PHYSICS PG NEW SYLLABUS (CBCS)

Math Methods-50 marks 4 credit

Semester-1

Mathematical Methods

Complex Variables Function of a complex variable – single and multiple-valued function, limit and continuity. differentiability – Cauchy-Riemann equations and their applications; analytic function – singularity and zero of an analytic function; power series – radius of convergence and circle of convergence; analytic properties of power series, polynomials, exponential function, trigonometric and hyperbolic functions, the function of z; branch point and branch cuts. contours and Riemann's definition of definite integral; estimation of an integral of a complex function along a regular arc, Cauchy's theorem (for simply and multiply connected regions), Cauchy's integral formula for an analytic function(for simply and multiply connected regions) and its derivatives; Taylor's and Laurent expansions; classification of singularities; analytic continuation; residues – Cauchy's residue theorem, contour integrations, Jordan's lemma, principal value of an integral. (12 lectures)

Vector Space and Matrices Vector space: Axiomatic definition, Linear Independence, Bases, dimension, Inner Product; Schwartz's Inequality, Triangle inequality, Orthogonality of Vectors, Orthonormal Basis, Gram-Schmidt Process of orthogonalization.

Matrices: representation of linear transforms and change of base; similarity, orthogonal and unitarity transformations; independent elements of a matrix; eigen values and eigen vectors;

Functions of a matrix; Caley-Hamilton theorem; Commuting matrices; Orthogonality of normal matrices. Hermitian, orthogonal and unitary matrices as special cases of normal matrices. (13 lectures)

Theory of differential equations Fuch's theorem; Linear independence of solutions – Wronskian, second solution; Sturm-Liouville theory; Hermitian operators; Completeness, inhomogeneous differential Equations: Green's functions.

Special Functions A general approach starting from the differential equation as well as from the generating function (series expansion for small arguments, recurrence relations, orthogonality relation, etc.) for the Bessel, Legendre, Hermite and Laguerre Functions; Leading term in the asymptotic expansion of Bessel function; Integral representation of Bessel function; Second solution and its singularity (in connection with boundary value problems). (18 lectures)

Group Theory Definitions; Multiplication table; Rearrangement theorem; Semi groups; Subgroups–necessary and sufficient condition to be a subgroup; Cosets; Lagrange's theorem on subgroups; Conjugate elements, class and factor groups; Class multiplication; Isomorphism and homomorphism; Illustrations with point symmetry groups; Group representations – faithful and unfaithful representations, reducible and irreducible representations; Schur's lemma; The great orthogonality theorem; Character of are presentation and orthogonality relations for characters; Construction of character tables; Decomposition of reducible representations; Application of representation theory in quantum mechanics. (10 lectures)

Integral Transforms

Fourier and Laplace transforms and their inverse transforms, Bromwich integral (use of partial fractions in calculating the inverse of Laplace transforms); Transform of derivative and integral of a function; Solutions of differential equations using integral transforms. (7 lectures)

Classical Mech-50 Marks 4 credit

An overview of the Lagrangian formalism
Symmetries of Lagrangian, central force problem, Runge- Lenz vector, stability of circular orbit, small oscillations, normal modes and frequencies. (6 lectures)

Hamilton's principle
Calculus of variations; Hamilton's principle; Lagrange's equation from Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action. (10 lectures)

Canonical transformations
Generating functions; examples of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum; Poisson bracket relations. (10 lectures)

Hamilton-Jacobi theory
The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator
problem; Hamilton's characteristic function; Action angle variables. (4 lectures)

Rigid bodies
Inertia tensor and principal axis system; ; orthogonal transformations and rotations (finite and infinitesimal); Euler's theorem, Euler angles; Inertia tensor and principal axis system; Euler's equations; Heavy symmetrical top with precession and nutation. (12 lectures)

Introduction to Chaos
Stable and unstable fixed points, Linearization, Logistic Map, bifurcation route to chaos. (6 lectures)

Special theory of relativity
Lorentz transformations; 4-vectors, Tensors, Transformation properties, Metric tensor, Raising and lowering of indices, Contraction, Symmetric and antisymmetric tensors; 4-dimensional velocity and acceleration; 4-momentum and 4-force; Covariant equations of motion; Relativistic kinematics (decay and elastic scattering); Lagrangian and Hamiltonian of a relativistic particle. (12 lectures)

Quantum Mechanics I -50 Marks 4 credit

1 BASIC PRINCPLES OF QUANTUM MECHANICS

Heisenberg's uncertainty principle, implications in kinematics, Stern Gerlach

Experiment, Principle of superposition of states, illustration by schematic Sequential Stern Gerlach (6 lectures)

2.Dirac'sformulatipn of quantum mechanics: the description of states

The bra and ket space; Linear operators; Hermitian and unitary operators; Completeness; Matrix representation, change of basis; Formulation of quantum Description of dynamical states in bra(c) ket formalism. ; Observables. Compatible and incompatible observables, quantum mechanically Uncertainty product. and Heisenberg's principle. (8 lectures)

3 Coordinate and Momentum space

Coordinate and Momentum, operators ; x and p in these representations. Wave functions in position and momentum space. Complete set of commuting observables. Coordinate representation – wave mechanics . wave function , Schrodinger's equation. The time independent Schrodinger's equation. Energy eigenvalues
Stationary states. Scattering states and bound states. (6lectures)

4. The theory of angular momentum

Representation in terms of coordinates and momentum.. The angular momentum algebra.
Eigenvalues of the total angular momentum. The complete set of commuting observables for the angular momentum eigen-kets. Addition of angular momenta. Coupled and uncoupled states, the Clebsch Gordon coefficients.. Explicit calculation of the C-G coefficients for the individual angular momenta ½ ½ and ,1/2.,1.

