University of Kalyani

M.Sc. Physics

Syllabus

UnderChoice Based Credit System

(2017 onwards)

Department of Physics

Kalyani-741235

M.Sc. Physics

Course / Unit paper	*Subject / Topics*	*Credit Point*	*Class Test (20%)*		*Written Exam. (80%)*	*Total Marks*
Unit-1	Mathematical Methods	**3**	**15**		**60**	**75**
Unit-2	Classical Mechanics	**3**	**15**		**60**	**75**
Unit-3	Quantum Mechanics 1	**3**	**15**		**60**	**75**
Unit-4	Electronics	**3**	**15**		**60**	**75**
Unit-5	**Practical :** Electronics and Solid State – group A Students only Or Nuclear Physics and Optics – Group B students only	**4**	Internal Assessment-1 (Performance) **20**		Experiment in Examination **80**	**100**
1ST Sem.		**16**				**400**
			2nd Semester			
Unit 6	Advanced Mathematical Methods and Relativity	**2**	**10**		**40**	**50**
Unit 7	Electrodynamics	**2**	**10**		**40**	**50**
Unit 8	Quantum Mechanics II	**2**	**10**		**40**	**50**
Unit 9	Statistical Mechanics	**2**	**10**		**40**	**50**
Unit 10	Applied Physics (**CBCS**)	**4**	**20**		**80**	**100**
Unit 11	**Practical :** Nuclear Physics and Optics – Group B Students only Or Electronics and Solid State – group A Students only	**4**	Internal Assessment-1 (Performance) **20**		Experiment in Examination **80**	**100**
2nd Sem.		**16**				**400**
			3rd Semester			
Unit 12	Atomic and Molecular Spectroscopy	**3**	**15**		**60**	**75**
Unit 13	Solid state Physics	**3**	**15**		**60**	**75**
Unit 14	Nuclear Physics	**3**	**15**		**60**	**75**
Unit 15	Elementary Particle Physics and Field Theory	**3**	**15**		**60**	**75**

Course/ Unit Paper	***Subject / Topics***	***Credit Point***	***Class Test (20%)***		***Written Exam. (80%)***	***Total Marks***
16	Special Practical (1) : Solid State Physics/Nuclear Physics / Electronics	4	Internal Assessment-1 (Performance) **20**	-	Experiment in Examination **80**	**100**
3rd Sem Total		**16**				**400**
			4th Semester			
Course/ Unit paper	***Subject/Topics***	***Credit Point***	***Class Test (20%)***	***Seminar***	***Written Exam (80%)***	***Total Marks***
Unit-17	Special paper(I) : Solid State Physics/Nuclear Physics/ Electronics	**3**	**15**		**60**	**75**
Unit-18	Special paper(II) : Solid State Physics/Nuclear Physics/ Electronics	**3**	**15**	**-**	**60**	**75**
Unit-19	Group A : Project	**3**	Internal Assessment **20**	Seminar / Viva **30**		**50**
	Group B : Numerical Methods and Computer Application		**5**	**5**	**15**	**25**
Unit-20	**Elective Paper :A.** Applied Nuclear Physics**/ B**. Adv. Condensed Matter Physics and Materials Science / C. Applied Electronics	**3**	**15**	**-**	**60**	**75**

Unit-21	Special Practical (II) : Solid State Physics/Nuclear Physics / Electronics	4	Internal Assessment-1 (Performance) **20**	-	Experiment in Examination **80**	**100**
4th Sem total		**16**				**400**
Grand Total		**64**				**1600**

Note: Class tests and seminars will be part of the continuous evaluation process.

Unit – 1: Mathematical Methods

Full Marks: 75 **Credit points: 3**

Module-I

Group Theory : Group of transformation, generators of a group, classes, subgroups, costs, factor groups, direct product, permutation groups, isomorphism and homomorphism, reducible and irreducible representation.

Analysis: Point set, neighborhood, isolated point, limit point etc. Convergence of a sequence, infinite series, absolute convergence and conditioned convergence test of convergence (ratio test, Cauchys root test, Raabes test).

Functions of Complex Variables: (a) Limit, continuity, differentiability, analyticity, necessary and sufficient condition for analytic function, Cauchy-Riemann conditions; multivaluedness of functions, singularities, branch points and cuts, Riemann sheets.

(b) Jordan curve; rectifiable arc and its length; contours; Riemanns definition of integration and the integrability of a function; Primitive function, Darboux inequality, simply and multiply connected domains.

Module-II

Complex integrals : Cauchys theorem, Cauchys integral formula; derivatives of an analytic function; Liouvillestheorem; indefinite integrals; Moreras theorem, Taylors theorem and Laurents Theorem; zeros and singularities of a function; essential singularity; limiting points of zeroes and poles; Weierstrass theorem; the point at infinity.

Calculus of Residues : Residue and evaluation of residue; Cauchys 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 (MittagLeffler Expansion).

Module III

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.

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 Fuchs theorem; Frobenius method of obtaining the second solution, self adjoint operator; the Sturm Liouville problem, boundary conditions (Dirichlet, Neumann and Cauchy Problem).

Module IV

Series solution of differential equation and Special Functions: Hyper-geometric 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); Generating functions; recursion relation; orthonormality; asymptotic behavior; graphical representation.

References:

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 Harvil: 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 Hilbert: Methods of Mathematical Physics – John Wiley.
8. Smirnov: Course on Higher Mathematics – Pergamon.
9. Lang: Linear Algebra - Addison Wesley
10. Finkbeiner:Matricesand 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 – 2:Classical Mechanics

Full Marks: 75 **Credit points: 3**

Module-I

Lagrangian formulation: Problems involving systems with non-holonomic constraints.

TwoBody 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, Laplace-Runge-Lenz Vector.

Hamilton's Equations of Motion : Legendre transformation; Hessian determinant; Hamiltonian and 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.

Module-II

Canonical Transformations : Equations of canonical transformation; generating functions; examples of canonical transformations; integral invariants of Poincare; Lagrange and Poisson brackets as canonical invariants; infinitesimal contact transformations; constants of motion and symmetry principles; generators of infinitesimal symmetry transformations.

Hamilton-Jacobi theory : Hamilton's principal and characteristic functions; 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.

Module-III

Rigid Body Dynamics: Degrees of freedom; space-fixed and body-fixed set of axesand orthogonal transformation; Euler's angles; Euler's theorem on the motion of a rigid body; infinitesimal rotations. Moments of inertia; 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 and asymmetrical top.

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.

Module-IV

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

Non-linear Dynamics and Chaos : Non-linear Equations : autonomous systems; critical points; stability; Liapunov direct method; periodic solutions; Poincare Bendixon theorem; limit cycles; Lienard theorem. Non-linear Oscillation and Chaos; Perturbations and the Kolmogorov – Arnold – Moser theorem (no derivation).

Refrences :

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. RaychaudhuriA.K: Classical Mechanics – Oxford.
8. Simmons: Differential Equations – Tata-McGraw Hill.
9. Bhatia: Classical Mechanics – Narosa.

Unit – 3:Quantum Mechanics I

Full Marks: 75 **Credit points: 3**

Module-I

Linear Vector Space formulation : Linear vector space; linear independence of vectors; complete set of states; inner product; dual space; orthogonalisation; linear operators; Hermitian and unitary operators; eigenvectorsandeigenvalues; diagonalization of matrices and Cayley-Hamilton theorem; basic features of the states and eigenvalues of a Hermitian operator.

States and observables: States and observables of a system as vectors and operators respectively, and related discussion; commutation rules and commutator algebra; discussion on the simultaneous eigenstates of two operators; uncertainty relations;

Representations: Matrix representation of operators; change of basis; coordinate representation of states and operators; momentum eigenfunctions; box and delta function normalization; momentum representation.

Module-II

Linearharmonic oscillator: Eigenvalue problem by the operator method and related discussions.

