff transformations. (3)

4. Static Susceptibility of Interacting Systems (Insulators); Localised moment and exchange Hamiltonian, mean field and random phase approximations; magnetic phase diagram, critical points and critical exponents. (4)

5. Static Susceptibility of Interacting Systems (metals) : Exchange enhancement of Pauli susceptibility. (2)

   Stoner criterion for onset of ferromagnetism; Hubbard model. (3)

6. Magnetic Impurity : Local moment formation and Anderson theory of dilute alloys; Kondo effect; quantum Hall effect. (3)

V) X-ray Scattering, Neutron Scattering, Mossbauer Effect :

1. X-ray Scattering : Debye – Waller factor; fundamental and superstructure reflection – determination of long range order paramenter. (2)

2. Neutron Scattering : Scattering cross-section; scattering from single nucleus, composite target and crystals; elastic and inelastic scattering; incoherent and coherent scattering; magnetic scattering of neutrons; scattering by ions with spin and angular momentum. (5)

3. Mossbauer Effect : Introduction to the theory; isomer shift; quadrupole splitting; magnetic hyperfine splitting. (3)

Reference Books :

1. Ashcroft and Mermin : Solid State Physics – Saunders.
2. Ibach and Luth : Solid State Physics – Narosa.
3. White : Quantum Theory of Magnetism – Springer Verlag.
4. Mattis : Theory of Magnetism, Vol, I – Springer Verlag.
5. Ziman : Models of Disorder – Cambridge.
6. Ziman; Principles of Theory of Solids – Cambridge.
7. Madelung : Solid State Physics – Springer Verlag.
8. Seitz and Turnbull : Solid State Theory, Vol. 1 – Academic Press.
9. Callaway : Quantum Theory of Solids, Vols. I and II – Academic Press.
10. Harrison : Solid State Theory - Tata McGraw Hill.
11. Azaroff : X-ray Crystallography – Academic Press.
12. Squires : Thermal Neutron Scattering – Cambridge.
13. Lovesey : Theory of Neutron Scattering – Cambridge.
14. Frauenfelder : Mossbauer Effect – Benjamin.
15. Chopra : Thin Films – McGraw Hill.
16. Mitin, Kochelap and Stroscio : Quantum Heterostructures – Cambridge.

Unit 16

Paper II

Electronics Special

Full Marks : 50 **No. of Lectures – 60**

Group A : Communication Fundamentals :

1. Antennas: Basic Considerations; antenna parameters; current distributions; short electric double; half wave dipole; longer antenna; effect of ground; image antenna; field strength at a point close to the antenna; microwave antenna and other directional antennas. (5)

2. Propagation of Radio Waves : Types : Ground and surface wave propagation; ionosphere's; virtual heights and critical frequencies of layers; propagation of radio waves through ionosphere; loss of energy in the ionosphere; skip distance and MUF; single hop and multi-hop transmission; Chapman's theory; influence of earth's magnetic field; Appleton – Hartree formula.

   Propagation of microwaves through space; environmental effects; radiometer; microwave radiation hazards. (10)

3. Digital Communication : Different forms of pulse modulation; time division multiplexing; digital signal; bit transmission and signalling rate; sampling theory and analysis; error probability and error check; UART and modem; electronic exchange. (5)

4. Satellite Communication : Principle of satellite communication; communication satellite link design; digital satellite communication; multiple access techniques; demand assignment control; speared spectrum technique; code division; satellite orbit and inclination; ideas of global communication network. (5)

Group B : Analog & Digital Circuits, Microprocessors and Computers

1. Advanced Analog and Digital Circuits : Comparators; regenerative comparator; function generator (sine, square and triangular), digital and analog multiplexer; voltage controlled oscillated oscillator; phase locked loop; successive approximation; parallel comparator and dual slope A/D converter; Karnaugh mapping and basic concepts of digital circuit design; idea of sequential circuit design; state diagrams. (7)

2. Microprocessors and Computer Fundamentals; Basic idea of a microprocessor; 8085 architecture; registers; flags; interrupts; instruction set; concepts of assembly language programming; machine cycles; timing diagrams; I/O ports; design concept of a simple system using 8085 μP fundamentals; memory segmentation; interrupt handling; simple features of other Intel processors up to the latest one. (22)

3. Digital Image Processing : Basic classes; image perfection; image sampling and quantisation; image scanning; image display and recording; image analysis and computer vision. (6)

Reference Books :