Application of wave mechanics:
Three dimensional problems in Cartesian coordinates; 3D well and Fermi energy, Angular momentum operators, Spherical harmonics; Radial equation of free particle and three dimensional harmonic oscillator; Eigenvalue of a 3D harmonic oscillator by series solution. (8 lectures)

5 Approximate methods

Time independent perturbation theory (8)

First and second order corrections to the energy eigenvalues; First order corrections to the eigenvectors; Degenerate perturbation theory; Application to one electron system-Relativistic mass correction, Spin-orbit coupling, Zeeman effect and Stark effect.

6.. Variation method. Examples. (2 lectures)

7.Heliumatom

First order perturbation; Exchange degeneracy; Variational method; Ritz principle for excited states for Helium atom. (3 lectures)

8.WKB approximation
The method of WKB approximation, quantization rule, tunneling through a barrier; Qualitative discussion of alpha decay. (4 lectures)

9.Measurement and Interpretation
Double Stern-Gerlach experiment for spin-1/2 system; EPR paradox; Idea ofquantumentanglement;Hiddenvariables.Schrodinger‟scat;Reductionofwavefuncti on;QuantumXeno effect. (6 lectures)

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Electronics+Instrumentation - 50 Marks 4 credit

Electronics

1. Power circuits
Series-fed class A power amplifier; Transformer coupled class A power amplifier; Class B power amplifier; Harmonic distortion; Class AB operation, Class C operation. (4 lectures)

2. Basic network and filter
Image Impedances, Characteristics impedance, propagation constant, properties of symmetrical network**,** Filter fundamentals; pass and stop bands**,** constant K-low pass, high pass, band pass, band eliminator, active filter, simple examples. (8 lectures)

3. Transmission line
Transmission line equation and solution; Reflection and transmission coefficient; Standing wave and standing wave ratio; Line impedance and admittance; Impedance calculation in terms of source impedance and load impedance; Smith chart. (10 lectures)

4. Communication principle
Basic principles of amplitude, frequency, phase modulation, frequency spectra of modulated waves, power distribution in AM wave, square law modulator, balanced modulator, average and envelope detection, Double side band suppressed carrier modulation (DSBSC), Single side band modulation (SSB), Coherent detection of DSBSC modulated waves, frequency modulation method and demodulation, narrow band FM, Electromagnetic communication spectrum, Concept of Noise, signal-to-noise (S/N) ratio. Basic ideas of digital communication. Digital modulation techniques: Binary phase shift keying (BPSK), Differential phase shift keying (DPSK), Quadrature phase shift keying (QPSK), M-ARY PSK, frequency shift keying (FSK), M-ARY FSK, amplitude shift keying (ASK). (12 lectures)

5. Physics of semiconductor device
Basic semiconductor equations; p-n diode current voltage characteristics; PN diode capacitances; Ebers-Moll equation, heterojunction. (5 lectures)

Metal semiconductor junctions: Schottky barriers; Rectifying contacts; Ohmic contacts; Typical Schottky barriers. Characteristics of some semiconductor devices- Tunnel diode, Gunn diode and IMPATT. (6 lectures)

6. Digital Circuits
Digital to analog converter (R-2R ladder network, weighted register and modified weighted register), Sample and Hold circuits, quantization & encoding, analog to digital converter (Parallel comparator, successive approximation, dual-slop). (5 lectures)

7. Instrumentation
FTIR, UV-Visible spectroscopy, Scanning tunneling microscope, Transmission electron microscope, Scanning electron microscope. Propagation of errors, Distribution, Least square fit, Criteria for goodness of fit, Chi-square fit, Binomial distribution, Poisson and normal distribution. Production and measurement of high vacuum: Rotary pump, Diffusion pump, Turbomolecular pump, Ion pump; McLeod gauge, Pirani gauge, Penning gauge. Thin film technology, low temperature Physics. (10 lectures)

General Experiments -50 marks 4 credit

General Laboratory (Electronics) for Semester-I

1) Construction of a regulated power supply on a bread board, using (i) a power transistor as
pass element (ii) a second transistor as a feedback amplifier and (iii) a zener diode as a reference voltage source and to study its operational characteristics.

2) Construction of active low-pass, high-pass and band-pass filters circuit using OP-AMP.

3) Solution of differential equations using OP-AMP

4) Design and study of multivibrators

5) To design and fabricate a temperature controller and to study its performance characteristics

6) Design and study the ECL OR/NOR logic

NON-Electronics

1) Experiments with Michelson Interferometer.
2) Frank – Hertz Experiment.
3) Determination of ‘e’ by Millikan’s oil drop method.
4) Experiments with a G. M. counter.
5) Experiments with Laser and its characteristics.
6) Study of a Photovoltaic Cell.