Coherent states etc.: Coherent states; mixed states; density matrix and its properties with examples; use of the density matrix in calculating the average values.

Stationary state problems: Bound and scattering states; reflection and transmission from a potential barrier (finite square well and delta function well and barrier as examples).

Time dependent systems: Expectation values; time dependence of expectation values of observables; time evolution of states; explicit use of the dynamical equation of motion to analyze the physicsof a two state system (the ammonia molecule may be chosen as an example).

Module-III

Schrödinger, Heisenberg and Interaction pictures: Introduction to the three representations; equation of motion in Schrödinger, Heisenberg and Interaction pictures; time translation operator.

Time dependent Schrödinger equation : Single particle system; probability density and current; initial value problems; Greens function; propagator concept; free particle moving in space; Fourier transforms; Gaussian wave packet and its spreading; Ehrenfest theorem.

Module-IV

Angular momentum : Angular momentum as generator of rotation; commutation rules; eigenvalues and matrix representation; orbital angular momentum and its eigenfunctions; spin angular momentum; algebra of Pauli spin matrices; spin half particle in a magnetic field.

Addition of angular momenta: ClebschGordan coefficients; Tensor operators and Wigner-Eckart theorem (statement only).

References:

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 – 4:Electronics

Full Marks: 75 **Credit points: 3**

Module-I

Power Circuits: Regulated power supply; basic concepts; series and op-amp regulator and SMPS; SCR firing and firing angle, power control.

Integrated Circuits: Fabrication techniques of IC components and devices : LSI,VLSI.

Operational Amplifiers: 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) nonzero output resistance and iv) off-setand drift; common mode rejection ration.

Amplitude Modulation and Detection: sideband, power relation; modulation index, typical amplitude modulation circuit; detection of amplitude modulated waves; envelope; average detection.

Module-II

Network Analysis: Constant k and m derived low and high pass; band pass and band elimination Filters, propagation constants, characteristic impedance for T and II sections, neper and decibel.

Noise: Different sources of noise; signal to noise ratio; definition and calculation of noise figure.

Frequency Modulation and Detection: Concepts of frequency and phase modulation, 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.

Antenna and Radar Systems : a) Antenna : Basic considerations; antenna gain; resistance, band width and beam width, high frequency antenna, b) Radio method Detection and Ranging; pulse radar; Block diagram and range equation.

Module-III

Devices: MOSFET, CMOS, UJT, SCR, Triac, Diac, IGBT.

Waveform Generators: Pulse generation and shaping by astable, monostable and bistablemultivibrators; IC555.

Digital Circuits and Systems : bistable latch, flip-flops; SR, JK, Master slave; shift registers; counters (up-down); encoder-decoder; digital to analog converter; summing and R-2R ladder type, analog to digital converter; counting and tracking; Memory cell and array.

Module-IV

Elements of Microprocessors : Basic concepts; block diagram of 8085; instruction set; memory interfacing; machine cycle and timing diagram; idea of assembly language programming.

Transmission Lines, Waveguides and Microwaves: Parallel wire and coaxial lines; transmission line equation; characteristic impedance; propagation constant; high frequency transmission lines; travelling wave interpretation; VSWR : Coefficient of reflection; principle of stub line matching; directional coupler. Rectangular waveguide; waveguide modes; resonant cavities; microwave oscillators; reflex klystron; magnetron.

References:

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 and Balmain : Radiation and Radiating Systems – Prentice Hall India.
8. Kennedy : Electronic Communication Systems – Tata McGraw Hill.
9. Taub and Schilling : Principles of Communication Systems – Tata McGraw Hill.
10. Carlson : Communication Systems – Tata McGraw Hill.
11. Haykin ; Communication Systems – John Wiley.
12. Stallings : Data and Computer Communications – Prentice Hall.
13. Gaonkar : Microprocessor Architecture, Programming and Applications with 8085.
14. Ryder : Networks, Lines and Fields – Prentice Hall India.
15. Millman and Grabel : Microelectronics – McGrawHill.
16. Millman : Microelectronics – McGraw Hill.
17. Malvino and Leach :Digital Principles and Applications – Tata McGraw Hill.
18. Terman : Electronic and Radio Engineering - McGraw Hill.
19. Kraus : Antenna – McGraw Hill.
20. Reich, Ordnung and Skalnick : Microwave Principles – Affiliated East West Press.
21. Sarkar : Microwave Propagation and Technique – S. Chand.
22. Ram : Fundamentals of Microprocessors and Microcomputers – D. Rai and Sons.
23. Rafiquazzaman : Microprocessors – Prentice Hall India.
24. Malvino : Digital Computer Electronics – Tata McGraw Hill.
25. Streetman : Solid State Electronic Devices – Prentice Hall India.

Unit – 5: Practical

Full Marks: 100 **Credit points: 4**

Nuclear Physics and Advanced Optics (Group A students only)

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 the half-life of a long lived radioactive sample (^{40}K).
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 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/spectrometer, 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 emission spectra of Cu and to determine the energy diagram with possible transition.
9. Study of the Zeeman splitting of Na-D lines using a constant deviation spectroscope and Fabry-Perot etalon.

Electronics and Solid State Physics (Group B students only)

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-band width product using R-C coupling.
3. Experiments on Diac, Triac, SCR and UJT.
4. Design and construction of astablemultivibrator 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.
9. Determination of Hall coefficient and carrier concentration.
10. Dielectric constant measurement as a function of temperature.

Unit – 6: Advanced Mathematical Methods and Relativity

Full Marks:50 **Credit points: 2**

Module-I

Integral Transforms: Fourier transform, Laplace transforms; Parsevals theorem and convolution theorem; partial differential equation and its classification; Solution of partial and ordinary differential equation by above transformations.

Green's Functions: Inhomogeneous differential equation (Poisson equations, wave equation,etc.); Green's Functions, definition and properties (for self adjoint differential operators only) computation of Green's function, direct computation, eigenfunction expansion, integral transform method.

Module-II

Numerical Integration: Trapezoidal; Simpson 1/3; Monte-Carlo – average method.

Root Searching of Algebraic Equations: Bisection method; Regulafalsi; Secant Method; Newton-Raphson; simultaneous equations; numerically – square root.

Matrix Manipulation: Upper and lower triangular matrices; Basic Gaussian elimination; Pivoting and Gauss-Jordan Elimination; Solution of linear simultaneous equations; Determinant; Inverse; diagonalisation; eigenvalues and eigenvectors of matrices.

Ordinary Differential Equations (First Order) : Euler's method; Runge-Kutte method in one-dimension.

Numerical Analysis : Methods of interpolation, least square curve fitting, Quadrature formulae.

Module-III

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

Module-IV

Relativity : Lorentz transformations, Minkowski space, light cone structure, allowed region; 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.

Covariant Formulation of 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 Lorentzforce.Covariant Lagrangian formulation of particle mechanics in presence of electromagnetic fields.

References :

1. Sokolnikoff : Tensor Analysis-Wiley Toppan
2. Lass : Vector and Tensors-McGraw Hill Kogakusha
3. Joshi :Matricesand 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-McGrawHill Kogakusha
10. NarlikerJV : General Relativity and Gravitation-Oxford University Press.
11. Dirac P M A : Introduction to general Relativity
12. Narliker J V : Cosmology-Cambridge University Press.
13. TolmanRelativity : Cosmology and Thermodynamics
14. A.W. Joshi : Group theory.
15. Sastry : Introductory Methods of Numerical Analysis.

Unit – 7:Electrodynamics

Full Marks: 50 **Credit points : 2**

Module-I

Non Stationary Systems : Maxwell's equations in moving medium, Lorentz force, conservation of momentum and energy, Pointing's theorem, Maxwell's stress tensor, scalar and vector potentials, gauge transformations-Lorentz gauge and Coulomb gauge, the inhomogeneous wave equations; solution of inhomogeneous wave equations by Green's function; retarded and advanced solutions.

