Syllabus for the Post Graduate Course
Physics

First Semester:

Paper-1(50 Marks): Mathematical Methods-IV
Paper-2(50 Marks): Classical & Relativistic Mechanics
Paper-3(50 Marks): Quantum Mechanics-III

Practical-1(Internal Assessment=15+End Semester=35): Computer
Practical-2(Internal Assessment=15+End Semester=35): General-I

Second Semester:

Paper-4(50 Marks): Quantum Mechanics & Spectroscopy
Paper-5(50 Marks): Electrodynamics & Plasma Physics
Paper-6(50 Marks): Electronics & Communication

Practical-3(Internal Assessment=15+End Semester=35): General-II
Practical-4(Internal Assessment=15+End Semester=35): Electronics-I

Third Semester:

Paper-7(50 Marks): Statistical Mechanics-II
Paper-8(50 Marks): Solid State Physics-III
Paper-9(50 Marks): Nuclear & Particle Physics-III

Practical-5(Internal Assessment=15+End Semester=35): Electronics-II
Practical-6(Internal Assessment=15+End Semester=35):Advance Level-I

Fourth Semester:

Paper-10(50 Marks): Elective Paper
Paper-11(50 Marks): Advanced Paper-I
Paper-12(50 Marks): Advanced Paper-II

Practical-7(Internal Assessment=15+End Semester=35):Advance Level-II
Minor Project work (Seminar Presentation & Viva=25+ Report =25): To be assigned by the Department

Syllabus for the Post Graduate Course
Physics

Theory:

First Semester:

Paper-1: Mathematical Methods-IV Lecture=50+14(Tutorial)

I. **Complex Analysis:** Preliminaries; Analytic function, Cauchy-Riemann equation; Power series, Radius of convergence and circle of convergence; analytic properties of power series, polynomials, exponential function, trigonometric and hyperbolic functions; Branch point and branch cut; Idea of Riemann surface Contours and Riemann's definition of definite integral; Estimation of an integral along a regular arc; Cauchy's theorem (elementary proof);Cauchy's integral formula; Classification of singularities; Analytic continuation; Residue, Cauchy's residue theorem; Principal value of an integral. (15)

II. **Differential equations:**

(a) ***Ordinary second order linear homogeneous equation:*** Sturm-Liouville theory; Hermitian operators; Completeness; Simple applications; Linear independence of solutions, Wronskian, construction of second solution; Regular and irregular singular points, Frobenius's method; Applications to solutions of Gauss's hypergeometric equation, Bessel's equation and Legendre equation; Generating functions, recurrence relations, orthogonality relations, integral representation and asymptotic expansion of Bessel, spherical Bessel, Legendre and associated Legendre functions.
(8)

(b) Inhomogeneous equation: Green's function technique.
(2)

III. **Integral transforms:** Fourier and Laplace transforms; Bromwich integral (use of partial fractions in calculating inverse Laplace transforms); Transform of derivative and integral of a function; Solution of differential equations using integral transforms. (6)

IV. **Linear algebra and Vector space:** Preliminaries of matrices; Similarity, orthogonal and unitary transformations; Hermitian, orthogonal and unitary matrices as special cases of normal matrices; Eigenvalues and eigenvectors; Functions of a matrix; Cayley-Hamilton theorem; Preliminaries of vector space; Schwarz's inequality, Gram-Schmidt orthogonalisation. (7)

V. **Group Theory:** Preliminaries; Isomorphism and homomorphism, group representation, character of representation, reduction of a representation, Rotation group and its applications.
(12)

Paper-2: Classical & Relativistic Mechanics **Lecture=50+14(Tutorial)**

I. Lagrangian and Hamiltonian dynamics: Preliminaries; Derivation of Lagrange's equation from Variational principle; Noether's principle: some specific applications of Lagrangian and Ham iltonian formalism (6)

II. Canonical transformation and Hamiltonian- Jacobi Theory: Generating function; Poisson bracket formalism, Hamilton Jacobi theory; Action-Angle variables; Adiabatic invariants; Liouville's theorem.
(10)

III. Rigid body: Preliminaries; Euler angles; Heavy symmetrical top. (8)

IV. Continuum Mechanics: Stress and strain tensor; Dilatation, shear, rotation; Deformation energy; Elastic constants; Isotropic body; Elastic wave.
Motion of a perfect fluid; Euler's equation and Bernoulli's equation; Navier-Stokes equation for an incompressible fluid (6)