Semester II

Electrodynamics: 50 Marks 4 credit

1. Introduction

Electrostatics and magnetostatics – an overview.; Multipole expansion of (i) scalar potential and energy due to bounded static charge distribution and (ii) vector potential due to bounded stationary current distribution; Electromagnetic Induction–Faraday's law .(5 lectures)

2. Electromagnetic fields

Maxwell's equations in stationary and moving media; Energy flow–Poynting vector; Maxwell's stress-tensor for electromagnetic fields; Electromagnetic momentum; Radiation pressure. (5 lectures)

3. Radiation from time-dependent sources of charges and currents

Scalar and Vector Potentials – gauge invariance of Electrodynamics; Inhomogeneous wave equations and their solutions by Green's function method; calculation of radiation from (i)monochromatic sources emitting pulses of finite duration and (ii) strictly monochromatic sources – multipole expansion of potentials in the radiation zone; Electric dipole radiation. (9 lectures)

4. Radiation from moving point charges

Lienard-Wiechert potentials; Fields due to a charge moving with uniform velocity; Fields due to an accelerated charge; Radiation at low velocity and corresponding frequency spectrum of the outgoing radiation; Radiation when velocity (relativistic) and acceleration are parallel; Bremsstrahlung; Synchrotron radiation; Cherenkov radiation (qualitative treatment only). (14 lectures)

5. Radiation reaction, scattering and dispersion

Radiation reaction from energy conservation; Line breadth and life time of charged harmonic oscillator; Scattering of electromagnetic radiation by free and bound electrons; Radiation reaction as damping term in dispersion; Kramers-Kronig dispersion relation. (9 lectures)

6. Relativistic electrodynamics

Electromagnetic field tensor – covariance of Maxwell's equations; Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion; Field in variants--$E.B$ and $E^2 - B^2$; Covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field; Energy-momentum tensor and the conservation laws for the electromagnetic field; Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field. (10 lectures)

7. Plasma physics

Definition of plasma; Individual particle model --motion of plasma particles placed in electric and magnetic field; Magnetic mirrors. Magnetohydrodynamic approximation –Basic equations and wave propagation; Pinch Effect; Plasma Oscillations and Debye length. (8lectures)

Quantum Mechanics II - 50 marks 4 credit

WKB Approximation
Quantization rule, tunnelling through a barrier, qualitative discussion of α-decay. (3 lectures)
Time-dependent Perturbation Theory
Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations — Fermi's Golden rule; Sudden and adiabatic approximations. absorption – stimulated emission ; the dipole approximation and selection rules. (7 lectures)
Scattering theory
Laboratory and centre of mass frames, differential and total scattering cross-sections, scat-
tering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and
phase shifts; Ramsauer-Townsend effect; Relation between sign of phase shift and attractive
or repulsive nature of the potential; Scattering by a rigid sphere and square well; Coulomb
scattering; Formal theory of scattering — Green's function in scattering theory; Lippman-
Schwinger equation; Born approximation. (11 lectures)

Symmetries in quantum mechanics
Conservation laws and degeneracy associated with symmetries; Continuous symmetries —
space and time translations, rotations; Rotation group, homomorphism between SO(3) and
SU(2); Explicit matrix representation of generators for j = 1/2 and j = 1; Rotation matrices;
Irreducible spherical tensor operators, Wigner-Eckart theorem; Discrete symmetries — par-
ity and time reversal. (12 lectures)

Identical Particles
Meaning of identity and consequences; Symmetric and antisymmetric wavefunctions; Slater
determinant; Symmetric and antisymmetric spin wavefunctions of two identical particles;
Collisions of identical particles. (3 lectures)

Relativistic Quantum Mechanics
Klein-Gordon equation, Feynman-Stückelberg interpretation of negative energy states and
concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave so-
lution and momentum space spinors; Spin and magnetic moment of the electron; Non-
relativistic reduction; Helicity and chirality; Properties of γ matrices; Charge conjugation;
Normalization and completeness of spinors. (9 lectures)
Stat Mech-50 marks 4 credit

Introduction
Objective of statistical mechanics, macrostates, microstates, phase space and ensembles. ergodic hypothesis, postulate of equal a-priori probability and equality of ensemble average and time average, Liouville theorem. (5 lectures)

Interactions between two systems – thermal, mechanical and diffusive
Thermal interaction – concept of temperature and entropy, $S = K_B ln\,\Omega$, relation for a microcanonical system, nature of probability of finding a particular microstate of a system in thermal equilibrium, mechanical interaction – generalized force, diffusive interaction – chemical potential, counting of microstates of classical ideal gas and classical harmonic oscillator. (10 lectures)

Canonical ensemble
System in contact with a heat reservoir, partition function, evaluation of thermodynamic functions, energy fluctuation, d-dimensional classical ideal gas in canonical ensemble, virial theorem, Gibbs paradox and the resolution of the paradox. (6 lectures)

Grand canonical ensemble
System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number. Chemical potential of ideal gas, equivalence of ensembles. (4 lectures)

Classical non-ideal gas
Mean field theory and Van der Waals equation of state. (4 lectures)

Quantum statistical mechanics
Density matrix; Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices – one electron in a magnetic field, particle in a box; Identical particles – BE and FD distributions. (7 lectures)