Module-II

Fields and radiations: Fields and radiation of a localized oscillating source; multipole expansion of the scalar and vector potentials; radiation fields; electric and magnetic dipole and electric quadrupole fields; Hertz potential and corresponding field equations.

Multipole Radiations : Multipole expansion of the electromagnetic field; magnetic dipole radiation; electric dipole radiation; Electric quadrupole radiations; sources of multipole radiation-multipole moments.

Module-III

Moving Charge: Lienard-Wiechert potentials, the field of a uniformly moving point charge; convection potential and virtual photons.

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 generalization; Bremsstrahlung; Cerenkov radiation; radiation reaction; electromagnetic mass.

Module-IV

Scattering: Radiation damping; scattering by a free electron; scattering and absorption of radiation by a harmonically bound electron; scattering of electromagnetic waves from a system of charges, coherent and incoherent Bragg diffraction.

Magneto-hydrodynamics and Plasma Physics : Conducting fluid in a magnetic field; freezing in of lines of force; MHD equations; magnetic pressure; magnetic viscosity; pinch effect; Alfven waves; plasma oscillations; screened potential and Debye length.

References :

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. Reitz, MilfordandChristy :Foundations of ElectromagneticTheory-Addison Wesley.
5. Schwinger : Classical Electrodynamics-Perseus Books.
6. Landau and Lifshitz : Classical Theory of Fields-Pergamon.
7. Landau and Lifshitz : Electrodynamics of Continuous Media-Pergamon.
8. Chandrasekhar : Plasma Physics-Chicago University Press.
9. Stratton : Electromagnetic Theory-McGraw Hill.
10. Hauser : Electromagnetic Theory
11. A K Raychaudhuri : Electromagnetic Theory-Oxford University Press.

Unit – 8:Quantum Mechanics (II)

Full Marks: 50 **Credit points: 2**

Module-I

Approximation methods: Variational method for stationary state problems : simple applications. Time independent perturbation theory – non-degenerate and degenerate cases, examples.Time dependent perturbation theory – transition amplitude; constant and harmonic perturbations; Fermi's golden rule; simple examples.WKB approximation – simple examples; Adiabatic and sudden approximations – adiabatic theorem; dynamic and geometric phases; Berrys phase and the Aharonov – Bohm effect.

Symmetries : Symmetry operations as unitary and anti-unitary transformations; conservation laws from invariance principles. Discrete symmetries; reflection, inversion and parity; intrinsic parity; time reversal; Kramers degeneracy.Space translation; time displacement; application of symmetry arguments to derive the selection rules and degeneracy; breaking up of $\Lambda^{o} \rightarrow p + \pi^{-}$illustrating the use of conservation of angular momentum.

Module-II

Three dimensional potential problems : Central potential; eigenfunctions and eigenvalues (using separation of variables); solutions of the radial and the angular parts of the equation; rigid rotator; spherical potential well; hydrogen problem; charged particle in a magnetic field Landau levels.

Scattering theory: Scattering amplitude; differential and total cross sections; Scattering in a spherically symmetric potential, partial wave analysis; phase shifts andits evaluation; Born approximation, simple examples; hard sphere scattering; integral equation for scattering.

Module-III

Relativistic Quantum Mechanics-I: Klein-Gordon equation : Continuity equation and indefinite norm; free particle solutions; negative energy-momentum solutions and their interpretation, non-relativistic reduction and interpretation of Klein-Gordon equation (also in presence of weak, slowly varying electromagnetic fields); spin of the KG particle; invariance properties.

Module-IV

Relativistic Quantum Mechanics-II: Dirac equation: The conjugate Dirac equation continuity equation; non-relativistic correspondence; spin; helicity and magnetic moment of the Dirac particle. Lorentz covariance for the Dirac particle; gamma matrices, their different representations and properties;space reflection; parity; bilinear covariant; 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.

References:

1. David Griffiths : Introduction to Quantum Mechanics – Pearson Education.
2. L. Schiff : Quantum Mechanics – McGraw Hill Kogakusha
3. E. Merzbacher : Quantum Mechanics – John Wiley.
4. J.J. 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.
11. Baym : Lecture Notes on Quantum Mechanics – Benjamin.
12. Schweber : Relativistic Quantum Field Theory – Harper and Row.
13. Bjorken and Drell : Relativistic Quantum Mechanics – McGraw Hill.
14. Greiner: Relativistic Quantum Mechanics – Springer.
15. Ghatak and Lokanathan : Quantum Mechanics, Theory and Applications – Macmillan.

Unit – 9: Statistical Mechanics

Full Marks: 50 **Credit points: 2**

Module-I

Statistical Description : Principle of equal apriori 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; Stirlings 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 momnt fluctuation, specific heat and energy fluctuation.

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

Module-II

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.

Module-III

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.

Real Gas: Free energy; virial equation of state; second virial coefficient and Joule-Thomson expansion; inversion temperature, model calculation and van der Waals equation of state.

Phase Transitions : Liquid-gas, order-disorder, ferroelectric, ferromagnetic transitions critical points; Ehrenfests classification; order parameter; continuous and discontinuous transactions; landaus 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.

Module-IV

Quantum Statistics : Fermi and Bose distributions; quantum gas 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.

References:

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 – 10: Applied physics

Full Marks: 100 **Credit Points:4**

Module-I

Basic Physics:

Newtonian mechanics: Vectors; Newton's laws of motion; Force and acceleration; Work, Energy, Power; Newton's laws of Gravitation; Projectiles; Friction; Circular motion; Moment of Inertia.

Ray optics: Reflection and Refraction at a plane boundary; Refractive index; Snell's law; Fermat's principle; Image formation by reflection at a spherical boundary; Concave and Convex mirrors; Lenses.

Wave Optics: Interference, Diffraction, polarization

Elements of electricity and magnetism: Electric field and potential, Gauss law, Biot-Savart law, Ampere Circuital law, Maxwell's equation, Electromagnetic wave

Modern physics and relativity: Structure of atoms and nucleus, Radioactivity, Fission, Fusion, Superconductivity, Special theory of relativity.

Module-II

Applied Quantum Mechanics:

Basics: Schrödinger equation, Measurements, Expectation values, Stationary states, Approximation methods: Variational principle, Time independent and Time dependent perturbation theory; WKB approximation. .

Some elementary examples:

(a) Free electrons in one dimension, π - states in benzene; free electrons in three dimensions.
(b) Quantum slabs, wires and dots; quantum wells.
(c) The hydrogen atom problem.

Molecules:

(a) The Li_2 molecule: LCAO or tight binding states; bonding and anti-bonding state
(b) Molecular orbitals; Polar bonds; Non-orthogonal and overlap repulsion.

(c) The physics of N_2, CO and CO_2; cohesion; π -bonds; sp hybrids and σ -bonds.

Module - III

Data and error analysis: The presentation of physical quantities with their inaccuracies (measuring errors and uncertainties), Classification and propagation of errors.

Probability distributions: Binomial distribution; Poisson distribution; Gaussian or Normal distribution; Lorentzian distribution; the central limit theorem.

Processing of experimental data: Distribution function of a data series; the average and the mean squared deviation of a data series; estimates for mean and variance; χ^2Test of a distribution; handling data with unequal weights.

Fitting functions to data: Dependent and independent variables, method of least squares, fitting to a polynomial, minimizing χ^2 for Goodness of Fit, Linear-Correlation Coefficient.

Numerical Methods: Polynomial Interpolation, Numerical Differentiation and Integration, Roots of Nonlinear Equations.

Module - IV

Analytical techniques and their applications:

Characterization Techniques in Materials Science: Optical microscopy, electron microscopy, Spectrophotometry, Raman spectroscopy,Atomic force microscopy (AFM) X ray Diffraction. Nuclear Magnetic Resonance.

Atomic and Nuclear analytical methods: X-ray Fluorescence (XRF) and Particle-Induced X-ray Emission (PIXE), Rutherford Backscattering Spectroscopy, Neutron Activation Analysis, Accelerator Mass Spectrometry.