V. Continuous systems and Fields: Classical Lagrangian and Hamiltonian density; Equations of motion; Conservation theorems. (4)

VI. Nonlinear dynamics: Flows and maps; Fixed points and their stability; limit cycles; Hamiltonian of dissipative systems; Integrable systems; Canonical perturbation theory; Kolmogorov-Arnold-Moser Theorem; Tangent map and stability matrix; Lyapunov exponents. (8)

VII. Special Theory of Relativity: Lorentz transformation; 4-vector (time, space and light like), 4-velocity and accelaration; 4-momentum and force, Relativistic invariants and kinematics: decay, elastic collison and reaction, Lagrangian and Hamiltonian of relativistic particle. (8)

Paper-3: Quantum Mechanics-III Lecture=50+14(Tutorial)

I. Operator method in quantum mechanics (8)

Sequential Stern – Gerlach experiment; formulation of quantum mechanics in abstract space; representation of states and operators; uncertainty principle; one – dimensional harmonic oscillator; Schrodinger and Heisenberg pictures.

II Angular momentum (12)

Angular momentum algebra and its representations; matrix representations for j = ½ and j=1 ,spin,Addition of two angular momenta, Clebsch – Gordan coefficients, examples.
Conservation laws and degeneracy associated with symmetries; Continuous symmetries — space and time translations, rotations; Rotation matrices; Irreducible spherical tensor operators, Wigner-Eckart theorem; Discrete symmetries — parity and time reversal.

III. Approximation methods (14)

Time – independent perturbation theory; first and second order correction to energy eigenvalues; first order correction to energy eigenfunction; degenerate perturbation theory; applications – relativistic mass correction of hydrogen spectrum, spin – orbit coupling, Zeeman and Stark effects.Variational method; helium atom as example; first order perturbation; exchange degeneracy; excited states; linear variational principle.

IV. WKB Approximation: (4)

Quantisation rule, tunnelling through a barrier, qualitative discussion of α-decay.

V. Time-dependent Perturbation Theory: (12)

Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations — Fermi's Golden rule; Sudden and adiabatic approximations. Interaction of radiation with matter. Sinusoidal perturbation which couples two discrete states — the resonance phenomenon.Interaction of an atom with electromagnetic wave: The interaction Hamiltonian — Selection rules; Nonresonant excitation — Comparison with the elastically bound electron model; Resonant excitation— Induced absorption and emission.

Second Semester:

Paper-4: Quantum Mechanics & Spectorscopy Lecture=50+14(Tutorial)

I. Scattering theory: (12)

Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts; Ramsauer-Towwnsend 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; Collisions of identical particles.

II. Identical particles: (3)

Identical particles, symmetry under interchange, wave functions for bosons and fermions, Slater determinant.

III. Relativistic Quantum Mechanics: (11)

Klein-Gordon equation, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; Non-relativistic reduction; Helicity and chirality; Properties of γ matrices; Charge conjugation; Normalisation and completeness of spinors; Lorentz covariance of Dirac equation; Bilinear covariants and their transformation under parity and infinitesimal Lorentz transformation; Weyl representation and chirality projection operators.

Spectroscopy:

I. Fine and Hyperfine structure: (4)

Fine structure of spectral lines; Selection rules; Lamb shift. Hyperfine interaction and isotope shift; Hyperfine splitting of spectral lines; selection rules.

II. Many electron atom: (3)

Equivalent and nonequivalent electrons; Energy levels and spectra; Spectroscopic terms; Hunds rule; Lande interval rule; Alkali spectra.

III. Molecular Electronic States: (5)

Concept of molecular potential, Separation of electronic and nuclear wavefunctions, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wavefunctions; Shapes of molecular orbital; and bond; Term symbol for simple molecules.

IV. Rotation and Vibration of Molecules: (3)

Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential.

V. Spectra of Diatomic Molecules: (4)

Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra.

VI. Vibration of Polyatomic Molecules: Application of Group Theory: (5)

Molecular symmetry; Matrix representation of the symmetry elements of a point group; Reducible and irreducible representations; Character tables for C2v and C3v point groups; Normal coordinates and normal modes.