Ideal Bose and Fermi gas
Equation of state, Chemical potential of bosons, Bose Einstein condensation- estimation of critical temperature for Bose Einstein condensation, variation of condensate fraction with temperature, examination of pressure, specific heat, free energy and entropy of ideal Bose gas, properties of liquid Helium. (7 lectures)

Ideal Fermi gas
Equation of state, thermodynamic functions at $T = 0$, Fermi energy, Fermi momentum, Fermi temperature, derivation of Sommerfeld expansion- low temperature behaviour of chemical potential, average energy and specific heat, white dwarf stars and Chandrasekhar limit. (6 lectures)

Special topic
Ising model – exact solution for one dimensional case, mean field theory of Ising model, evaluation of critical exponents. (5 lectures)

Non-equilibrium Statistical Mechanics
Irreversible processes, Classical Linear Response Theory, Brownian Motion, Master Equation, Fokker-Planck Equation, Fluctuation-Dissipation Theorem. (6 lectures)

Gen Expt -50 marks 4 credit

General Laboratory (Electronics) for Semester-II

1) Designing of modified weighted resistor digital to analog (D/A) converter.

2) Construction and study of analog to digital (A/D) converter

3) Construction and study of decade and other counters

4) Study of amplitude modulation and demodulation

5) Study of frequency modulation and demodulation

6) Programming the 8085 microprocessor

Non-electronics

1) Study of Surfaces and Interfaces using Optical Metallurgical Microscopy.
2) Determination of Lande g-factor by ESR Spectroscopy.
3) Experiments with Fibre Optics.
4) Study of a LED.
5) Experiments based on Faraday Effect.
6) Specific Heat Capacity of Solids.

Computer-50 marks 4 credit
(Fortran90,Python Languages only)

Module 1:
Finding roots of a functions by Newton Rapson, Bisection and a Hybrid of them. Applications to polynomials (all roots including complex ones). Transcendental and its combination with other functional forms. (3 Lectures)

Module2:
Solutions of simultaneous algebraic equations: Gauss elimination with pivoting, Gauss-Siedel and Jacobi. Inversion and Diagonalization of matrix (Jacobi). (6 Lectures)

Module3:
Interpolation: Lagrange interpolation with equal and unequally spaced data points: Derivation of Newton-Cotes integration formulas with two, three, four, five data points. Composite formulas. First and Second order differentiation formulas. Spline interpolation. (6 Lectures)

Module 4
Numerical solution of differential equations: solution of first and second order ODE, Euler and Runge Kutta methods; implementation with predictor corrector.
Solution of partial differential equations in two and three independent variables. (7 Lectures)

Module 5
Numerical integration: Application of Newton-cotes and Gaussian Quadrature formulas. Integration of tabulated data points. 2D and 3D integration, Monte Carlo method. (5 Lectures)

Module 6
Curve fitting: Least square fitting to data points, Linear and non liear fit. Polynomial function, exponential, harmonic and combination of them. (4 Lectures)

Module 7
Application of Fourier methods: Discrete Fourier transform and Fast Fourier transform of function and tabulated data points. Convolution and correlation. (7 Lectures)

[For each module simple codes have to developed]

Module 8
Application to Physical problems:(1) Diffraction Intensity expression by single slit of finite dimension and straight edge. Plotting of data (2) Finding bound state eigenvalues in QM finite square well problem. (3) To find eigenvalues and eigenvectors in a double well potential (few states). Plotting of Probability functions (4) Numerical solution of radial Schrodinger equation in a central atomic potential. Verify virial theorem. Plotting of radial probabilities for 1s, 2s,3s,2p,3p and 3d states. (5) To find eigenvalues and eigenfunctions for few states for an anharmonic 1D oscillator. Calculation of <r> at finite temperature. (6)Find out numerically the temperature dependence of chemical potential of a non interacting bose gas.(7)Phase space averaging
of physical quantities: energy of a classical 1D oscillator(8)Numerical solution of Duffing oscillator
and plotting of phase portrait in nonlinear dynamics problem (9)Spectrum analysis by FFT of a given tabulated data. Plotting of output(10)Consider a box function, find autocorrelation function. Plotting of output. (12 Lectures)

Marks Distribution: LNB-10, Open Viva-10, Expt:30 (Examination hoursrs 4)
(there will be two LNB one for modules 1-7 and other for module 8 only, at least 8 problems have to be done from Module 8)

Old MSc Physics Syllabus
COURSE STRUCTURE

Semester – III

Atomic, Molecular and LASER Physics

1. One electron atom (2):
Introduction; Quantum states; Atomic orbitals;Parity of the wavefunction; Angular and radial distribution functions.

2. Interaction of radiation with matter (3):
Time-dependent perturbation theory; Rate expression; Radiation-electric dipole interaction; Line shape function; Selection rules for one electron atom.

3. Line shape and line width (2):
Time correlation function and spectral Fourier transform; Properties of time correlation functions; Spectral line shape and line width.

4. Fine and hyperfine structure (5):
Solution of Dirac equation in a central field; Relativistic correction to the energy of one electron atom; Fine structure; Alkali spectra; Hyperfine interaction and isotope shift; Hyperfine splitting of one electron atomic spectrum; Selection rules.

5. Many- electron atom (3):
Independent particle model; Central field approximation; Equivalent and non-equivalent electrons; Energy levels and spectra; Hund's rule; Spectroscopic terms.