Biological effects of radiation: Physical and chemical damage; dose, dose rate; damageof tissue levels, Radiation shielding and its safety, Nuclear Medicine; Radiation therapy.

Medical imaging physics: X-rays, fluoroscopy, angiography, and computed tomography, ultrasound (including lithotripsy), MRI and positron emission tomography (PET).

Medical optics: Pulse oximetry, Endoscopy, Laser medicine

Bio technology: Biomaterials and artificial organs: Drug delivery and control release.

Unit – 11: Practical

Full Marks: 100 **Credit points: 4**

Nuclear Physics and Advanced Optics (Group B students only)

List of Experiments:

Given in Unit – 5.

Electronics and Solid State Physics (Group A students only)

List of Experiments:

Given in Unit-5.

Unit – 12:Atomic and Molecular Spectroscopy

Full Marks: 75 **Credit points: 3**

Module-I

Atomic Spectroscopy : One electron atom : Hydrogen spectrum; spectral series limit and term values; Ritz combination principle; summary of Bohr-Somerfield model; semi-classical treatments of relativistic corrections and spin-orbit interaction; Thomas correction; non-relativistic limit of Diracequation; existence of intrinsic spin and anomalous magnetic moment; Dirac – Coulomb problem; relativistic spin-orbit and Darwin terms; correction to Bohr-Somerfield term values; fine structure constant; Lamp-Rutherford splitting; evaluation of integrals $< r^{1/k} >nl$; features of alkali spectrum; double structure; Born Heisenberg approximation; induced dipole field; quantum defects Rydberg and Ritz terms; X-ray spectrum and screening.

Module-II

Many Electron atoms : Schrödinger equation for many electron system; central field approximation; product function and Hartee equation; Pauli exclusion principle; Slater determinant; Hartree-Fock approximation; exchange integral; Koopmans theorem, Aufbau principle and the periodic table, Electronic configuration; multiplicity of terms; Russel Saunders coupling; Hunds rule; Lande interval rule; j-j coupling; land g factor, Thomas Fermi approximation.

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.

Module-III

Molecular structure and Spectra: 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.

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 moleculesand Hunds schemes; symmetry of molecules; Λ doubling.

Rotational and Vibrational Energy Levels : Quantization of rotation of a rigid body; rotational spectrum and bond length measurements; rotation-vibration spectrum; Frank Condon principle; Condon parabola; Fortrat diagram P, Q and R branches; band head; fine structure. Fluorescence and phosphorescence; photo dissociation; Raman spectrum.

Module-IV

Semi-classical treatment of emission and absorption of radiation by atomic systems; Einstein's A and B coefficients; selection rules;

LASER : basic principle of laser; interaction of atomic system and radiation-density matrix of two-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.

References:

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:Lasrs – Wiley Interscience.
13. Svelto : Principles of Laser – Plenum Press.

Unit – 13:Solid State Physics

Full Marks: 75 **Credit points: 3**

Module-I

Crystal diffraction : Symmetry, Braggs Law; experimental diffraction methods; Laue derivation of amplitude of scattered wave; Laue diffraction; reciprocal lattices; Brillouin zones : crystal structure factor; geometrical structure; atomic form factor.

Imperfections in solids: Different types of defects and dislocation, Point defects and line defects; defect concentration; disorder.

Crystal Binding: Various mechanisms of bindings in solids : cohesive energy; criteria of structural stability.

Module-II

Lattice Vibrations: Lattice dynamics; Harmonic approximation; vibration of monatomic and diatomic linear lattices; dispersion relations and normal modes; quantization of lattice vibration and phonons; determination of force constants from experimental dispersion relations; anharmonic crystal interactions and thermal expansion (qualitative discussion only).

Electron States and Band Theory : Free electron theory; periodic boundary condition; electron in periodic potential; Bloch theorem; Krönig-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.

Module-III

Transport Properties: Boltzmann transport equation; electrical conductivity of metals and alloys; thermal conductivity of metals and insulators; Wiedemann-Franz law; isothermal Hall effect; quantum Hall effect.

Semiconductors: Intrinsic and extrinsic semiconductors; carrier mobility; lifetime and diffusion of minority carrier.

Superconductivity : Experimental facts and qualitative explanations; thermodynamics and electrodynamics of superconducting transitions; Meissner effect, London equation, penetration depth; type I and type II superconductors; flux quantization; Josephson effect; High $T_c$superconductivity; ionic conductivity; superionic conductivity; hopping conductivity.

Module-IV

Magnetism in solids : Magnetic moment of an atom; paramagnetism and diamagnetism of atom; Hund's rule; magnetism in metals; ferromagnetism in insulators; spontaneous magnetization; antiferromagnetism and ferrimagnetism; ferromagnetic domains; anisotropy and energy; ferromagnetic spin waves; paramagnetic resonance; nuclear magnetic resonance (NMR); ferromagnetic resonance.

Optical and Dielectric Properties of Solids : Luminescence; decay mechanisms; thermoluminiscence; thalium activated alkali halides; color centers; excitons; photoconductivity; dielectric solid in static and alternating electric fields; losses; relaxation times; Ferro-electricity; different models and thermodynamic treatment of phase change. Thermo-electricity; electrets.

References:

1. Aschroft and Mermin: Solid State Physics – Saunders
2. C. Kittel : Introduction to Solid State Physics – John Wiley
3. Azaroff: Introduction to Solids – Tata McGrawHill.
4. J. Dekker: Solid State Physics- Macmillan.
5. Ali Omar: Elementary Solid State Physics: Principles and Applications – Addison Wesley.
6. D.L. 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.
8. Keer:Principlesof Solid State – Wiley Eastern.

Unit – 14:Nuclear Physics

Full Marks: 75 **Credit points: 3**

Module-I

Nuclear Systematics:

Mass: Change; binding energy; separation energy.

Nuclear size: electron scattering and form factors, charge density radius and potential radius, Wood-Saxon potential, experimental methods of determination.

Static Electric and Magnetic Moments of a Nucleus; magnetic dipole and electric quadrupolemomnts.

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.

Nuclear Disintegrations: Nuclear Emission: Penetration of potential barrier; nature of barrier for neutrons. Protons and alpha particles; Gamows theory of alpha disintegration and calculation of reduced widths and decay half-lives. Gamma disintegration and selection rule.

Module-II

Two Nucleon System:

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.

Scattering Problem : *n-p* scattering at low energies; partial wave analysis; effective range formula and scattering length, shape-independent approximation; modification of effect range for deuteron bound state; scattering by hard sphere and finite square-well potential. *p-p* scattering at low energies; identity of particles antisymmetrisation of wave function; comparison with n-p scattering; interference between nuclear and Coulomb forces; effect range.

n-*n* scattering; charge-independence and charge symmetry, isotope spin and isobaric analog states mirror nuclei, exchange forces and saturation, repulsive core.

Module-III

Structure of Complex Nuclei : Nuclear 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. 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 electromagnetic moments, Schmidt limits; anomalous magnetic moments of nucleons and qualitative discussions about their origin.

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

Module-IV

Nuclear Reactions : Classification; conservation principles; kinematics and Q-values; exoergic and endorgic reactions; threshold energy, Experimental setup; 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).

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.

Interaction of charged particles with matter-ionization formula, range-energy relationship, charged particle detectors, energy measurement and identification of charged particles.

References:

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: Addison Wesley.

Unit – 15:Elementary Particle Physics and Field Theory

Full Marks: 75 **Credit points: 3**

Module-I

Elementary Particle: 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; Yukawas prediction; typical strengths, coupling constants, lifetimes, reaction cross-sections. Modern methods of producing particles.

Kinematics: Relativistic Kinematics and Mandelstam variables.

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; time reversal invariance and the principle of detailed balance; CPT thereon (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.

Module-II

Particles and resonances: Classification into hardrons and leptons, baryons and mesons, Properties of Charged Pions and 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).