Paper-5: Electrodynamics & Plasma Physics **Lecture=50+14(Tutorial)**

I. **Electrostatics and Magnetostatics:** Formal solution of the electrostatic boundary value problem with Green’s function; Boundary value problems in cartesian, spherical and cylindrical Coordinates; Mutipole expansion; Electrostatics of macroscopic media. Magnetostatics--- boundary value problems. (10)

II. **Maxwell’s equations:** Vector and scalar potentials; Gauge transformations; Poynting’s Theorem; Group velocity and dispersion, Kramers – Kronig relations. Resonant cavities and waveguides: Energy flow and attenuation in waveguides; Power losses in a cavity. (5)

III. **Relativistic electrodynamics:** Tensors in Minkowski space, Electromagnetic field tensor, covariance of electrodynamics, transformation of electromagnetic fields; Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field; Lagrangian for the electromagnetic field; stress tensors, conservation laws. (10)

IV. **Fields and Radiation of a localized oscillating source:** Inhomogeneous wave equation and it's solution by Green's function method; Multipole expansion of potentials and fields; Electric dipole fields and radiation; Magnetic dipole and electric quadrupole fields; Angular distribution of multipole radiation; Energy and angular momentum of multipole radiation; Multipole radiation from a linear center-fed antenna. (8)

VII. **Radiation by moving charges:** Solution of the inhomogeneous wave equation in covariant form, invariant Green's function; Lienard-Wiechert potentials and fields for a point charge; Potentials and fields due to a charge moving with uniform velocity; Angular distribution of radiation emitted by an accelerated charge; Total power radiated by an accelerated charge; Synchroton radiation; Cherenkov radiation. Radiation damping. (10)

VIII. **Plasma Physics:** Motion of charged particles in an uniform magnetostatic field, in a combined uniform electrostatic and magnetostatic field, in non-uniform magnetostatic fields and time-varying electromagnetic fields; Adiabatic invariance of flux through orbit of particles; Magnetohydrodynamic waves; Frequency dispersion characteristics of a plasma, electron plasma oscillations; The Pinch effect; Debye shielding. (7)

Paper-6: Electronics & Communication Lecture=50+14(Tutorial)

I. Networks and Filters (8)

Reduction of complicated network, T and Π section and their conversion, bridge-T, parallel-T and lattice network, characteristic impedance, propagation constant, constant *k* and *m* derived low pass and high pass filters, active filters: low pass, high pass, band pass, band reject and all pass, Butterworth polynomials.

II. Communication Principles (12)

Types of modulation, frequency spectrum and power relations in amplitude modulated wave, suppression of carrier, balanced modulator, suppression of unwanted sidebands, diode detector, optimum RC time constant, mathematical representation of frequency modulation (FM), frequency spectrum of FM wave, phase modulation, intersystem comparisons, reactance modulator and Armstrong's method of FM, basic FM demodulators, TRF and superheterodyne receiver, basic principles of TV and TV cameras.

III. Physics of Semiconductor Devices (10)

Carrier concentrations in semiconductors, Fermi levels in semiconductors, band structure of a p-n junction, basic semiconductor equations, p-n diode current-voltage characteristic and its temperature dependence, capacitance of p-n junctions, currents in a transistor, Ebers-Moll equation and application, metal-semiconductor junctions: Schottky contact and ohmic contact.

IV. Special Semiconductor Devices (8)

Brief idea of light emitting diode, photodiode and solar cell, p-n-p-n devices: SCR, diac, triac, UJT and programmable UJT, negative resistance devices: tunnel diode, IMPATT diode and Gunn diode, Microwave oscillation.

V. Digital Electronics and Microprocessor **(12)**

Karnaugh map representation of logical functions and simplification (up to 4 variables), logic families, DTL and TTL gates, MOS circuits: inverter, NAND and NOR gates, synchronous counter, instruction set of microprocessor 8085, types of instructions, op codes, assembly language programming, idea of stack, subroutine, program counter and interfacing concepts.

Third Semester:

Paper-7: Statistical Mechanics-II Lecture=50+14(Tutorial)

I. Introduction: (10)

Limitaions of thermodynamics, Objectives of Statistical Mechanics, Macrostates, Microstates, Phase space, Statistical ensembles, Ergodicity, Isolated system, Statistical equilibrium, Postulate of equal a priori probability, Boltzmann definition of entropy, Classical Liouville's theorem.

II. Statistical Mechanics of weakly Interacting system: (5)

System in contact with a heat reservoir, Thermal equilibrium, Statistical definition of temperature, Gibb's distribution (applying equal a priori probability), Canonical partition function, Entropy, Free energy, Fluctuations. Entropy of ideal gas, Gibbs' paradox, Sackur-Tetrode equation.

