COURSE STRUCTURE

Semester -I

Mathematical methods I	Marks- 50
Classical Mechanics	Marks – 50
Quantum Mechanics I	Marks -- 50
Electronics	Marks – 50
General Experiments I	Marks – 100
	Total - 300

Semester - II

Mathematical Methods II	Marks – 50
Classical electrodynamics	Marks -- 50
Quantum Mechanics II	Marks – 50
Instrumentation	Marks -- 25
Computer Programming	Marks – 25
General Experiments II	Marks – 100
	Total - 300

Semester – III

Atomic, Molecular and LASER Physics	Marks – 50
Nuclear and Particle Physics	Marks – 50
Statistical Mechanics	Marks – 50
Solid State Physics	Marks – 50
Numerical Methods	Marks -- 50
	Total --- 250

Semester – IV

Advanced Paper I	Marks – 50
Advanced Paper II	Marks - 50
Elective paper	Marks – 50
Advanced Experiment/ Project/Review	Marks – 100
	Total - 250

Total marks : 1100

Advanced paper:

Choice A:
Condensed Matter Physics I
Condensed Matter Physics II
Condensed Matter Physics (Advanced Experiments)

Choice B:
Advanced Electronics I
Advanced Electronics II
Electronics (Advanced Experiments)

Elective papers:

Choice A: Astrophysics
Choice B: High Energy Physics
Choice C: Physics Teaching Methodology
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SEMESTER -I

Mathematical Methods I

1. Complex Variables [15]
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, Cauchy's Integral formula for an analytic function and its derivatives; Taylor's and Laurent expansions; Classification of singularities; Analytic continuation; Residues – Cauchy’s residue theorem, contour integrations, principal value of an integral.

2. Theory of differential equations [10]
(a) Second Order Linear Homogeneous differential Equations:
Singular Points – regular and irregular singular points; Frobenius method; Fuch’s theorem; Linear independence of solutions – Wronskian, second solution; Sturm-Liouville theory; Hermitian operators; Completeness.
(b) Inhomogeneous differential Equations: Green's functions.

3. Special Functions [10]
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).

4. Vector Space and Matrices [15]

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

(b) Matrices:
Representation of linear transforms and change of base; Partititioning of a matrix; Orthogonal, unitary, adjoint, hermitian matrices; 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.

Classical Mechanics

1. Overview of Lagrangian formalism (4)
Constraints, D'Alembert's principle, Lagrange's equations; Small oscillations, normal modes and frequencies;

2. Rigid bodies (7)
Independent coordinates, orthogonal transformations, Euler angles, angular velocity in Eulerian variables; Inertia tensor and principal axis system (recapitulation); Euler's equation; Heavy symmetrical top with precession and nutation.

3. Hamilton's principle (8)
Calculus of variation; Hamilton's principle; Lagrange's equations from Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action.

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

5. Hamilton Jacobi theory (6)
The Hamilton Jacobi equation for Hamilton's principal function; The harmonic oscillator problem; Hamilton's characteristic function; Action angle variables.

6. Mechanics of continuous systems (8)
Lagrangian and Hamiltonian formulations for continuous systems; Canonical equations from a variational principle, Poisson's brackets and conjugate field variables. Electromagnetic field Lagrangian.

7. Special theory of relativity (12)
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.

Quantaum Mechanics I

1. Wave-packet (2)
Gaussian wave packet; Fourier transform; Spreading of a wave packet; Fourier transforms of delta and sine functions. Parseval's theorem.

2. Coordinate and Momentum space (1)
Coordinate and Momentum representations; x and p in these representations.

3. Eigenvalues and eigenfunctions (2)
Momentum and parity operators; Commutativity and simultaneous eigenfunctions; Complete set of eigenfunctions; Expansion of wave function in terms of a complete set.

4. One-dimensional problems (5)
Square well problem ($E > 0$) and ($E < 0$); Delta function potential; Double delta potential; Application to molecular inversion; Multiple well potential – Kronig-Penny model.

5. Three-dimensional problems (8)
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.

6. Time independent perturbation theory (8)
First and second order corrections to the energy eigenvalues; First order correction to the eigenvectors; Degenerate perturbation theory; Application to one electron system-- Relativistic mass correction, Spin-orbit coupling, Zeeman effect and Stark effect.