1. Kennedy : Electronic Communication Systems – Tata McGraw Hill
2. Taub and Schilling : Principles of Communication Systems – Tata McGraw Hill
3. Carlson : Communication Systems – Tata McGraw Hill
4. Haykin : Communication Systems – John Wiley
5. Rajaraman : Fundamentals of Computers – Prentice Hall
6. Balaguruswamy : Programming in C – Tata McGraw Hill
7. Bose : Hardware and Software of Personal Computers – New Age International
8. Tanenbaum : Computer Networks – Prentice Hall
9. Bertsekas and Gallagher : Data Network – Prentice Hall
10. Stallings : Data and Computer Communications – Prentice Hall
11. Gaekwad : Op-amps and Linear Integrated Circuits – Prentice Hall India
12. Gaonkar : Microprocessor Architecture, Programming and Applications with 8085-
13. Gandhi : Theory and Practice of Microelectronics – John Wiley
14. Jain : Fundamentals of Digital Image Processing – Prentice Hall India.

Unit 16

Paper II

Nuclear and Elementary Particle Physics Special

Full Marks : 50 **No. of Lectures – 50**

Elementary Particle Physics :

1. Group Theory: Definitions, Groups and their properties, Lie group,generators, Casimir operators, irreducible representations, *U(1), O(3), SU(2), SU(3), SL(2,C)* and SU(n), root and weight diagrams, Young tableaux. (9)
2. Gauge Field: Gauge invariance in classical electromagnetism and quantum mechanics; global and local gauge transformations; abelian and non-abelian gauges; examples – $U(1)$ and $SU(3)$; local gauge invariance; Yang – Mills fields; QED. (5)
3. Electromagnetic Interactions :
   a) Perturbation Theory : Time ordered and normal ordered products; Wick's theorem; propagators and Green's functions; vacuum expectation values; S matrix; Dyson's expansion; Feynman rules; crossing symmetry; cross-section and decay rates. (3)
   b) Applications of perturbation theory; Compton effect and other examples. (2)
   c) Radiative Corrections : One loop renormalisation; regularisation and power counting; renormalisation-charge, mass and vertex corrections. (2)
4. Weak Interactions :
   a) Phenomenology : Parity violation and V – A interaction; calculation of typical lifetimes (neutron, pion and muon decays). (3)
   b) Weak Currents; CVC and PCAC; charged and neutral currents; sum rules; Cabbibo theory; intermediate vector bosons. (4)
   c) Vacuum; Goldstone theorem; spontaneous symmetry breaking; massive gauge bonsons and Higgs mechanism; electroweak interactions and the Weinberg – Salam – Glashow model.

      Lagrangian and Feynman rules for electroweak interactions; weak – electromagnetic ($e^+e^- \to \mu^+\mu^-$), *W* and *Z* decays – lifetimes, widths and branching ratios. (4)

5. Hadron Structure and Strong Interactions :

   a) Hadron Spectroscopy : Group theoretical construction of hadron states – connection with quark model; *SU*(2) and isospin; *SU* (3) and hypercharge; properties of hadrons as predicted by group theory; symmetry breaking; Gell-Mann-Nishijima-Okubo mass formula; ϕ-ω mixing. (5)

   b) Nucleon Structure : Probing a charge distribution with electrons – form factors; elastic e-p scattering – nucleon from factors, inelastic lepton – hadron scattering – structure functions; Bjorken scaling and partons; Adler sum rules; hadron production in e^+e^- scattering – Drell Yan process. (5)

   c) Quantum chromodynamics : Non-abelian *SU* (3) gauge invariance and QCD; QCD Lagrangian and Feynman rules; colour; quark-quark interaction; gluons and gluon coupling; jets; confinement and asymptotic freedom. (5)

6. The Standard Model; some tests for the model. (3)

Reference Books :

1. Halzen and Martin : Quarks and Laptons – John Wiley.
2. Lichtenberg : Unitary Symmetry and Elementary Particles – Academic Press.
3. Aitchison and Hey : Gauge Theories in Particle Physics – Adam Hilger.
4. Jauch and Rohrlich : Theory of Photons and Electrons – Addison Wesley/Springer Verlag.
5. Bjorken and Drell : Relativistic Quantum Mechanics – McGraw Hill.
6. Bjorken and Drell : Relativistic Quantum Fields – McGraw Hill.
7. Mandl and Shaw : Quantum Field Theory – John Wiley.
8. Itzykson and Zuber : Quantum Field Theory – McGraw Hill.
9. Ryder : Quantum Field Theory – Cambridge.
10. Quigg : Introduction to Gauge Theories of Strong, Weak and Electromagnetic Interactions – Benjamin.
11. Cheng and Li : Gauge Theories of Elementary Particle Physics – Oxford.
12. Close : An Introduction to Quarks and Partons – Academic Press.