III. Grand canonical ensemble: (5)

System in contact with particle reservoir, Chemical potential, Grand partition function, Density fluctuations, Critical Opalescence.

IV. Non ideal Classical gas: (8)

van der Waals equation of state, Liquid-gas transition, Mean field theory, Critical exponents, Cluster Integrals, Mayer-Urshel expansion.

V. Advanced topics: (7)

Ising model, Exact solution in one dimension, Peierls argument, Bragg-Williams theory, Landau theory, Critical exponents and scaling theory, Universality, Basic idea of renormalization technique.

VI. Quantum Statistical Mechanics: (6)

Density Matrix, Quantum Liouville theorem, Density matrices for microcanonical, canonical and grand canonical systems, Example--One electron in a magnetic field, B-E and F-D distributions and their applications.

VII. Ideal Bose and Fermi gas: (9)

Equation of state of ideal Bose gas, Bose condensation, Superfluidity, Equation of state of ideal Fermi gas, Fermi gas at finite T.Electronic specific heat, Pauli spin paramagnetism, Sommerfeld electrical conductivity .

Paper-8: Solid State Physics-III Lecture=50+14(Tutorial)

I. Crystal Structure and Diffraction from Periodic Structure: [4]

Crystals, Crystal Symmetry and Bravais Lattices. Reciprocal Lattice and Brillouin Zone. Bragg-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 Diffraction Method. Electron and Neutron Diffraction by Crystals.

II. Lattice Dynamics: [8]

The Harmonic Approximation, The Adiabatic Approximation, Normal Modes of a One-Dimensional Monatomic Bravais Lattice, Normal Modes of a One-Dimensional Monatomic Bravais Lattice with a Basis, Normal Modes of Two and Three-Dimensional Monatomic Bravais Lattice. Inelastic Neutron Scattering by Phonon. Lattice Specific Heat. Anharmonic effects in Crystal-Thermal Expansion and Thermal Conductivity. Mossbauer Effect.

III. Electron States and Band Theory of Solids: [10]

Electron States in Crystals, General Properties of Bloch Functions, Boundary Conditions in a Finite Crystal. Density of States. Electron Band Calculations: The Tight Binding Approximation and Wannier Functions, The Nearly-Free-Electron Approximation and k.p Theory. Example of Band Structures (Si, Ge, GaAs & Zn). Fermi Surfaces. Cyclotron Resonance and Determination of Effective Masses. Boltzmann Transport Equation: Relaxation Time Approximation, Determination of Electrical Conductivity.

IV. Dielectric Properties of Solids: [5]

Static Dielectric Properties, Ferroelectrics and Piezoelectrics, Electromagnetic Waves in Solids. Frequency Dependent Polarizabilities. Dielecric relaxation. Electronic Polarizability. Free Carrier Effects. Ionic Polarizibility.

V. Magnetic Properties of Solids: [10]

Fundamental Concepts, Diamagnetism and Paramagnetism (Quantum Theory). The Exchange Interaction, Exchange Interaction between Free Electrons, Spontaneous Magnetization and Ferromagnetism. The Band Model of Ferromagnetism, The Temperature Behaviour of a Ferromagnet in the Band Model. Ferromagnetic Coupling for Localized electrons, Ferrimagnetism and Antiferromagnetism. Spin Waves. Magnetic Resonance Phenomena.

VI. Superconductivity: [8]

Some fundamental Phenomena Associated with Superconductivity. Phenomenological Description by Means of the London Equation. The BCS Ground State. Consequences of the BCS Theory and Comparison with Experimental Results. Supercurrents and Critical Currents. Coherence of the BCS Ground State and the Meissner-Ochsenfeld Effect. Quantization of Magnetic Flux. Type-II Superconductors. Novel High Temperature superconductors. One-Electron Tunneling in Superconductor Junctions,. Cooper Pair Tunneling – The Josephson Effect.

VII. Defects in Solids and Optical Properties: [5]

Frenkel and Schottky Defects, Defects in Growth of Crystals. The Role of Dislocations in Plastic Deformation and Crystal Growth. Colour Centers and Photoconductivity.

Luminescence and Phophorescence. Alloy, Order-Disorder Phenomena, Bragg-Williams Theory.

Paper-9: Nuclear & Particle Physics-III   Lecture=50+14(Tutorial)

I.Nuclear Properties: (3)
Nuclear radius and charge distribution, binding energy, Angular momentum, parity, magnetic dipole moment and quadrupole moment.