6. Nuclear motion (3):
Separation of electronic and nuclear motions; Born-Oppenheimer approximation; Solution of equation for nuclear motion – Morse potential.

7. Microwave spectroscopy (4):
Classification of molecules according to their symmetry properties; Rotational spectrum of diatomic molecules as rigid or non-rigid rotor; Energy levels, selection rules and spectrum; Intensity of the spectral lines; Energy levels and spectrum of symmetric-top-like molecules.

8. Infrared spectroscopy (4):
Vibrating diatomic molecule; Harmonic oscillator approximation; Anharmonicity; Selection rules for harmonic and anharmonic oscillators; intensity of spectral lines; Vibrating rotator; Rotational fine structure of vibration spectrum; P,R branches.

9. Electronic spectroscopy (7):
Electronic spectra of diatomic molecules; Vibrational coarse-structure of electronic bands; Intensity distribution; Frank-Condon principle; Dissociation and pre-dissociation;

Dissociation energy; Rotational fine-structure of electronic bands; P, Q, R branches; Shapes of molecular orbitals; Pi and sigma bonds; Symmetry; Spectroscopic terms.

10. Molecular symmetry and Group theory (4):

Matrix representation of the symmetry elements of a point group; Reducible and irreducible representations; Character tables for C_{2v} and C_{3v}
point groups; Normal coordinates and normal modes; Application of group theory to molecular vibration.

11. Raman effect(3):

Quantum theory; Molecular polarizability; Pure rotational, pure vibrational and vibrational-rotational Raman spectra of diatomic molecules; Intensity alteration in Raman spectra of diatomic molecules; Application of IR and Raman spectroscopy in the structure determination of simple molecules (qualitative.)

12. LASER Physics and application(10):

Spontaneous and stimulated emission; Einstein's coefficients; Idea of light amplification; Threshold condition for LASER excitation; Pumping schemes; Three and four-level LASERs. Ruby, carbon dioxide, dye and semiconductor LASERs; Optical resonators; Longitudinal and transverse modes; Mode selection; Q-switching; Mode locking; Monochromaticity; Temporal and spatial coherence; Saturation spectroscopy; Homogeneous and inhomogeneous broadening; Burning and detection of holes in Doppler broadened two-level systems.

Nuclear and Particle Physics

1**. General properties of nuclei**: **(4)** ;
nuclear radius, charge distribution, form factor, spin and magnetic moments, parity, angular momentum, electric quadrupole moments, meson theory- quarks and lepton-overview.

2. **Two-nucleon problem and nuclear forces**: **(8)**
Deuteron ground state, excited states, two-nucleon scattering, n-p scattering, partial wave analysis, phase-shift, scattering length, charge symmetry and charge independence of nuclear forces. Exchange nature of nuclear forces, elementary discussion on Yukawa's theory.

3. **Nuclear model (7**)
Basic need, Fermi gas model, shell model, collective model –rotational states and vibrational level.

4. **Nuclear reactions**: (9)
Direct and compound nuclear-reactions, experimental verification of Bohr's independence-hypothesis, resonance reactions, Breit-Wigner one-level formula, Compound nucleus formation and break-up, Statistical theory of nuclear reactions and evaporation probability, Optical model, Transfer reactions, Nuclear fission: Experimental features, spontaneous fission, liquid drop model, barrier penetration, statistical model, Super-heavy nuclei, Nuclear reactor, India's peaceful nuclear programme, nuclear waste and problems.

5. β-decay and γ-decay (9)
β emission and electron capture, Fermi's theory of allowed β decay, Selection rules for Fermi and Gamow-Teller transitions, Parity non-conservation and Wu's experiment.
γ-electric and magnetic transition, angular momentum selection rule, Mossbauer Effect.

6. Detector material and nuclear instrumentation: **(6)**
Radiation, Bethe-Bloch formula for charge particle energy loss, gamma ray energy loss, energy and time resolution of a detector, different nuclear radiation detectors, ADC, DAC, preamp and amplifier, pulse height discriminator, SCA, MCA.

7. Particle Physics: **(12)**
Symmetries and conservation laws, Hadron classification by isospin and hypercharge, SU(2) and SU(3):Groups, algebras and generators; Young tableaux rules for SU(2) and SU(3); Quarks; Colour; Elementary ideas of electroweak interactions and standard model.

Statistical Mechanics

1. Fundamentals and microcanonial systems (6)
Objective of statistical mechanics; Method of statistical mechanics, macrostates, microstates, probability, ensembles, ergodicity, postulate of equal a priori probability.

2. Interactions between two systems – thermal, mechanical and diffusive (10)
Thermal interaction – concept of temperature and entropy, $S = k \ln \Omega$ relation for a microcanonical system, heat, second law of thermodynamics for a classical ideal gas; Nature of $\rho(E)$ distribution in equilibrium after thermal interaction; Mechanical interaction – generalized force; First law and equation of state for an isolated system; Diffusive interaction – chemical potential.

3. Canonical systems (6)
Partition function; Equation of state; Energy fluctuation and C_v **;** Microcanonical and canonical distributions using Lagrange's undetermined multiplier; Entropy of an ideal gas mixture according to Classical Statistical Mechanics and Gibbs' paradox.

4. Grand canonical system (4)
Partition function; Equation of state; Fluctuation in the number of particles; $PV = kT \ln Z$ relation.