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

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

9. Operator Method in Quantum Mechanics (12)
Linear vector space; Linear operators; Hermitian and unitary operators; Completeness; Matrix representation, change of basis; Formulation of quantum mechanics in vector space language; Uncertainty principles for two arbitrary operators.

10. Time evolution (3)
Schrodinger, Heisenberg pictures.

11. Measurement and Interpretation (4)
Double Stern-Garlach experiment for spin-1/2 system; EPR paradox; Idea of quantum entanglement; Hidden variables. Schrodinger's cat; Reduction of wave function; Quantum Xeno effect.

12. Applications of Operator Method(8)
One dimensional harmonic oscillator by operator method; 3D harmonic oscillator; Angular momentum operators and their commutation relations; Raising and lowering operators; Matrix representation for $j = ½$ and $j = 1$; Spin; Addition of two angular momenta : Clebsch-Gordan coefficients; Coupling schemes in atoms, L-S and j-j coupling.

Electronics

1. **Basic network and filter (10)**
Reduction of complicated network: T and pi section, their conversation, examples, characteristics impedance, propagation constant, constant K-low pass, high pass, band pass, band eliminator, active filter, simple examples.

2. **Communication principle (12)**
Basic principles of amplitude, frequency, phase modulation, frequency spectra of modulated waves, power distribution in AM wave, balace modulator, average and envelope detection, frequency modulation method and demodulation, basic ideas of digital communication (digital signals, symbols, characteristics of data transmission circuits, bandwidth requirements, data transmission speed, Nyquist criterion noise, pulse shaping, PCM, PCM band width, FSK, PSK)and internat.

3. **Analog circuit (3)**
Analog computation, multivibrators, wave form generator (square wave, triangular wave and pulse generator)

4. **Physics of semiconductor device 1 (8)**
Carrier concentration in semiconductors, band structure of p-n junction, basic semiconductor equation, p-n diode current voltage characteristics, dynamic diffusion capacitances, elbers-Moll equation.

5. **Physics of semiconductor device 2 (12)**
Metal semiconductor junction, Schottky barriers, rectifying contacts, ohmic contact, miscellaneous semiconductor devices (Tunnel diode, photo diode, solar cell, LED & semiconductor laser, LDR, p-n-p-n switch, SCR, UJT, Diac, Triac)

6. **Digital Electronics (15)**
Combinational logic: Decoder, Encoder, Multiplexer, De-multiplexer
Sequential logic: Shift registors, synchronous and asynchronous counter, modulo-n counters, DAC, ADC, introduction of microprocessor (architecture and programming).

LIST OF GENERAL EXPERIMENTS

Semesters I & II

Non-electronics

1. Experiments with Michelson's interferometer.
2. Experiments with LASER
3. Determination of Lande g-factor by ESR spectroscopy
4. Experiments with a G. M. counter
5. Determination of Planck's constant
6. Determination of 'e' by Millikan's oil drop method
7. Study of a photovoltaic cell
8. Measurement of the Hall coefficient of a semiconductor

(At least 6 experiments from this group are to be performed)

Electronics

1. Study and use of field effect transistor (FET)
2. Study and use of unijunction transistor (UJT)
3. Design and study of multivibrators
4. Construction and study of active filters
5. Construction and study of decade and other counters
6. Construction and study of multiplexer and demultiplexer
7. Construction and study of ADC and DAC
8. Study of amplitude modulation and demodulation
9. Study of frequency modulation and demodulation
10. Programming the 8085 microprocessor

(At least 8 experiments from this group are to be performed)

Semester II

Mathematical Methods II

1. Integral Transforms [10]

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.

2. Group Theory [10]

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 a representation and orthogonality relations for characters; Construction of character tables; Decomposition of reducible representations; Application of representation theory in quantum mechanics.

3. Tensor Calculus [15]

Tensor as a generalized concept of a vector in an Euclidian space E^3. To generalize the idea in n-dimensional space. Transformation of coordinates in E^n; Summation convention; Contravariant and covariant vectors. Invariants, contrvariant, covariant and mixed tensors; Algebra of tensors – summation, subtraction, outer product, inner product and contraction; Quotient law, reciprocal tensor; Riemannian space, line element, metric tensor, reciprocal metric tensor; Associate vector, Christoffel symbols and their law of transformation; Covariant differentiation of vector.