II. Two body bound state and scattering: (8)
Properties of deuteron, Schoredinger equation and its solution for ground state of deuteron, r.m.s. radius, spin dependence of nuclear forces and the necessity of tensor forces. Experimental np scattering data, phase shifts, singlet and triplet potentials, effective range theory, low energy p-p scattering; charge independence of nuclear forces, Isospin symmetry, exchange interaction.

III. Beta and gamma decay: (9)
Beta-decay and electron capture, Fermi's theory, selection rules (Fermi and Gamow-Teller), Parity non-conservation- Wu's experiment: detection of neutrino, two component theory & double beta decay.
Multipole radiation and selection rules of gamma decay and transition probabilities, internal conversion.

IV. Nuclear models:
(7)
Fermi gas model, Extreme single particle models; spherical shell model, Collective model – vibration and rotation, Nilsson Model.

V. Nuclear reaction and Fission: (10)
Q-value, Compound nuclear formation and break up; Resonance scattering and reaction: Breit-Wigner dispersion relation; Optical model, transfer reactions. Spontaneous fission, mass and energy distribution of fragments, elementary theory based on barrier penetration, Photofission.

VI. Nuclear Astrophysics: (3)
Nucleosynthesis and abundance of elements, neutron star.

VII. Particle Physics: (10)
Symmetries and conservation laws, Hadron classification by isospin and hypercharge, SU(2) and SU(3), weight diagram: Elementary ideas of electroweak interactions and standard model.

Fourth Semester:
Paper-10: Elective Paper   Lecture=50+14(Tutorial)

1. Physics of Liquid Crystals

I. **Structure and classification of mesophases:** **(5)**
Thermotropic and lyotropic liquid crystals; Uniaxial and biaxial nematics; Cholesterics; Smectics (smectic A, smectic C, smectic E, hexatic phase); Blue phases; Polymer liquid crystals; Discotic liquid crystals; Ferroelectric liquid crystals; Banana-shaped liquid crystals.

II. **Molecular theory of liquid crystals:** **(9)**
Symmetry and order parameters; Nematic-isotropic phase transition – Maier-Saupe theory, Generalized mean-field theory, McMillan's theory of smectic A liquid crystals.

III. **Elastic continuum theory of liquid crystals:** **(8)**
General expression of free energy of deformed nematic liquid crystals; Franck's elastic constants; Distortion due to external electric and magnetic fields; Freedericksz transition; The twisted nematic Cell.

IV. **Landau theory of liquid crystals phase transitions:** **(15)**
Landau-de Gennes theory; Nematic-isotropic transition; Cholesteric-isotropic transition; Nematic-smectic A transition; Smectic A-Smectic C transition; Smectic A- isotropic transition; Smectic C–isotropic transition; Smectic A–smectic C* transition; Nematic and smectic A fluctuations; Mean-field description of the discotic liquid crystals; Impurity effect on the nematic-isotropic and nematic-smectic A transitions: Multicritical points; Critical phenomena in liquid crystals.

V. **Hydrodynamic equations for liquid crystals:** **(5)**
Hydrodynamic equations; Reversible and irreversible hydrodynamics; Conservation of angular momentum; Hydrodynamics- nematic, cholesteric and smectic A phases.

VI. Soliton in liquid crystal: **(4)**
Nematic liquid crystal, smectic liquid crystal, ferroelectric liquid crystal.

VII. **Liquid Crystal displays:** **(4)**
Optical properties of on ideal helix; Agents influencing the pitch; Basic principle of liquid crystal displays, Twisted nematic liquid crystal and cholesteric liquid crystal displays; Ferroelctric Liquid Crystal displays; Polymer dispersed liquid crystals.

2. Microwave

I.Transmission line and waveguide: **(12)**
Transmission line equations and solutions, input impedance, open circuited and short circuited transmission line, high frequency transmission line; Interpretation of wave equations, Rectangular wave guide- TE and TM modes, Power transmission, excitation of modes, circular waveguide- TE TM and TEM modes, power transmission, excitation of modes.

II.Microwave Components: **(9)**

Scattering parameter and Scattering matrix, Properties of S-parameter, Quality factor and Q-value of a cavity resonator, Q-value of a coupled cavity; Wave guide tees, magic tee, hybrid ring, couplers, Ferrites and Faraday's rotation, Circulator, Isolator and Terminator, $\lambda/4$ – section filter, tuner and Sliding short.