13. Martin and Shaw : Elementary Particles – John Wiley.
14. Perkins : Introduction to High Energy Physics – Addison Wesley/Cambridge.
15. Hughes : Elementary Particles – Cambridge.
16. Griffiths : Inroduction to Elementary Particles – John Wiley
17. Kane : Modern Elementary Particle Physics – Addison Wesley
18. Muirhead : Physics of Elementary Particles – Pergamon.

Unit 16

Paper II

Solid State Physics Special

Full Marks : 50 **No. of Lectures – 50**

I) Many Body Physics :

1. Fermi Liquid Theory :

   a) Interacting Fermi system; ^{3}He; ^{4}He; elementary excitations; quasiparticles and their energies; Laudau parameters.

   b) Equilibrium Properties: Specific Heat; compressibility; effective mass; magnetic susceptibility.

   c) Transport Properties: First and zero sound.

2. Single particle propagator; spectral representation; Green's function for quasiparticles; retarded response functions; density fluctuation excitations and collective modes.

3. Properties of Electron Gas: Hartree-Fock approximation; exchange energy and quasiparticle energy in HF approximation; inhomogeneous electron gas-Kohn-Hohenberg theory. (10)

II) Optical Properties of Solids:

1. General Survey of Optical Properties of Solids; response of a crystal to electromagnetic fields; dielectric function and long wavelength dielectric response of an electron gas to an electric field; plasma oscillation; dispersion relation for electromagnetic wave; Kramers Kroenig relations; dispersion relations for dielectric function and $\varepsilon(\omega)$.

2. Derivation of Sum Rules; Friedel sum rules and oscillations; separation of conduction electron and interband effects; simple theory of optical absorption due to interband transition. (8)

III) Superconductivity :

1. Survey of Experimental results : Zero resistance; persistent current; perfect diamagnetism; critical magnetic fields; flux quantisation; specific heat, entropy and latent heat; energy gap, microwave absorption; isotope effect; systematics.
2. Phenomenological Theory : Thermodynamics; London equations and magnetic field penetration; Pippard's non-local modification of fluxoid.
3. Semi-phenomenological theory : Superconducting order parameter and Ginzburg-Landau equations; G-L coherence length and kappa parameter; flux quantisation; upper critical field; surface energy.
4. Microscopic Theory : Froehlich effective electron-electron attraction; Cooper pairing; BCS theory of the ground state of Type I superconductors; significance of the energy gap parameter; elementary excitations in superconductors; density of states.
5. Tunneling Phenomena : Single electron and Cooper pair tunnelling in normal superconducting and superconducting-superconducting junctions; Josephson equation; dc and ac Josephson effect; Shapiro steps; effect of magnetic field; superconducting interference; SQUID magnetometer.
6. Introduction to high temperature superconductivity (12)

IV) Magnetic Resonance and Relaxation :

1. Basic Theory : Quantum mechanical description of spin in a static field; rotating magnetic field; Bloch equation and its solution in weak radio-frequency field.
2. Local field; magnetic dipole broadening and method of moments.
3. Magnetic interaction of nuclei with electrons; quenching orbital motion and chemical shift; Fermi contact interaction; Knight shift.
4. Spin-lattice Relaxation : Spin temperature and spin-lattice relaxation time; relaxation of nuclei in metals and Korringa relation. (8)

V) Transport Properties :

1. Boltzmann's Kinetic Equation : Collision term; relaxation time approximation; Kubo-Greenwood formulation of the transport problem.
2. Macroscopic Transport Coefficients : electrical conductivity; thermal conductivity; thermo-emf; Peltier coefficient; Thomson coefficient-single and multiple charge carriers.
3. Galvanomagnetic Effects : Hall mobility and magnetoresistance- single and multiple charge carriers, Giant magnetoresistance (GMR) and Collosal magnetoresistance (CMR)
4. Relaxation Time : Charge carrier scattering and relaxation time; different scattering processes and corresponding cross sections. (12)

Reference Books :

1. Pines and Nozieres : Theory of Quantum Liquids – Benjamin.
2. Schrieffer : Superconductivity – Pergamon.
3. Ibach and Luth : Sollid State Physics – Narosa.
4. Abrikosov, Gorkov and Dzyaloshinski : Methods of Quantum Field Theory in Statistical Physics – Dover.
5. Fetter and Walecka : Quantum Theory of Many Particles Systems – McGraw Hill.
6. Tinkham : Superconductivity – McGraw Hill.
7. Ziman : Principles of the Theory of Solids – Tata McGraw Hill.
8. Kittel : Quantum Theory of Solids – John Wiley.
9. March and Jones : Quantum Theory of Solids, Vols. I and II – Dover.
10. Callaway : Quantum Theory of Solids, Vols, I and II – Academic Press.
11. Slichter : Principles of Magnetic Resonance – Springer Verlag.
12. Seeger : Semiconductor Physics – Springer Verlag.
13. Kireev : Semiconductor Physics – MIR.