Strong Interactions and Hadrons : 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; Zweigsrule; Pauli principle and the colour of quarks. Gluons as mediators in quark quark interaction.

Weak Interaction: Phenomenology conservation laws and selection rules in weak decays Nuclear Beta Decay: Fermi theory and Kurie plot (qualitative discussion); log$f\tau$values classification and selection rules; role of Neutrino in parity non-conservation; Muon Decay : Different types of neutrinos.

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.

Module-III

Quantum Mechanics of Fields and Many Particle Systems (Second Quantization)

Identical particles: Bosons and Fermions; Symmetric and antisymmetric many body wavefunctions.

Method of Second Quantization : Lagrangian formalism; Noethers theorem; in-variance under transformations and operator requirements; quantization of a field obeying Schrödinger'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 quantized notation.

Quantization of Klein-Gordon Field: Single component free Hermitian scalar field; plane wave and spherical wave decompositions; energy, momentum and displacement operators; symmetry of states; non-hermitian scalar field; chargeoperator; particles and antiparticles.

Module-IV

Quantization of Dirac Field: Plane wave representation; quantum conditions; energy and momentum operators; positivity of energy; current and charge operators symmetrisation.

Quantization of the Electromagnetic Field: Maxwell's equations and the electromagnetic field tensor; quantization in the radiation gauge; transverse photon.

Interacting Fields: Brief discussion; quantized electromagnetic field interacting with a classical source; application to atomic transition probabilities; scattering of radiation (Compton Effect); S matrix and the evolution operator.

References:

1. Schiff: quantum Mechanics-McGrawHillKogakusha
2. Merzbachr : 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 Particles – Pergamon.
9. Greiner : Relativistic Quantum Mechanics-Springer.
10. Ghatak and Lokanathan : Quantum Mechanics, Theory and Applications-Macmillan
11. George Greenstein and Arthur G. Zajonc : The Quantum Challenge-Narosa
12. David Griffiths: Introduction to elementary particles – Wiley.
13. Martin and Shaw : Elementary Particles – John Wiley.
14. Perkins : Introduction to High Energy Physics – Addison Wesley.
15. Hughes : Elementary Particles – Cambridge.
16. S. N. Ghoshal : Nuclear Physics – S. Chand.

Unit – 16:Special Practical-(I)

Full Marks: 100 **Credit points: 3**

For Group-A Students

Solid State Physics Special Practical-(I)

1. To interpret a Debye-Scherer 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. Determination of density of color centers induced in alkali halides.
6. Study of thermoluminiscence.

Nuclear Physics Special Practical-(I)

1. Determination of half-life of Indium by thermal neutron activation and study of beta ray absorption.
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 ^{103}Rh* and to ^{104}Rh ground state, and estimation of the spin cut-off parameter.

Electronics Special Practical-(I)

1. Design and construction of an IC regulated and stabilized 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 using IC 555 timer.
4. OP AMP based experiments: active filters, Wien bridge oscillator.
5. Construction and application of OP AMP comparator, Schmidt triggers.
6. Experiment based on PLL.

7. Experiment on Pulse Modulation using IC 555 timer.

<u>For Group-B Students</u>

Solid State Physics Special Practical-(II)

1. To measure the electrical conductivity of a sample by the four probe method and to study the variation of conductivity with temperature.
2. a) To determine the Hall coefficient, electrical conductivity, mobility and carrier concentration in a given material. B) To determine its magneto resistance.
3. To determine the susceptibility of single crystals by Goe's method.
4. To use ESR for the study of solids.
5. Study of ferroelectric properties of solids by P-E loop tracer.

Nuclear Physics Special Practical-(II)

1. 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.
2. Beta spectroscopy with scintillation detectors and measurement of conversion electron fraction.
3. Gamma spectroscopy with scintillation detectors using single-channel and multi-channel analyzers: 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.
4. Measurement of the thickness of a thin foil from alpha energy loss.
5. Beta-gamma coincidence measurements: study of decay schemes and lifetime of nuclear levels.
6. Gamma-gamma coincidence measurements: angular correlation of the two positron annihilation gammas from ^{22}Na source.
7. Study of angle dependence of Compton shift and scattering cross section and determination of the classical electron radius.
8. Study of alpha scattering from metal targets and verification of the Rutherford formula and identification of the target element.

Electronics Special Practical-(II)

1. Study of the characteristics of a solar cell.
2. a) To setup 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.
3. Measurement of attenuation in optical fibers.
4. a) Solving problems by writing programs in assembly language and to verify these with 8085 and 8086 kits. B) Interfacing of a keyboard, and A/D converter and a stepper motor with an 8085 kit.
5. Study of transmission line characteristics.
6. Study of A/D and D/A conversion.

Unit – 17:Special Paper-(I)

Full Marks: 75 **Credit points: 3**

Solid State Physics Special-(I)

Module-I

Fundamental Ideas of Group: Elementary concepts of group; symmetry transformation as elements of a group; multiplication table; group representation; reducible and irreducible representations; character table.

Crystal Symmetry: Point group; translational symmetry and space group (elementary ideas only); effect of symmetry on physical properties.

Electron states in Solids: Crystalline Solids:Pseudo potential approach; APW; OPW (qualitative).

Non-crystalline Solids : Electronic density of states; Greens 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.

Module-II

Lattice Dynamics: Born Oppenheimer approximation and separation of nuclear and electron motions; internuclear potentials; lattice Hamiltonian, harmonic approximation, cubic and quadratic terms; force constants and their symmetries. Dynamical matrix, normal coordinates quantization of lattice vibration, Phonons, Grüneisen formula.

Effects of defects in Lattice Vibration: Rayleighs theorem; local (defect) modes; qualitative change in frequency spectrum.

Electron Phonon Interaction: Interaction Hamiltonian in second quantized form; qualitative discussions on electron phonon interactions.

Magnetic properties of solid: Diamagnetism and paramagnetism in metals; de Hass van Alphen effect; van Vleckparamagnetism; quenching of orbital angular momentum; crystal field splitting.

Band model of ferromagnetism; temperature behavior of ferromagnetism in band model; Hubbard model.

Module-III

Magnetic properties of solid (contd.): Exchange interaction in real systems: Direct exchange interactions; exchange interactions between free electrons; Exchange enhancement of Pauli susceptibility; ferromagnetic coupling of localized electrons.

Double exchange; super exchange; RKKY interaction.

Spin waves in ferromagnets; Holstein-Primakoff transformation; Dispersion relation for magnons, magnon heat capacity.

Spin waves in antiferromagnets; Ground state energy; Dispersion relation for antiferromagnetic magnons.

Magnetic phase diagram; critical points and critical exponents; quantum Hall effect.

Module-IV

X-ray Scattering, Neutron Scattering, Mossbauer Effect : X-ray Scattering : Debye Waller factor; fundamental and superstructure reflection determination of long range order parameter.

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.

MössbauerEffect: Introduction to the theory; isomer shift; quadrupole splitting; magnetic hyperfine splitting.

References:

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. Matis: 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 – 17:Special Paper-(I)

Full Marks: 75 **Credit points: 3**

Nuclear and Particle Physics Special-(I)

Module-I

Two Body Interactions: Scattering: Spin dependence of the interaction – singlet and triplet scattering lengths; coherent scattering from ortho and para-hydrogen; singlet state of the deuteron; high energy np, pp, nn scattering; Serbr force and jastrows idea of repulsive core, exchange forcesand saturation.

Deuteron problem: Electric quadrupole and magnetic moments of the deuteron detailed analysis with intrinsic wave function; Tensor forceand the Rarita Schwinger equations. Photo-disintegration of the deuteron.

Meson-physics: Yukawas hypothesis, OPEP, OBEP, Lippmann Schwinger equation, charged and neutral pion exchange, T-matrix; pseudo-scalar meson field, Derivation of OPEP.