4. Non Linear Dynamics [15]

(a) Non Linear Systems:
2nd Order Differential Equation in the Phase Plane, Autonomous Equations in The Phase Plane, Conservative Systems : the Damped Linear Oscillations, Non Linear Damping, some applications.

(b) 2nd Order Non linear System in two variables and Linearization:
General phase plane, Linear approximation at Equilibrium Points, General solution of a linear System, Classifying equilibrium Points, Constructing Phase Diagram, some applications.

Classical Electrodynamics

1. Introduction (4)
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 .

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

3. Radiation from time-dependent sources of charges and currents (8)
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.

4. Radiation from moving point charges (12)
Leinard-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; Breemsstrahlung; Synchroton radiation; Cherenkov radiation (qualiatative treatment only).

5. Radiation reaction, scattering and dispersion (7)
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.

6. Relativistic electrodynamics (13)
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 invariants -- $\vec{E}.\vec{B}$ 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.

7. Plasma physics (6)
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

<u>Quantum Mechanics II</u>

1. Approximation methods for time dependent problems (8)
Time dependent perturbation theory, Interaction picture; Evolution operator; Constant and Harmonic perturbations – Fermi's Golden rule; Sudden and adiabatic approximations; Geometrical and dynamical phase.

2. Scattering theory (10)
Scattering cross-section and scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts; Ramsauer-Townsend effect (only S-wave scattering); Relation between sign of phase shift and attractive or repulsive nature of the potential; Scattering by a rigid sphere and Coulomb scattering; Lippmann Schwinger equation and Born approximation.

3. Symmetries in quantum mechanics (12)
Conservation laws and degeneracy associated with symmetries; Continuous symmetries – space and time translations, rotations; Continuous group, symmetry group and group representations in connection with rotation group; Rotation matrices; Irreducible

spherical tensor operators, Wigner-Eckert theorem; Discrete symmetries – parity and time reversal.

4. Identical particles (3)
Meaning of identity and consequences; Symmetric and antisymmetric wave functions; Slater determinant; Symmetric and antisymmetric spin wave functions of two identical particles; Collisions of identical particles.

5. Path integral methods (6)
Path integral formulation of quantum mechanics; Some applications; Equivalence between path integral and canonical approaches; Aharonov-Bohm effect.

6. Relativistic quantum mechanics (15)
Klein-Gordon equation, its limitations; Dirac equation and spin of the electron, plane wave solution; Lorentz covariance of Dirac equation; Bilinear covariants; Non-relativistic reduction- magnetic moment; Necessity and interpretation of negative energy states;

7. Field quantization (6)
Euler-Lagrange equations; Noether's symmetry; Field quantization – scalar field with occupation number representation; Fermion and electromagnetic fields (qualitatively);.

Instrumentation

Basics of data acquisition (5); Transducers and bridges (3); Gas detectors (characteristics and pulse formation)(3); Scintillation and semiconductor detectors(3); Electronic pulse processing(2); UV-Vis and FTIR spectrophotometer (2); Production and measurement of high and ultra-high vacuum (3); Cryogenics (up to production of liquid He^4)(4); LASER cooling and trapping(2); Crystal and thin film preparation(3); Ion implantation (1); Atomic force microscope (AFM)(2); Scanning tunneling microscope (STM)(1).

Computer Programming

1. Basics of computer
Components of a computer, compiler, operating systems etc.

2. C language
Constants and variables; Input and output statements; Reading and writing formats; Arithmetic and logical expressions; Control assignment statements; Buld-in functions; Arrays; Loops, Switch operations, usage of break and continue; Flow chart, algorithm and programming; Pointers; Structures; Functions; File management; Allocation of memory, etc. Applications to physical problems.

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 Ω relation for a microcanonical system, heat, second law of thermodynamics for a classical ideal gas; Nature of ρ(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 Electronics I

Syllabus to be prepared.

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.

Advanced Electronics II

Syllabus to be prepared.

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)

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 $e^+e^- \to \mu^+\mu^-$, 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

Advanced Experiments (Electronics)

Syllabus to be prepared.