Unit 17

Elective Papers

Full Marks : 50

(1) Physics and Technology of Semiconductor Devices

(2) Radio-astronomy and Related Astrophysics

(3) Advanced Microprocessor and Microcontroller

(4) Nanoscience

(5) Systematics of Non-conventional Superconductors

(6) Nuclear Physics (Advanced)

(7) Gravitation and Cosmology

Unit 17

Elective Paper : Physics and Technology of Semiconductor Devices

Full Marks : 50 **No. of Lectures : 45**

1. Crystal Growth : Growth of single crystals by Czochralski technique, distribution coefficient, rapid-stirring and partial-stirring conditions; zone process. (6)
2. Epitaxial Growth of Semiconductors : Epitaxial growth of silicon layer by vapour phase reduction of silicon tetrachloride; kinetics of growth, mass-transfer control and surface-reaction control conditions. Molecular beam epitaxy. (4)
3. Thermal Oxidation : Formation of silicon dioxide layer on silicon; kinetics of oxide growth, diffusion-controlled and reaction-controlled cases; expression of oxide layer thickness as a function of time. (4)
4. Diffusion of Impurities : Diffusion of acceptor and donor impurities; Gaussian and complementary error function types of impurity profiles. (3)
5. MIS Diode and CCD : Energy band diagrams for ideal metal-insulator-semi-conductor diodes in equilibrium and under different applied voltages; accumulation, depletion and inversion cases; surface potential; solution of Poison's equation; space charge and electric field, differential capacitance, MIS capacitance-voltage curves; Charge coupled Devices. (8)
6. Metal-Semiconductor Contact : Energy band diagram of metal-semiconductor contact under different biasing conductions; space-charge and depletion layer capacitance; Schottky effect; current-voltage relationship; general experession of barrier height; surface state effects. (8)
7. Thin Films : Production of thin films, conductivity of different types of thin films. (8)
8. Micro-electronics Technology : Fabrication of integrated circuits using steps of epitaxial growth, thermal oxidation, masking and etching, diffusion of impurities, and metal-semiconductor contact formation. (4)

References :

1. A.S. Grove : Physics and Technology of Semiconductor Devices – Prentice Hall.
2. S.M. Sze : Physics of Semiconductor Devices – Wiley Interscience.
3. B.G. Streetman and Sanjay Banerjee : Solid State Electronic Devices – Prentice Hall India.
4. S.K. Gandhi : Theory and Practice of Microelectronics – John Wiley.
5. K.L. Chopra : Thin Film Phenomena – McGraw Hill.
6. M.A. Green : Solar Cells – Operating Principles, Technology and System Applications – Prentice Hall.
7. H.J. Hovel : Solar Cells (Semiconductors and Semimetals, Vol. II, Eds. R.K. Willardson and A.C. Beer) – Academic Press.
8. K.L. Chopra and S.R. Das : Thin Film Solar Cells – Plenum Press.
9. K. Barnham and D. Vvedensky (Eds.) : Low-Dimensional Semiconductor Structures – Cambridge University Press.

Unit 17

Elective paper : Radio Astronomy & Related Astrophysics

Full Marks : 50 **No. of Lectures – 50**

1. Astronomical Universe : The Big Bang Nucleo-synthesis, Rough scales of the universe, contents of the universe, Radio astronomy and the cosmos, sources of cosmic radio waves, Astronomical instruments and Techniques. (3)
2. Solar System : Planets and their satellites, Asteroids, Meteoroids, Comets. (2)
3. Atmospheres of planets : Thermal structure of terrestrial planets, Runaway Greenhouse effect, the exosphere. (3)
4. Origin of the earth and the solar system : Solar Nebula theory, Planetsimal theory, Age of the earth and radioactive elements, Radio active dating, Exposure ages of meteoroids, Motion of the planets, Evolution of the earth's atmosphere, Formation of ozone layer, Role of life in changing the earth's atmosphere. (4)
5. Astronomical Telescopes : Reflecting telescope, Refracting telescope, Angular resolution, methods of observing the sun by projection and photographic technique, Orientation of drawings, counting sunspots at the wolf number, calculation of active area, observation of solar spectrum, spectro-heliographs observing with coronagraph, Measurement of solar diameter. Inner coronal photography, Photographing the plasma corona, spectroscopic study of the corona. (8)
6. Starts in the sky : Life cycle, Black body model, Morgan-Keenan spectral classification, Hertzsprung – Russel diagram, Mass luminosity relationship of a star in main sequence, size limits of a star. (4)
7. Sun as a Star : Atmosphere of the sun, Interior, chromospheres and corona, Magnetic activity, principles of stellar structure convection zone of the sum (4)
8. Astronomical Measurements : Measurement of solar flux density, solar brightness distribution, polarization, Receivers and antennas for radio astronomy. (6)