III.Microwave Measurement: (11)

Reflection co-efficient, Transmission co-efficient, standing wave and standing wave ratios, line impedance and line admittance, Smith chart, Single Stub and Double Stub matching, Microwave bridge, measurement of frequency, attenuation and phase, measurement of dielectric parameters of amorphous solids – dielectric constant, measurement of microwave power, Insertion loss, return loss.

IV.Microwave Source: (11)

Conventional Sources and their limitations.

a. Vacuum Tube Sources – Klystron, Reflex Klystron, Traveling wave tubes, Magnetrons, and Gyrotrons.

a. Microwave transitors and FETs - GUNN, IMPATT, TRAPATT and Parametric devices – Single and double stage parametric amplifiers.

b. LASER - Laser processes, Pockels – cell, Laser modulators, Infrared radiation and sources.

V.Antenna: (7)

Transmitting and receiving antennas, antenna gain, resistance and bandwidth, Antenna dipoles, straight, folded and broadband dipoles, Beam width and Polarization, Antenna coupling.

3. Physics of Remote Sensing

I. Introduction (2)

Overview of the remote sensing processes, passive and active sensing techniques, Why observe earth from space? Airborne and spaceborne systems, concept of signatures.

II. Electromagnetic wave and interaction with matter (7)

Different ranges of electromagnetic spectrum useful to remote sensing, characteristics of solar radiation, angular distribution of radiation, polarization, absorption, dielectric constants and refractive indices of materials, surface scattering, Lambertian surface, BRDF, volume scattering and volume absorption, radiative transfer equation, reflection and emission from materials in visible, near-infrared, thermal infrared and microwave region.

III. Interaction of electromagnetic wave with atmosphere (4)

Composition and structure of atmosphere, molecular absorption and scattering, microscopic (aerosol) and macroscopic (rain, cloud, fog etc.) particles, ionosphere, turbulence, atmospheric sounding, estimation of greenhouse gases.

IV. Remote Sensors and instrumentation (8)

Principles of radiometry, physical basis of spectral signatures, surface characteristics and observation geometry, overview of remote sensors: classification, selection of parameters, resolutions and field of view, definition of bands, optomechanical and pushbroom scanner, dwell time, hyperspectral sensor, high spatial resolution imaging systems, brief idea on spaceborne and airborne sensors like MSS, TM, LISS, SPOT, CZCS, WiFS, OCM, MODIS, AVHRR, AVIRIS and Hyperion, lidar, microwave sensors, principle of radar and microwave radiometer.

V. Space platforms (4)

Principles of satellite motion, launching and locating a satellite in space, types of orbit, orbital perturbations, geosynchronous and geostationary orbits, sunsynchronous orbit, brief idea of satellite systems like LANDSAT, IRS, METEOSAT and ENVISAT, principle of satellite communication.

VI. Data reception and analysis (6)

Multispectral and hyperspectral imagery, data product formats, sources of errors in received data and correction, georeferencing, idea of photogrammetry, colour triangle, false colour composite, visual image analysis, fundamentals of digital image processing: image enhancement, histogram equalization, band combination and definition of indices, classification techniques, frequency domain analysis, digital elevation model, advanced techniques, e.g. fuzzy logic and artificial neural network.

VII. Geographic Information Systems (3)

Need of GIS, data entry and data structures, raster and vector data analysis, data integration and modelling

VIII. Some applications of remote sensing (8)

(a) Plant science: precision agriculture, vegetation indices, leaf area index, forestry type and density mapping, land cover/use mapping
(b) Earth and hydrospheric science: spectral observation of rocks and minerals, spectral changes with water depth, ocean and coastal researches, investigation on snow and glacier, fisheries and wetland management
(c) Atmosphere and others, future trends

IX. Demonstration classes (8)

(i) Experiment on spectroradiometry to study spectral signatures, radiance etc.
(ii) To handle multispectral satellite data with computer software.
(iii) Image processing techniques: enhancement, spatial filtering, classification etc.
(iv) Handling of hyperspectral image

Paper-11: Advanced Paper-I Lecture=50+14(Tutorial)

1. Astrophysics

I. Solar System and Stars: (12)

(a) The Solar system (4)

Sun: description, chemical composition, energy source, spectrum; Planets; Origin of the solar system.