5. Classical non-ideal gas (4)
Mean field theory and Van der Waals equation of state.

6. Quantum statistical mechanics (8)
Density matrix; Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices – one electron in a magnetic field, particle in a box; Identical particles – BE and FD distributions.

7. Ideal Bose and Fermi gas (9)
Equation of state; Bose condensation; Equation of state of ideal Fermi gas, Fermi gas at T = 0 K and above; Variation of Fermi energy with temperature and specific heat of free electron gas.

8. Special topics (8)
Ising model – partition function for one dimensional case; Chemical equilibrium and Saha ionization formula; Phase transition and critical indices, Landau's theory.

9. Non-equilibrium statistical mechanics (5)
Introduction; Boltzmann's H-theorem; Relaxation; The Fokker-Planck equation.

Solid State Physics

1. Crystal structure (8)
Bravais lattice – primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; Symmetry operations and classification of 2-d and 3-d Bravais lattices; Crystal structure – basis, crystal class, point group and space group (information only); Common crystal structures – NaCl and CsCl structure, crystals of alkali and noble metals, close packed structure, cubic ZnS structure; Reciprocal lattice and Brillouin zone; Bragg and Laue formulation of X-ray diffraction by a crystal; Atomic and crystal structure factors; Experimental methods of X-ray diffraction – Laue, rotating crystal and powder method; Electron and neutron diffraction by crystals (qualitative discussion); Intensity of diffraction maxima; Extinctions due to lattice centering.

2. Band theory of solids (6)
Bloch equation; Empty lattice band; Nearly free electron bands; Band gap; Number of states in a band; Tight binding method; Effective mass of an electron in a band – concept of holes; Band structures in copper, GaAs and silicon; Classification of metal, semiconductor and insulator; Fermi surface – cyclotron resonance; Boltzmann transport equation – relaxation time approximation, electrical and thermal conductivity.

3. Lattice dynamics (7)
Classical theory of lattice vibration under adiabatic and harmonic approximation; Vibrations of linear monatomic and diatomic lattices, accoustical and optical modes, long wavelength limits; Optical properties of ionic crystal in the infrared region.; Adiabatic approximation (qualitative discussion); Normal modes and phonons; Inelastic scattering of neutron by phonon; Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity; Anharmonic effects in crystals – thermal expansion and thermal conductivity; Mossbauer effect.

4. Dielectric properties of solids (5)
Static dielectric constant – electronic and ionic polarization of molecules, orientational polarization, static dielectric constants of gases; Lorentz internal field; Static dielectric constants of solids; Complex dielectric constant and dielectric losses, relaxation time; Classical theory of electronic polarization and optical absorption; Ferro-electricity -- dipole theory, case of BaTiO3.

5. Magnetic properties of solids (7)
Origin of magnetism; Diamagnetism – quantum theory of atomic diamagnetism, Landau diamagnetism (qualitative discussion); Paramagnetism – quantum theory of paramagnetism, case of rare-earth and iron-group ions, crystal field splitting, quenching of orbital angular momentum; Van-Vleck paramagnetism and Pauli paramagnetism; Ferromagnetism – Curie-Weiss law, temperature dependence of saturated magnetization, Heisenberg exchange interaction, ferromagnetic domains; Ferrimagnetism and antiferromagnetism; Neutron scattering and magnetic structures.

6. Magnetic resonances (3)
Nuclear magnetic resonance, Bloch equations, longitudinal and transverse relaxation time; Hyperfine field; Electron-spin resonance.

7. Imperfections in solids and optical properties (6)
Frenkel and Schottky defects, defects in growth of crystals; The role of dislocations in plastic deformation and crystal growth; Colour centres and photoconductivity; Luminescence and phosphors; Alloys – order-disorder phenomena, Bragg-Williams theory; Extra specific heat in alloys.

8. Superconductivity (8)
Phenomenological description of superconductivity – occurrence of superconductivity, destruction of superconductivity by magnetic field, Meissner effect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect; Outlines of the BCS theory; tunneling; Flux quantization and Josephson effect; Vortex state (qualitative discussions); High T_C superconductors (information only).

Numerical Methods

Integer and floating pont arithmetic, errors; Determination of zeroes of linear and transcendental equations by bisection and Newton-Raphson method, convergence of solutions; Solution of simultaneous linear equations; Gauss elimination, pivoting, iterative method (Gauss-Seidal method) and convergence, Gauss Jordan method and matrix inversion; Interpolation with equally and unevenly spaced points: Lagrange's interpolation and interpolation using difference tables; Curve fitting by least square method; Numerical differentiation, numerical integration by trapezoidal rule, Simpson's rule and Gaussian quadrature; Numerical solution of ordinary first order differential equations by Euler and Runge-Kutta methods, reduction of higher order differential equations; Miscellaneous topics; Sorting, random number generators, etc.

SEMESTER IV

Advanced I:

Condensed Matter Physics I

1. Fundamentals of many-electron system : Hartree-Fock theory (13)
The basic Hamiltonian in a solid – electronic and ionic parts, the adiabatic approximation; Single-particle approximation of the many-electron system – single product and determinantal wave functions, matrix elements of one and two-particle operators; The Hartree-Fock (H-F) theory – the H-F equation, exchange interaction and exchange hole, Koopmans theorem; The occupation number representation – the many electron Hamiltonian in occupation number representation; the H-F ground state energy.