9. Sun's sporadic radio emission : characteristics of radio emission flux and sunspots; local sources of radio emission, frequency spectrum of radio emission and microwave bursts, chromospheric flares, polarization of radio emission, Noise storms, Type-II bursts. (6)

10. Influence of solar radiation on earth's atmosphere : Global electrical circuit, Types of solar radiation, Ionization radiation, Solar Moleculation of atmospheric electrification. Effects of geomagnetic disturbances of solar origin. (4)

11. Life of stars : Stellar structures and models, Equations of hydrostatic equilibrium inside a star, Energy transport mechanism, Main sequence of lifespan, Nuclear reactions inside main sequence, Proton-proton chain reaction, CNO cycle, Red Giant phase.

12. Mysterious Objects of the Universe : Black holes, Pulsars, Quasars, Dark matter, Galaxies. (2)

References :

1. Astronomy and Astrophysics by A.B. Bhattacharya, S. Joardar and R. Bhattacharya – Infinity Science Press (USA).
2. Telescope and Technique by C.R. Kitchen – Springer.
3. Observational Astrophysics by R.C. Smith – Cambridge University Press.
4. Observational Astrophysics by D.S. Birney – Cambridge University Press.
5. Observational Astrophysics by P. Lena – Springer.
6. Practical Astronomy by P. Duffet Smith – Cambridge University Press.
7. Electronic and Computer Aided Astronomy by J. Tinbergen – Cambridge University Press.

Unit 17

Advanced Microprocessor and Microcontroller

Full Marks – 50

(Theory – 30 marks) **No. of Lectures : 30**

1. Advance topics on the 8085 microprocessor :
   - (a) Interrupt handling with vectored interrupts, Use of INTR input using 8259, Interrupt service routine. (3)
   - (b) Serial communication using SOD and SID pins and use of SIM and RIM instructions (1)
   - (c) Timing diagram of different operations including fetch-execute overlap (2)
   - (d) Microprocessor kit design with the 8085 (2)
   - (e) Comparison with other equivalent processors (Z 80, 6800) (1)
2. The 8086 microprocessor :
   - (a) Block diagram, Memory segmentation, Instruction set (3)
   - (b) Assembly language programming with the 8086 (3)
   - (c) Interrupts in the 8086 (2)
3. Support chips :

   USART – 8251, DMA controller, 8255A for its higher modes (3)
4. Microcontrollers :
   - (a) The 8051 architecture (2)
   - (b) Basic assembly language programming concept (3)
   - (c) Design concept of the 8051 based system (3)
   - (d) A few applications of the 8051 (2)

References :

1. Digital Computer Electronics-Malvino & Brown
2. Microprocessor, Architecture, Programming and Application – R.S. Gaonkar.
3. Microprocessor and Interfacing, Programming and Hardware – Douglas V Hall.
4. The 8051 Microcontroller-Kenneth Ayala.

Practical (20 marks) :

1. Interfacing circuits with the 8085
   (a) Use of handshaking modes of 8085 for controlling simple instruments.
   (b) Printer interfacing.
   (c) Serial data communication.
   (d) Use of interrupts in a simulation of process control system.

2. 8086 based experiments :
   (a) Assembly language programming using MASM.
   (b) Interfacing of display units with a 8086 kit.

3. Experiments with microcontroller kit (8051).
   (a) Interfacing a stepper motor using the 8051.
   (b) Data communication using the 8051.