(b) Observational tools (4)

Blackbody radiation; Specific intensity and flux density; Stellar parallax; Magnitudes Colour index; Basic optics and optical telescopes; Radio telescopes, Infrared, ultraviolet and X-ray telescopes; Coordinates and time.

(c) Star (4)

Classification; Formation of spectral lines; Saha's equation; Hertzsprung-Russell diagram; Opacities; Radiative transfer; Structure of spectral lines;

II. Stellar Structure and Evolution; (29)

(a) Star formation (2)

Interstellar dust and gas; Formation of protostars; Pre-main sequence evolution

(b) Stellar Interior (5)

Hydrostatic equilibrium; equation of state; Lane-Emden equations; Energy sources; Energy transport and convection.

(c) Post main sequence evolution (5)

Evolution on the main sequence; Late stages of evolution; Fate of massive stars, supernovae;

(d) Degenerate remnants of stars (8)

White dwarfs; Chandrasekhar limit; Neutron stars; Pulsars.

(e) Binary stars (6)

Classification; Mass determination; Accretion disks in close binaries; White dwarfs, neutron stars and black holes in binaries; Hulse-Taylor binary pulsar.

(f) Accretion discs (3)

Thin accretion discs; Thick accretion discs; Accretion discs in binaries;

3. Galaxies: (9)

(a) The Milky Way Galaxy (3)

Distribution of stars; Morphology; Kinematics; Interstellar medium; Galactic Centre.

(b) Nature of galaxies (4)

Hubble sequence; Spirals and irregular galaxies; Spiral structure; Elliptical galaxies.

(c) Galactic evolution (2)

Interaction of galaxies; Formation of galaxies.

2. Communication Electronics

I. Signals and Noise (5)

Types of noise, atmospheric noise, extra-terrestrial noise, man-made noises, thermal noise, shot noise and others, noise calculation, equivalent noise voltage, noise current, noise power, noise resistance, signal-to-noise ratio, noise temperature, noise in reactive circuit, addition of noise in amplifiers in cascade.

II. Radio Wave Propagation (7)

Propagation in free space, tropospheric propagation, radio horizon, Earth's atmosphere, pressure and density variations, scale height, formation of ionospheric layers, Chapman's theory, plasma frequency and critical frequency, secant law and maximum usable frequency, virtual height, fading.

III. Radar (5)

Elements of a radar system, radar equation and performance factors, radar transmitting system, radar antennas and lobe switching duplexer, indicators for radar receiver, moving target indicator, continuous wave radar, application of radar beacon.

IV. Mobile Communication **(2)**

Concepts of cell and frequency reuse, description of cellular communication standards, pagers.

V. Digital Communication **(8)**

Digital signal, symbols, characteristics of data transmission circuits, bandwidth requirements, data transmission speed, Nyquist criterion, noise, crosstalk, echo suppression, distortion, equalizer, digital codes, error detection and correction, pulse shaping, PCM, quantization, PCM bandwidth, signal-to-noise ratio, digital carrier systems – ASK, FSK, PSK, QASK, QPSK, UART, modem: classification and interface.

VI. Satellite Communication **(8)**

Synchronous satellites, structure of satellite communication system, active and passive satellites, advantages and disadvantages, modem and codec, orbits, station keeping, satellite attitude, control, transmission path, loss, frequency allocation and band spectrum, general link design equation, C/N and G/T ratio, atmospheric effects on link design, uplink design, complete link design, satellite analog communication, frequency division multiplexing, S/N and C/N ratio in FM, satellite digital communication, elements of digital communication system, multiple access techniques – TDMA, FDMA, satellite earth station and launch vehicle, various satellite applications.

VII. Computer Communication **(6)**

Types of networks – circuit, message and packet switching, network topologies – star, ring, bus, tree, features of network design and examples – ARPANET, LAN, ISDN, Internet, Medium access techniques – TDMA, FDMA, CSMA, ALOHA, slotted ALOHA, network protocols.

VIII. Transmission Line, Waveguide and Antenna **(9)**

Parallel and coaxial line, transmission line equation, characteristic impedance, propagation constant, lossy line, idea of Smith Chart, VSWR, open and short circuit impedance, principle of stub line matching, parallel plane waveguide, rectangular waveguide, modes, resonant cavities, antenna: antenna resistance, antenna temperature, gain, half-wave dipole, effect of ground, directional antenna

Optical fiber: an optical waveguide, optical communication systems: Transmitter, receiver; point-to-point fiber link, repeater.