2. The interacting free-electron gas : Quasi electrons and Plasmon (17)
The H-F approximation of the free electron gas-exchange hole, single-particle energy levels, the ground state energy; Perturbation theoretic calculation of the ground state energy; Correlation energy – difficulty with the second order perturbation theoretic calculation, Wigner's result at high density, low density limit and Wigner interpolation formula; Cohesive energy in metals; Screening and Plasmons; Experimental observation of plasmons; The dielectric function of the electron gas; Friedel oscillation; Quasi-electrons; Landau's quasi-particle theory of Fermi liquid; Strongly correlated electron gas; Mott transition.

3. Spin-spin interaction : Magnons (12)
The exchange interaction; Direct exchange, superexchange, indirect exchange and itinerant exchange; Spin-waves in ferromagnets – magnons, spontaneous magnetization, thermodynamics of magnons; Ferromagnetic domains, anisotropy energy and Bloch wall; Spin-waves in lattices with a basis – ferri- and antiferromagnetism; Ordered magnetism of valence and conduction electrons, the collective electron model; Kondo effect; Measurement of magnon spectrum.

4. Superconductivity (10)
Electron-electron interaction via lattice – Cooper pairs; BCS theory; Ginzburg-Landau theory and London equation; Meissner effect; Type II superconductors – characteristic length; Josephson effect; "Novel High Temperature" superconductors.

5. Disordered systems (13)
Disorder in condensed matter – substitutional , positional and topographical disorder; Short and long range order; Atomic correlation function and structural descriptions of glasses and liquids; Anderson model for random systems and electron localization; mobility edge; Qualitative application of the idea to amorphous semiconductors and hopping conduction.

Advanced II:

Condensed Matter Physics (Advanced paper II)

1. Symmetry in crystals (7)

Concepts of point group; Point groups and Bravais lattices; crystal symmetry – space groups; Experimental determination of space groups; Symmetry and degeneracy - crystal field splitting; Kramer's degeneracy; Quasicrystals – general idea; approximate translational and rotational symmetry of two-dimensional Penrose tiling; Frank-Casper phase in metallic glass.

2. Lattice dynamics (12)

Classical theory of lattice vibrations in 3-dimensions under harmonic approximation; dispersion relation – acoustical and optical, transverse and longitudinal modes; lattice vibrations in a monatomic simple cubic lattice; frequency distribution function; normal coordinates and phonons; occupation number representation of the lattice Hamiltonian; thermodynamics of phonons; the long wavelength limits of the acoustical and optical branches; neutron diffraction by lattice vibrations; Debye-Waller factor; atomic displacement and melting point; phonon-phonon interaction; interaction Hamiltonian in the occupation number representation; thermal conductivity in insulators.

3. Electron states (8)

Bloch's theorem; symmetry of the reciprocal lattice; translational and rotational symmetry of electron energy in the reciprocal space; representation of bands in different schemes; plane wave; orthogonalized plane waves and the pseudopotential metod; density of states; principles of photoelectron sspectroscopy.

4. Electronic properties:I (7)

Motion of electrons in bands and the effective mass; currents in bands and holes; scattering of electrons; the Boltzmann transport equation and relaxation time; electrical conductivity of metals – scattering due to impurities; resistance at high and low temperatures; U-processes; thermoelectric effects; thermal conductivity; the Wiedemann-Franz law; phonon drag.

5. Electronic properties:II (8)

Electronic properties in a magnetic field; classical theory of magnetoresistance; Hall effect and magnetoresistance in the two band model; k-space analysis of electron motion in a uniform magnetic field; idea of closed, open and extended orbit; cyclotron resonance; other types of resonance; energy levels and density of states in a magnetic field;Landau diamagnetism; de Hass-van Alphen effect; quantum Hall effect; magnetic breakdown.

Elective papers:

Astrophysics

I. **Astrophysics**: Preliminaries (1)

II. **Solar Astrophysics**: Solar system – description; Sun – size, mass, distance, density, temperature distribution, radiation, composition, deferent parts, energy source, radiative processes, solar neutrino problem; Planets – general features, origin of solar system (7)

III. **Fluid Astrophysics**: hydrostatic equilibrium, Lane-Emden equations and their solutions, mass and radius of a polytropic star (4)

IV. **Stellar Evolution**: protostar, birth of a star, H-R diagram, evolution with deferent initial masses, Supernova explosion & remnants (6 lectures)

V. **Compact Stars**: White Dwarf; Neutron Star; Pulsar; Black Hole (5)

VI. **Galaxy**: Classification of galaxies, formation; clusters and large scale structures; Quasars and active galactic nuclei; Milkyway and local group (5)

VII. (a) **Dynamics of gravitational field**: Einstein's field equations; Bianchi identities and conservation of the stress tensor; Einstein's equations for weak gravitational fields; The Newtonian limit (4)

(b) **Schwarzschild metric and related topics**: Derivation of Schwarzschild metric; Basic properties of Schwarzschild metric coordinate-systems and nature of R=2M surface; Effective potential for particle orbits in Schwarzschild metric, general properties; Gravitational red-shift (4)

(c) **Astro-particle physics**: Cosmic rays; On-going searches for exotic particles from extra-terrestrial sources; gravitational waves (10)