Unit-17

Elective Paper : Nanoscience

Full Marks : 50 **No. of Lectures : 45**

1. Thin Films : Self-assembled Monolayers; Self-assembly; Physical deposition; Vacuum deposition; Sputter deposition; Colloidal self-assembly; Molecular beam epitoxial growth (MBE); Electron beam lithography (EBL); Electrophoresis, electro-osmosis; Langmuir – Blogett (LB), Laser Ablation; Sensor devices. (10)
2. Nanoscience : Fullerene; Carbon Nanotube : single walled and multiwalled (MWWT); Photonic Band gap; Photonic crystal; Quantum Tunneling Quantum dot; quantum cryptography; quantum computer; single electron transistor (SET); Nano-lithography; spintronics; superlattice; (10)
3. Liquid crystals : Ideas of Liquid crystals; Nematic, cholestoric, smectic phases; Paraelectric, Ferroelectric, Antiferroelectric, Ferrielectric Liquid crystals, Ising model, ANNI model, Extended ANNI model, Landau theory; Landou deGennes theory; Landau – Ginzburg theory; Discotic and Columner phases; order parameter; spontaneous polarization; Tilt angle; chirality; Liquid crystalline Polymer (LCP); Light emitting polymer (LEP); Blended co-polymer. (15)
4. Dielectric Process : Complex dielectric permitivity; Dielectric constant and loss; Dielectric relaxation phenomena; Goldstone mode; soft mode; $\alpha,\beta,\gamma,\delta,\sigma$ relaxations phenomena; glass transition; Gelatanization; thermal & dynamic Transition. (10)
5. Experimental technique : Atomic Force Microscopy (AFM), X-ray diffraction and spectroscopy (XRD & XPS); Fourier Transform infrared spectroscopy (FTIR); Time-resolved FTIR; SEM; TEM; STM; Ellipsometry; Circular dichroism. (5)

References :

1. Chopra : Thin Films – McGraw Hill.
2. Supriya Dutta : Electronic Transport in Mesoscopic Systems – Cambridge University Press.
3. John H. Davies : The Physics of Low Dimensional Semi-conductors – Cambridge University Press.
4. Y. Imry : Physics of Mesoscopic Systems – Cambridge University Press.
5. Handy/Lahmani : Nanoscience – Springer.
6. Guozhang Cao : Nanostructures and Nanomaterials – Springer.

Unit-17

Elective Paper : Systematics of Non-conventional superconductors

Full Marks : 50 **No. of Lectures : 40**

1. Non-conventional Superconducting Materials : Definition; characteristics; s-wave, d-wave, and p-wave superconductors; materials showing non-conventional superconductivity; electronic structure of the materials. (7)
2. Experiemtnal Observations : Electronic, thermal, and magnetic properties of non-conventional superconductors; possible pairing mechanism and different types of interactions in these materials as is evident from experimental findings. (12)
3. Theoretical study : Model Hamiltonians; approximations used; results obtained; variations of results for different Hamiltonians and different approximations used; comparison with experimental findings. (13)
4. Recent works on non-conventional superconductors. (6)
5. Possible mechanisms of non-conventional superconductivity (2)

References :

1. High T_c Superconductivity and the C_{60} Family, Edited by Sunqi Feng and Hai-Cang Ren, Gordon and Breach Publishers.
2. Effective Models for Low-Dimensional Strongly Correlated Systems, by G.G. Batrouni, Didier.
3. J.G. Bednorz and K. Muller, Z. Phys. **B64**, 189 (1986).
4. P.W. Anderson, Science **235**, 1196 (1987).
5. E. Dagotto, Rev. Mod. Phys. **66**, 763 (1994).
6. E. Dagotto, Phys. Rev. **B45** 10741 (1992).
7. S. Mollah, H.D. Yang and B K Chaudhuri, Indian J. Phys. **77A**(1), 9 (2003).

Unit 17

Elective Paper : Nuclear Physics (Advanced)

Full Marks : 50 **No. of Lectures – 38**

1. Compound Nuclear Reactions ; Formation and decay; multilevel Breit-Wigner formula; Weiskopff – Ewing formula; continuum states; Evaporation modet; level – density – Erickson's formula; Nuclear temperature; Hauser – Feshbach formalism. (8)

2. Direct reactions :

   a) Formalism : Gell-Mann Goldberger two potential formula; PWBA and DWBA; method of coupled channels. (4)

   b) Optical Model : Its properties and calculation of its parameters; elastic and inelastic collisions; rearrangement collisions; stripping, pick up, knock on reactions; form factors and spectroscopic factors – connection with nuclear structure (calculation of a single-nucleon transfer reaction) (5)

   (c) photon-induced reactions; photo excitation, photodisistegration of the Deutron (3)

3. R-matrix : Definition and properties; giant resources; Feshback's unified theory of nuclear reactions (3)

4. Heavy ion reactions : Information obtained from these reactions; the applicability of classical approach; Coulomb excitation & scattering; grazing collisions, head-on collisions and their features; WKB method of calculating cross-sections; fusion reactions; exotic model (6)

5. Meson-physics : Yukawa's hypothesis, OPEP, OBEP, Lipmon – Schwingar equation, charged and neutral pion exchange, T-matrix; pseudo-scalar meson field, Derivation of OPEP. (3)

6. Nuclear Astrophysics : Particle and nuclear interactions in the early universe; Primordial Nucleosynthesis; Stellar nucleo-synthesis. (2)

7. Applications : Nuclear Medicine; Projection Imaging, with internal and external radiation, computed Tomography, Magnetic Resource Imaging – Principles, Radiation therapy.