Module-II

Nuclear Shell model : Residual interaction single-particle model and individual particle model; justification of Nordheims rule; configuration mixing; antisymmetrization of wave functions of two and three nucleons in unfilledshell; coefficients of fractional parentage. Pairing interaction and is effects. Electromagnetic transition in the Shell model.

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 and VMI model; electromagnetic moments and transition rates in the collective model.

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

Module-III

Nuclear Reactions : Compound Nuclear Reactions; Formation and decay; multilevel Breit-Wigner formula; Weiskopff-Ewing formula; continuum stats; Evaporation model; level density, Ericksons formula; Nuclear temperature; Hauser-Feshbach formalism.

Direct reactions: Formalism: PWBA and DWBA; method of coupled channels; form factors and spectroscopic factors connection with nuclear structure (calculation of a single-nucleon transfer reaction).

Optical Model: Its properties and calculation of its parameters; Phenomenological optical model, Feshbach's formalism.

Module-IV

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

Electro-Magnetic Transitions: Interaction of electromagnetic radiation with matter, E-type and M-type multiple transitions, rate, selection rules, single particle transition, internal conversion, coefficient and rate, internal pair creation, angular correction.

References:

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 Nuclear Structure, Vols. I and II – Benjamin.
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.
10. Cohen: Concepts of Nuclear Physics – Tata McGraw Hill.
11. Wong: Introductory Nuclear Physics – Prentice Hall.
12. Blatt Weiskopff: Theoretical Nuclear Physics – Dover.
13. Krane: Introductory Nuclear Physics – Wiley.
14. Lilley: Nuclear Physics Principles and Applications – Wiley.

Unit – 17:Special Paper-(I)

Full Marks: 75 **Credit points: 3**

Electronics Special-(I)

Module-I

Tunnel diode: Effect of high doping, degenerate semiconductors, energy band diagrams of a tunnel diode in equilibrium and under different biasing conditions, current-voltage characteristics, tunneling current, excess current and thermal current, equivalent circuit and input impedance.

Solar Cells and LED : 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, solution of continuity equation, spectral response, limitations of a solar cell and methods of improvement of its performance. Photo-diode. Direct and indirect band gap semiconductors, materials used for the fabrication of light emitting diodes, construction and principle of operation of LED.

MIS Diode and CCD: Energy-band diagrams for ideal metal-insulator-semiconductor diodes in equilibrium and under different applied voltages, accumulation, depletion and inversion cases, space-charge and electric field, differential capacitance, MIS CV curve. Charge coupled devices.

Module II

Metal-Semiconductor Contact : Energy-band diagram of metal semiconductor contact under different biasing conditions : space-charge and depletion layer capacitance : Schottky effect; current-voltage relationship; general expression of barrier height; surface state effects.

IMPATT 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.

Gunn Diode: Principle of operation of a Gunn diode, simplified band diagram of GaAs, transferred electron mechanism, formation and drift of space-charge domains.

Module-III

Op-amp application: Buffer, precession rectifier, log amplifier, anti-log amplifier, multiplier and divider.

Switched capacitor, MOSFET realization.

Computer Networking : Principle of computer networks, Circuit switching; Message switching; Packet switching; classification of different type of networks, merits and demerits; LAN, MAN, WAN and their applications, Network topologies; Star, Ring, Tree, Bus topologies; Internet.

Module-IV

Optoelectronics : Classification and fabrication principles of optical fibres, Step and graded index fibers, Wave propagation in optical fiber media, Losses in fibre, Optical fiber source and detector, Optical joints and Coupler, Fiber characteristics; Basic principles of optical fiber communication, Digital optical fiber communication system.

Quantum Electronics: Spontaneous and stimulated emission of radiation, Einstein's coefficients, Laser rate equation and lasing condition. Three level laser system, He-Ne laser, Carbon dioxide laser, Q-switching, Semiconductor lasers, **Maser**; Technique and principle.

References:

1. Sze: Physics of Semiconductor Devices-Wiley Inter-science.
2. Grove: Physics and Technology of Semiconductor Devices-John Wiley.
3. Streetman: Solid State Electronic Devices-Prentice Hall India.
4. Smith: Semiconductors-Cambridge.
5. Dekker: Solid State Physics-Macmillan.
6. Lengyel: Introduction to Laser Physics-Wiley Inter-Science.
7. Ghatak: Laser Physics-Tata McGraw Hill.
8. Kao: Optical Fiber Systems Technology and Design-Tata McGraw Hill.
9. Gower: Optical Communication Systems-Prentice Hall India.
10. Keiser: Optical Fiber Communications-Tata McGraw Hill.
11. Senior: Optical Fiber Communication-Prentice Hall India.
12. Gandhi: Theory and Practice of Microelectronics-John Wiley.
13. Hovel: Solar Cells (Semiconductors and Semimetals, Vol. II)-Academic Press.
14. Green: Solar Cells-Operating Principles, Technology and System Application-Prentice Hall.

Unit – 18:Special Paper-(II)

Full Marks: 75 **Credit points: 3**

Solid State Physics Special-(II)

Module-I

Many Body Physics:

Fermi Liquid Theory: Interacting Fermi system; ^{3}He; ^{4}He; elementary excitations; quasi-particles and their energies; Landau expansion of free energy functional.

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

Transport Properties: First and zero sound.

Single particle propagator; spectral representation; Greens function for quasi-particles; retarded response functions; density fluctuation excitations and collective modes.

Properties of Electron Gas: Hartree-Fock approximation: exchange energy and quasi-particle energy in HF approximation.

Module-II

Optical Properties of Solids : 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; KramersKroenig relations; dispersion relations for dielectric function and $\varepsilon (\omega)$.

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.

Magnetic Resonance and Relaxation:

Basic Theory: Quantum mechanical description of spin in a static field; rotating magnetic field; Bloch equation and its solution in weak radio-frequency field.

Local field; magnetic dipole broadening and method of moments.

Magnetic interaction of nuclei with electrons; quenching orbital motion and chemical shift; Fermi contact interaction; Knight shift.

Spin-lattice Relaxation: Spin temperature and spin-lattice relaxation time; relaxation of nuclei in metals and Korringa relation.

Module-III

Superconductivity:

Survey of Experimental results: Zero resistance; persistent current perfect diamagnetism; critical magnetic fields; flux quantization; specific heat, entropy and latent heat; energy gap, microwave absorption; isotope effect; systematic.

Phenomenological Theory: Thermodynamics; London equations and magnetic field penetration; Pippards non-local modification of fluxoid.

Semi-Phenomenological theory: Superconducting order parameter and Ginzburg-Landau equations; G-L coherence l4ength and kappa parameter; flux quantization; upper critical field; surface energy.

Microscopic Theory of Superconductivity: Froehlich effective electron-electron attraction; Copper pairing; BCS theory of the ground state of Type I superconductors; significance of the energy gap parameter; elementary excitations in superconductors; density of states.

Tunneling Phenomena: Single electron and Cooper pair tunneling in normal junctions; Josephson superconducting and superconducting-superconducting equation; dc and ac Josephson effect; Shapiro steps; effect of magnetic field; superconducting interference; SQUID.

Introduction to high temperature superconductivity.

Module-IV

Transport Properties:

Boltzmann's Kinetic Equation: Collision term: relaxation time approximation; Kubo-Greenwood formulation of the transport problem.

Macroscopic Transport Coefficients: electrical conductivity; thermal conductivity; thermo emf; Peltier coefficient; Thomson coefficient-single and multiple charge carriers.

GalvanomagneticEffects: Hall mobility and magnetoresistance-single and multiple charge carriers, Giant magneto resistance (GMR) and Colossal magnetoresistance (CMR).

Relaxation Time: Charge carrier scattering and relaxation time; different scattering processes and corresponding cross sections.