(d) **Cosmic phenomena**: Dark matter; Dark energy; Cosmological constant and expanding Universe (14)

Advanced Statistical Mechanics

1. Classical Ising model (18) (i) Definition of the Ising model, application to binary alloy and lattice gas, mean field approximation for arbitrary dimension. (ii) One dimensional Ising model under external field by transfer matrix method, exact calculation, nature of phase transition (two spin space correlation function). (iii) Two dimensional Ising model under zero external field: High and low temperature expansion, expression for T by duality transformation. (iv) Mean field theory in ferromagnetic systems, critical exponents, breakdown of MFT for dimensions less than 4. (v) Kinetic Ising model: Stochastic Dynamics, Relaxation, Critical dynamics (introduction only), Single spin-flip Glauber model; Conserved Ising model - Kawasaki dynamics. (vi) Principles of computer simulation of Ising model by Monte Carlo algorithm and Molecular dynamics.

2. Quantum Ising Model (5) Introduction. Transverse Ising Model: Duality transformation and exact solution for the energy eigenvalues.

3. Phase transitions and critical phenomena (24) (a) Basic themes: Liquid-gas and uniaxial ferromagnetic phase transitions, first order and continuous phase transi- tions and criti_cal points, behaviour of thermodynamic functions near the critical point, convexity properties, critical exponents, scaling and hyperscaling relations, universality: Percolating systems geometric phase transition, self similarity and fractals. (b) Beyond mean field theory: Landau theory of phase transitions, critical exponents, Landau-Ginzburg hamilto_nian (φ 4 theory), Gaussian approximation for $T < Tc$ and $T > Tc$ partition function and thermodynamics. (c) Block spin transformation, scaling hypothesis etc: Classical models of the cell Hamiltonian, block hamiltonian and Kadanoff transformation, correlation length and statement of scaling hypothesis, scaling dimension, scale transformation and dimensional analysis. Critical phenomena in finite systems: finite size scaling ansatz. (d) Renormalisation group: Real space renormalisation group (RSRG): Motivation, definition of RG, recursion re_lations and fixed point, relevant, irrelevant and marginal parameters, flow diagrams, scaling field, critical exponent. (e) Percolation: RSRG in square and triangular lattices.

4. Irreversible Thermodynamics (6) Flux and Affinity, Correlation functions of fluctuations, Onsager Reciprocity Theorem, Thermoelectric effect.
5. Real Gas(3) Equation of State, Mayer-Ursell cluster expansion.
6. Applications in Quantum Statistical Mechanics
(7) Superfluidity, Thermionic effect of electrons, Photoelectric effect, Theory of neutron and white-dwarf stars. 7. Nonequilibrium Statistical Mechanics (6) Random Walk, Correlation functions, Langevein equation, Stationary Process.

High Energy Physics

1. Canonical quantization of free fields
Euler-Lagrange equation; Noether's symmetry; Real and complex scalar fields; Dirac (spinor) field; Electromagnetic field.

2. Interacting fields
Interaction picture; Covariant perturbation theory; Wick's theorem; Feynman diagrams.

3. Quantum electrodynamics
Feynman rules; Example of actual calculations such as Compton, Bhabha or Moeller scattering and $e^+e^- \rightarrow \mu^+\mu^-$, elastic e-p scattering; Electromagnetic form factors; Fermi theory of beta decay.

4. Renormalization
One loop diagrams; Basic idea of regularization and renormalization.

5. Introduction to functional method
Functional derivatives, generating functional, scalar field theory in functional form.

6. The Lorentz group
Continuous and discrete transformations – group structure, the SL(2,C) group, representations; Determination of spin and parity of particles; Relativistic kinematics; Mandelstam variables; Bilinear covariants; Trace relations.

7. Lie groups and its applications
Lie algebra and Lie group – representations, SU(2) and SU(3) symmetries; Global symmetry – isospin, quark model; Local symmetry – gauge invariance in QED.

8. Non-abelian gauge theories
Yang-Mills theory; Introduction to quantum chromodynamics – asymptotic freedom.

9. Symmetry breaking and its implications
Spontaneous symmetry breaking; Higgs' mechanism; Introduction to electroweak theory – masses of gauge bosons; Masses of fermions; Explicit symmetry breaking – finite and non-zero masses of pseudoscalar mesons.

Physics Teaching Methodology

1. Designing a course in Physics; preparation of course material; use of web (WWW)-based resources.

2. Presentation: Proper use of black/white board. Use of models and other teaching aids. Application of the Power-Point Presentation technique. Importance of worked-out examples.

3. Evaluation of students' learning. Continuous versus half-yearly/annual evaluation. Necessity of students' assessment of teacher.

4. Project work.

Marks distribution:

Theory: 25 marks
Project work and presentation : 25 marks

Advanced Experiments (Condensed Matter Physics)

1. Measurement of the band-gap of a semiconductor by the four-probe method
2. Dispersion relations in periodic electrical circuits – Study of the electrical analogues of monatomic and diatomic chains
3. Measurement of dielectric constant
4. Study of magneto-resistance and Hall effect at different temperatures
5. Measurement of magnetic susceptibility of $FeCl_3$ /$MnSO_4$ by Quincke's method
6. Study of the ferromagnetic-paramagnetic phase transition of ferrite