Biological effects of radiation : Physical & chemical damage; dose, dose rate; damage of tissue levels. (3)

References :

1. M.K. Pal : Theory of Nuclear Structure –East West Affiliated Press.
2. Preston : Physics of The Nucleus – Addison Wesley.
3. Preston & Bhadury : Structure of the nucleus –Addison Wesley.
4. Cohen : Concepts of Nuclear Physics –Tata McGraw Hill.
5. Wong : Introductory Nuclear Physics – Prentice Hall.
6. Blatt – Weiskopff : Theoretical Nuclear Physics – Dover.
7. Krane : Introductory Nuclear Physics –Wiley.
8. Lilley : Nuclear Physics – Principles & Applications – Wiley.
9. Bohr & Mottelson : Nuclear Structure-I & II – Benjamin.
10. Grenier and Maruha : Nuclear Models –Springer Verlag.
11. de Shalit and Talmi : Nuclear Shell Theory – Academic Press.
12. Sachs : Nuclear theory – Addison Wesley.
13. Satchler : Introduction to Nuclear Reactions – Oxford.
14. Jackson : Nuclear Reactions – Methuen.
15. Glendenning : Direct Nuclear Reactions – Academic Press.
16. Hodgson : Heavy ion Reactions – Oxford.
17. Broglia and Winther : Heavy Ion Reactions – Addison Wesley.

Unit 17

Elective Paper : Gravitation and Cosmology

Full Marks : 50 **No. of Lectures : 51**

1. A look at the sky : the Sun, distant stars, constellations, Galaxies, nebulae, cluster of galaxies, etc. (2)
2. Distance measurement : Trigonometric method, parallex, physical law dependent method, proper motions, Doppler shift, inverse square law of photometry, Hipparchu's classification of stars, luminosity and magnitudes (3)
3. Stellar spectroscopy : Composition of stars, colour index, Temperature of stars, classification of stellar spectra, Determination of mass of the Sun, stars, etc. Mass-luminosity relation, diameter of stars, binaries, velocity curve, light curve, Hertzsprung-Russel (HR) diagram, Main sequence, giants, etc. variable stars, pulsating stars (6)
4. Brief review of GTR, Schwarzschild exterior solution, Birkoff's theorem, singularity, horizon, Schwarzschild Black hole. Gravitational lensing. Kerr metric and Kerr Black hole. (6)
5. Maxwell's equation in GTR, Reissner-Nordtsrom solution, Charged black hole, Black hole Thermodynamics. (4)
6. Interior Schwarzschild metric of massive objects, Oppenheimer-Volkoff equation, white dwarfs, Chandrasekhar limit, Oppenheimer-Volkoff limit, neutron stars, Pulsars. (5)
7. Cosmology : Cosmological Principle, FRW models, Static Universe, red shift, Hubble law, Luminosity relation, angular size, source count, apparent magnitude, cosmological parameters, age of Universe, models with Λ-term. Rotation curve of spiral galaxies. Dark energy, etc. (7)
8. Relics of the Big Bang : The early universe and nuclosynthesis, cosmic microwave background radiation, COBE experiment and its implications, Power spectra (2)

9. Problem of Standard Cosmology : Horizon problem, flatness problem etc. Cosmology and particle physics, inflationary cosmology, Guth model, Linde model. (5)

10. Elementary idea of Quantum Cosmology, W.D. equation (4)

11. Cosmological singularity : Singularity theorem, Raychaudhuri equation (1)

12. Formation of large scale structure :
    Preliminaries, Jeans mass in expanding universe, Observational constraints, Role of dark energy. (4)

References :

1. Robert C. Smith : Observational Astrophysics – Cambridge University Press.
2. Bhatia : A Text-book of Astronomy and Astrophysics with elements of Cosmology – Narosa.
3. Abhayankar : Astrophysics – Stars and Galaxies – Tata McGraw Hill.
4. Carroll and Ostlie : Modern Astrophysics – Addison – Wesley.
5. Shu : The Physical Universe – University Science Books, California.
6. J.V. Narlikar : General Relativity and Cosmology – Macmillan.
7. J.V. Narlikar : Introducction to Cosmology – Cambridge.
8. Raychaudhuri Bannerjee and Banerji : General Relativity, Astrophysics and Cosmology – Springer Verlag.
9. Raychaudhuri : Theoretical Cosmology – Cambridge.
10. Weinberg : Gravitation and Cosmology – John Wiley.
11. Shapiro and Tenkolsky : Black holes, White Dwarfs, and Neutron Stars – John Wiley.
12. Padmanabhan : Theoretical Astrophysics, Vols. I, II and III – Cambridge.
13. Zeldovich and Novikov : Relativistic Astrophysics, Vol. I and II – Chicago University Press.
14. Kolb and Turner : The early Universe – Addison-Wesley.
15. Landau and Lifshitz : Classical Theory of fields – Pergamon.
16. Misner, Thorn and Wheeler : Gravitation – Freeman.