References:

1. Pines and Nozieres: Theory of quantum Liquids-Benjamin.
2. Schrieffer: Superconductivity-Pergamon.
3. Ibach and Luth: Solid 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 – 18:Special Paper-(II)

Full Marks: 75 **Credit points: 3**

Nuclear and Particle Physics Special-(II)

Module-I

Group Theory : Definitions, Groups and their properties, Lie group, generators, Casimir operators, irreducible representations, U(1), 0(3), SU(2), SU(3) and SU(n), root and weight diagrams, Young tableaux.

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.

Module-II

Electromagnetic Interactions: Perturbation Theory: Time ordered and normal ordered products; Wicks theorem; propagators and Greens functions; vacuum expectation values; S matrix; Dysons expansion; Feynman rules; crossing symmetry; cross-section and decay rates.

Applications of perturbation theory: Compton effect and other examples.

RadiativeCorrections: one loop renormalization; regularization and power counting; renormalization-charge, mass and vertex corrections.

Weak Interactions:Phenomenology: Parity violation and V-A interaction; calculation of typical lifetimes (neutron, pion and muon decays). CVC and PCAC; charged and neutral currents; sum rules; Cabbibo theory; intermediate vector bosons.

Module-III

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 ($e^+ + e^- \rightarrow \mu^+ + \mu^-$),$W$ and Z decays, lifetimes, widths and branching ratios.

Hadron Structure and Strong Interactions: 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.

Module-IV

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.

Quantum chromo dynamics: Non-abelian SU (3) gauge invariance and QCD; QCD Lagrangian and Feynman rules; color; quark-quark interaction; gluons and gluon coupling; jets; confinement and asymptotic freedom.

The Standard Model: some tests for the model.

References:

1. Halzenand Martin: Quarks and Leptons-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: Introduction to Elementary Particles-John Wiley.
17. Kane: Modern Elementary Particle Physics-Addison Wesley.
18. Muirhead: Physics of Elementary Particles-Pergamon.

Unit – 18:Special Paper-(II)

Full Marks: 75 **Credit points: 3**

Electronics Special-(II)

Module-I

Communication Fundamentals : Antennas : Basic Considerations; antenna parameters; current distributions; short electric doublet; 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.

Propagation of Radio Waves: Types : G round and surface wave propagation; ionospheres; 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 multihop transmission; Chapmans theory; influence of earth's magnetic field; AppletonHartree formula; Propagation of microwaves through space; environmental effects; radiometer; microwave radiation hazards.

Module-II

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

Radar Communication: Duplexer, Radar display, Doppler Radar, CWIF Radar, FMCW Radar, Moving Target Indicator (MTI), Blind Speeds, Radar Applications.

Satellite Communication : Principle of satellite communication; satellite frequency allocation and band spectrum, communication satellite link design; digital satellite communication; multiple access techniques; demand assignment control; speared spectrum technique; code division; satellite orbit and inclination; satellite link design, satellite applications, ideas of global communication network.

Module-III

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

Digital Image processing: Basic concept; image capture; image sampling and quantization; spatial and intensity resolution; basic mathematical tools for image processing; zooming and interpolation; Geometrical transformation; affine transform; outline of image analysis and recording.

Module IV

Microprocessors and Microcontrollers: Basic idea of a microprocessor; 8085 architecture; registers; flags; interrupts; instruction set; concepts of assembly language programming; machine cycles; timing diagrams; I/O ports; PPI(8255A) : 8086P fundamentals; Memory segmentation; Interrupt handling; Idea of the recent advances of microprocessors; Basic concepts of microcontroller 8051; architecture and programming model.

References:

1. Millman and Taub: Digital and Switching Waveforms – McGraw Hill Kogakusha.
2. Taub and schilling: Digital Integrated Electronics – McGraw Hill Kogakusha.
3. Millman and Halkias: Integrated Electronics – McGraw Hill Kogakusha.
4. Jordan and Balmain: Radiation and Radiating Systems – Prentice Hall India.
5. Kennedy: Electronic Communication Systems – Tata McGraw Hill.
6. Taub and Schilling: Principles of Communication Systems – Tata McGraw Hill.
7. Carlson: Communication Systems – Tata McGraw Hill.
8. Haykin: Communication Systems – John Wiley.
9. Tanenbaum: Computer Networks – Prentice Hall.
10. Bertsekas and Gallaghr: Data Network – Prentice Hall.
11. Stallings: Data and Computer Communications – Prentice Hall.
12. Gaonkar: Microprocessor Architecture, Programming and Applications with 8085-19.
13. Gonzalez and Woods: Digital image processing – Prentice Hall.
14. Jain: Fundamentals of Digital Image Processing – Prentice Hall India.
15. Millman and Grabel: Microelectronics – McGraw Hill.
16. Millman: Microelectronics – McGraw Hill.
17. Malvino and Leach: Digital Principles and Applications – Tata McGraw Hill.
18. Terman: Electronic and Radio Engineering – McGraw Hill.
19. Kraus: Antenna – McGraw Hill.
20. Reich, Ordnung and Skalnick: Microwave Principles – Affiliated East West Press.
21. Sarkar: Microwave Propagation and Technique – S. Chand.
22. Rafiquazzaman: Microprocessors – Prentice Hall India.
23. Malvino:Digial Computer Electronics – Tata McGraw Hill.
24. D. V. hall: Microprocessor and interfacing – Tata McGraw Hill.

Unit – 19

Full Marks: 75 **Credit points: 3**

Group A: Project

Mull Marks = 50

Assessment of Project paper and marks distribution: 30 marks are kept for an assessment by the teachers during presentation of the Project and 20 marks are kept for an assessment by the project supervisor.

Group B: Numerical Methods and Computer Application

Full Marks: 25

Module-I

FORTAN Language: Introduction to FORTRAN; Input, output statements; Control statements; DO Loops; Data statements; String manipulation; WHILE structure; Arrays and subscripted variables; Sub programs; data files.

Module-II

Programming: Programming (FORTRAN language) of the numerical methods already taught in Module-II (Unit-6).

References:

1. Numerical Receipts (in FORTRAN) – Press *et al.*, Cambridge.
2. Programming in FORTRAN – Schawm's Outline Series, McGraw Hill.

Unit – 20: Elective Paper

Elective – 20A: Applied Nuclear Physics

Full Marks: 75 **Credit points: 3**

Module-I

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, critical size of reactors with different shapes.

Module-II

Nuclear Fission and Nuclear Fusion : Energy release in fission, Nature of the fission fragments, Energy distribution between the fission fragments, Emission of neutrons in nuclear fission, Energetics of fission process, Bohr Wheeler theory, Cross section of neutron induced fission, Particle induced and photofission, Shell effect and shape isomerism, Nuclear fusion and thermo-nuclear reaction, Cross section of fusion reaction, Lawson Criterion, Different methods of satisfying Lawson criterion, Magnetic confinement, Toroidal confinement; Tokamak.

Module-III

Nuclear Astrophysics: The Hertzsprung Russell diagram (HRD), Electromagnetic spectra and abundance determinations, Neutrino astronomy, evolution of stellar structure, Spallation reactions, the Big bang contribution to cosmic-nuclosynthesis. The chemical evolution of galaxies, Energy production in the Sun, and the solar neutrino problem, Non-explosive stellar evolution and concomitant nucleosynthesis,the hot modes of hydrogen burning, the He to Si explosive burnings, supernova. The s-process, r-process and the p-process, Heavy-element nucleosynthesis by the s-and r-processes of neutron captures, Nuclear Cosmochronology.

Module-IV

Different Radiation detection: Gas detector, Scintillation detector and Solid state detectors.

Applications : Trace Element Analysis, Mass Spectrometry with Accelerators, material modification by swift heavy ion radiation, Man-made sources of radiation, Biological effects of radiation : Physical and chemical damage; dose, dose rate; damage of tissue levels, Radiation shielding and its safety, Nuclear Medicine; Projection Imaging, with internal and external radiation, computed Tomography, Magnetic Resource Imaging Principles, Radiation therapy.