Unit 18 and Unit 19

Special Subject Laboratory Experiments

Two Experiments are to be performed during the examination

Full Marks : 50 (For each experiment)

Time : 6 Hours (For each experiment)

Electronics Special :

1. Design and construction of an IC regulated and stabilised power supply (constant voltage/constant current) and the study of its characteristics.
2. Design and construction of a multistage amplifier using BJT's and FET's and the study of its gain and bandwidth.
3. Design and construction of a simple pulse generator of variable frequency and width.
4. Design and construction of a differential amplifier, an instrumentation amplifier, active filters with op-amps.
5. Study of the characteristics of a solar cell.
6. a) To set up a microwave bench and to measure the guide wavelength for verifying the relation between λ and λ_g.
   b) Study of Horn antenna using microwaves.
7. Measurement of attenuation in optical fibres.
8. a) Solving problems by writing programmes in assembly language and to verify these with 8085 and 8086 kits.
   b) Interfacing of a keyboard, an A/D converter and a stepper motor with an 8085 kit.
9. Construction and application of Schmidt triggers.
10. Study of modulation and demodulation.
11. Study of transmission line characteristics.
12. Study of A/D and D/A conversion.
13. To measure the conductivity of semiconductors by the four probe method.
14. To measure the Hall coefficient, mobility and carrier concentration for a given material.

Nuclear and Elementary Particle Physics Special :

1. Determination of the half-life of a long lived radioactive sample (^{40}K).
2. Determination of half-lives of the complex beta source produced by neutron activation of silver.
3. Estimation of percentage of silver in a sample by neutron activation.
4. Study of growth of radioactivity in a sample by neutron activation.
5. Determination of thermal neutron flux in a neutron Howitzer.
6. Determination of ratio of thermal neutron capture cross sections of ^{103}Rh to ^{104}Rh^{m} and to^{104}Rh ground state, and estimation of the spin cut-off parameter.
7. Beta spectroscopy with a magnetic spectrometer, obtaining the Fermi-Kurie plot to determine the maximum beta energy and shape factor correction for forbidden beta transitions.
8. Beta spectroscopy with scintillation detectors and measurement of conversion electron fraction.
9. Gamma spectroscopy with scintillation detectors using single-channel and multi-channel analysers :
   a) Study of resolution at different amplifier gains,
   b) Energy calibration for a fixed gain,
   c) Study of spectrum of ^{22}Na source and determination of the activity from sum peak analysis.
10. Measurement of the thickness of a thin foil from alpha energy loss.
11. Beta-gamma coincidence measurements : study of decay schemes and lifetime of nuclear levels.
12. Gamma-gamma coincidence measurements : angular correlation of the two positron annihilation gammas from ^{22}Na source.
13. Study of angle dependence of Compton shift and scattering cross section and determination of the classical electron radius.
14. Study of alpha scattering from metal targets and verification of the Rutherford formula and identification of the target element.

Solid State Physics Special :

1. To interpret a Debye-Scherrer powder x-ray photograph for a sample and to determine the dimensions of the unit cell and the number of atoms in it.
2. To interpret a Laue photograph and to identify the crystal planes.
3. To interpret rotation oscillation photographs and to determine lattice parameters.
4. To handle a goniometer, to study the external symmetry of single crystals and to verify the law of rotational indices.
5. To measure the electrical conductivity of a sample by the four probe method and to study the variation of conductivity with temperature.
6. a) To determine the Hall coefficient, electrical conductivity mobility and carrier concentration in a given material.
   b) To determine its magnetoresistance.
7. To determine the susceptibility of single crystals by torsion method.
8. To use NMR/ESR for the study of solids.
9. Determination of density of colour centres induced in alkali halides.
10. Measurement of absorption spectra and the study of structure near the absorption edge and determination of the bandgap energy.
11. a) Determination of the dielectric constant of a solid.
    a) Study of ferroelectric properties of ferroelectric solids.
12. Study of thermoluminiscence.

Unit 20

Project Work

Full Marks : 50 (Project work 40 + Seminar talk 10)

Project work to be made on the basis of subject-interest of the students in different areas of Physics discipline and under the supervision of a teacher of the department. Seminar talk on the Project-work to be conducted by the department. Project record to be maintained by the department.