References:

1. M.K. Pal: Theory of Nuclear Structure-East West Affiliated Press.
2. Preston: Physics of the Nucleus-Addison Wesley.
3. Preston and 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 and Applications-Wiley.
9. Bohr and Mottelson: Nuclear Structure-I and II-Benjamin.
10. Greiner 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 – 20 B: Advanced Condensed Matter Physics and Materials Science

Full Marks: 75 **Credit points: 3**

Module-I

Physics in low dimensions: Quantum electron transport (Landauer formula); introduction to quantum wells, quantum wires and quantum dots wave functions and energy levels. Fullerene and Carbon nanotubes (single walled and multi-walled). Photonic crystals.Elementary idea about Graphenes.Idea of spin transport in low dimensional systems (Spintronics).

Module-II

Experimental Nano science: Introduction; particle size dependent phenomenon in materials; classical nucleation theory and cluster formation; Physical methods; Inert gas consideration; chemical vapor deposition; PLD; mechanical milling.

Chemical methods: Sol-gel, hydrothermal, solvothermal, metal reduction methods.

Characterization Techniques:X-Ray diffraction; Scanning Electron Microscopy; Transmission Electron Microscopy; UV-visible.

Properties of nanomaterials: Mechanical, electrical, magnetic, optical properties.

Module-III

Liquid crystals : Basic idea; Nematic, Cholestoric and Smectic phases; Discotic and Columner phases; phase sequences and phase diagrams; order parameter.

Unconventional superconductors: Unconventional superconducting materials; definition, characteristics; s-wave, d-wave and p-wave superconductors; superconductor terminology.

Module-IV

High $T_c$superconductors: Materials; normal and superconducting state properties; electronic models; brief outline of the algorithms; applications.

Heavy Fermion Superconductors: Definition and materials; normal state and superconducting properties of heavy Fermions; experimental evidence of unconventional superconductivity; interplay of magnetism and superconductivity.

Possible pairing mechanism of unconventional superconductors, Recent works on unconventional superconductors.

References:

1. Quantum Transport: Atoms to Transistors – SupriyoDatta, Cambridge.
2. Electronic transport in mesoscopic systems – SupriyoDatta, Cambridge.
3. Principles of Condensed Matter Physics – P.M. Chaikin and T.C. Lubensky, Cambridge.
4. Introduction to Nanoscience and Nanotechnology – K.K. Chattopadhyay and A.N. Banerjee, PHI.
5. Quantum Heterostructures – V. Mitin, Cambridge.
6. Applied Quantum Mechanics – W. Harrison, World Scientific.
7. High TC superconductivity and the C60 family, Edited by SunqiFeng and Hai-CangRen, Gordon and Breach Publishers.
8. G.R. Stewart, Rev. Mod. Phys. **56**, 755, 1984.
9. J G Bednorz and K Muller, Z. Phys. **B64**, 189, 1986.
10. P W Anderson, Science **235,** 1196, 1987.
11. E Dagotto, Rev Mod. Phys.**66,** 763, 1994.
12. E Dagotto, Phys Rev, **B45**, 10741, 1992.

Elective– 20 C: Applied Electronics

Full Marks: 75 **Credit points: 3**

Module-I

Crystal Growth: Growth of single crystals by Czochralski technique, distribution coefficient, rapid-stirring and partial-stirring conditions; zone processes.

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.

Thin Films: Production of thin films, conductivity and other properties of different types of thin films. Thin film solar cells.

Module-II

Thermal Oxidation and Doping: 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. Doping of impurities.Ion implanta\tion technique.

Microelectronics technology: Fabrication of integrated circuits using steps of epitaxial growth, thermal oxidation, masking and etching, diffusion of impurities, and metallization.

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, wiresand dots. Ideal hetero-junction.Super lattices and multi-quantum-wells, doping super lattices.

Module-III

Practical use of op-amps: Instrumentation amplifier; Log amplifier; differential amplifier; Practical integrator; and Comparator.

Practical digital circuits: Counters and Timers; Memory unit and array; Ideas of instrument control through microprocessor.

Module-IV

Television: Basic concept; TV camera; Display; Scanning; Composite video signal; Receiver block diagram; Color TV system; Concepts of modern TV circuit; Different mode of distribution network.

PLL and its uses: Basic PLL; frequency multiplier; Use in FSK and FM.

References:

1. Grove: Physics and Technology of Semiconductor Devices-John Wiley.
2. Holland: Vacuum Deposition of Thin Films-Chapman and Hall.
3. Chopra: Thin Films-McGraw Hill.
4. Gandhi: Theory and Practice of Microelectronics-John Wiley.
5. Mitin, Kochelap and Stroscio: Quantum heterostructures-Cambridge University Press.
6. Barnham and Vvedensky (Editors): Low-Dimensional Semiconductor Structures-Cambridge University Press.
7. Chopra and Das: Thin Film Solar Cells-Plenum Press.
8. Millman and Taub: Digital and Switching Waveforms – McGraw Hill Kogakusha.
9. Taub and Schilling: Digital Integrated Electronics – McGrawHillKogakusha.
10. Gaekwad: Op–Amps and Linear Integrated Circuits – Prentice Hall India.
11. Kennedy: Electronic Communication Systems – Tata McGraw Hill.
12. Taub and Schilling: Principles of Communication Systems – Tata McGraw Hill.
13. Carlson: Communication Systems – Tata McGrawHill.
14. Haykin: Communication Systems – John Wiley.

Unit – 21: Special Practical-(II)

Full Marks: 100 **Credit points: 4**

For Group-B Students

Solid State Physics Special Practical-(I)

1. To interpret a Debye-Scherer 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. Determination of density of color centers induced in alkali halides.
6. Study of thermoluminiscence.

Nuclear Physics Special Practical-(I)

1. Determination of half-life of Indium by thermal neutron activation and study of beta ray absorption.
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 ^{103}Rh* and to ^{104}Rh ground sate, and estimation of the spin cut-off parameter.

Electronics Special Practical-(I)

1. Design and construction of an IC regulated and stabilized power supply (constant voltage/constant current) and the study of its characteristics.
2. Design and construction of a multistage amplifier using BJTs and FETs and the study of its gain and bandwidth.
3. Design and construction of a simple pulse generator of variable frequency and width using IC 555 timer.
4. OP AMP based experiments: active filters, Wien bridge oscillator.
5. Construction and application of OP AMP comparator, Schmidt triggers.
6. Experiment based on PLL.
7. Experiment on Pulse Modulation using IC 555 timer.

For Group-A Students

Solid State Physics Special Practical-(II)

1. To measure the electrical conductivity of a sample by the four probe method and to study the variation of conductivity with temperature.
2. a) to determine the Hall coefficient, electrical conductivity, mobility and carrier concentration in a given material. b) To determine its magnetoresistance.
3. To determine the susceptibility of single crystals by Goe's method.
4. To use ESR for the study of solids.
5. Study of ferroelectric properties of solids by P-E loop tracer.

Nuclear Physics Special Practical-(II)

1. 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.
2. Beta spectroscopy with scintillation detectors and measurement of conversion electron fraction.
3. Gamma spectroscopy with scintillation detectors using single-channel and multi-channel analyzers: 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.
4. Measurement of the thickness of a thin foil from alpha energy loss.
5. Beta-gamma coincidence measurements: study of decay schemes and lifetime of nuclear levels.
6. Gamma-gamma coincidence measurements: angular correlation of the two positron annihilation gammas from ^{22}Na source.
7. Study of angle dependence of Compton shift and scattering cross section and determination of the classical electron radius.
8. Study of alpha scattering from metal targets and verification of the Rutherford formula and identification of the target element.

Electronics Special Practical-(II)

1. Study of the characteristics of a solar cell.
2. a) To setup 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.
3. Measurement of attenuation in optical fibres.
4. 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.
5. Study of transmission line characteristics.
6. Study of A/D and D/A conversion.