3. Condensed Matter & Materials Physics-I

I.Fundamentals of Many-Electron Systems : Hartee-Fock Theory: **[12]**

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 Hatree-Fock (H-F) Theory. The H-F Equation. Exchange Interaction and Exchange Hole, Koopmans Theorem. The occupation Number Representation – The

Many Electrons Hamiltonian in Occupation Number Representation. The H-F Ground State Energy.

II.The Interacting Free-Electron Gas : Quasi Electrons and Plasmon: [12]

The H-F Approximation of the Free Electron Gas. Single- Particle Energy Levels, the Ground state energy. Calculation of the Ground State Energy. Cohesive Energy in Metals. Screening and Plasmons. Experimental Observations of Plasmons. The Dielectric Function of the Electron Gas. Friedel Oscillations. Landau's Quasi-Particle Theory of Fermi Liquid. Strongly Colelated Electron Gas. Mott Transition.

III.Coherence and Correlation: [8]

Types of Coherence. Density Matrix Formalism. Quantum Coherent Effects. Correlation Functions and Noise. Particle-Particle Correlation. The Fluctuation – Dissipation Theorem. Current Fluctuations and the Nyquist Formula. The Kubo Formula and Many-Body Theory of Metals. Messoscopic Effects.

IV. Spin and Magnetic System: [10]

Overview of Magnetic Properties. The Ising Model: Zero External Magnetic Field; Spontaneous Symmetry Breaking, External Magnetic Field-Hysteresis. Critical Fluctuations: Other magnetic models, Multicritical behaviour, Metamagnets, Critical Exponents and Magnetic Susceptibility, Landau Coarse Graining Theory. Renormalization Group Methods, Spin Waves and Goldstone Bosons. Spin-Spin Interactions: Ferromagnetic Instability, Localized States and RKKY Exchange Interactions. Spin Flip and Spin Dephasing.

V. Superconductivity Phenomena: [8]

Constructing Bosons from Fermions. Electron-Electron Interaction via Lattice-Cooper Pairs, BCS Wavefunction. Excitation Spectrum of a Superconductor. Ginzburg-Landau Theory and London Equation. Meissner Effect. Type-II Super Conductors-Characteristics Length. Josephson Effect. High Temperature Super Conductors.

4. Nuclear Structure

I.Nuclear Forces: (8)

A general discussion of NN interaction from deuteron and two nucleon scattering; Derivation of OPEP; Phenomenological NN realistic potential- origin of various terms. Effective interaction: Phenomenological forms: Skyrme and surface delta interaction, pairing plus quadrupole model.

II. Nuclear Models: (20)

(a) Nuclear shell model: Basic idea of an actual calculation (seniority scheme, qualitative discussion of cfp, configuration mixing)

(b) Collective model: Introduction of beta and gamma variables for collective motion of even and Odd nuclei . Specially for odd A nuclei, emphasis on particle- rotor coupling. Behaviour of nuclei at high-spin.

(c) Nilsson model, Super heavy nuclei.

III. Microscopic Calculation: (10)

(a) Occupation number representation, one and two-body operators; evaluation of matrix elements; Wick's theorem.

(b) Rudiments of HF and BCS calculation.

IV. Nuclear Matter: (12)
Brueckner Method; Infinite medium, idea of effective interactions in nuclei, neutron matter and neutron star.

5. Quantum field theory

I. Lorentz Group: (10)
Continuous and discrete transformations, Group structure, Proper and improper Lorentz Transformations, SL(2,C) representations, spinors, Poincare group and particle states.

II. Canonical quantization of free fields: (8)
Real and complex scalar fields, Dirac field, electromagnetic field.

III. Interacting fields: (8)
Interaction picture, Covariant perturbation theory, S-matrix, Wick's theorem, Feynman diagrams. Self-interacting scalar field.

IV. Higher order corrections: (6)
One-loop diagrams. Basic idea of regularization and renormalization. Degree of divergence. Calculation of self-energy of scalar in φ4 theory using cut-off or dimensional regularization. Elementary discussions on running couplings and renormalization group.

V. Path integral quantization: (8)
Path integral in quantum mechanics, Path integral in Field theory, quantisation of scalar, spinor fields.

VI. Non-abelian gauge theory: (10)
Non-abelian gauge theory and its quantisaion by path integral technique, Spontaneous symmetry breaking, Goldstone bosons, Higgs mechanism.

Paper-12: Advanced Paper-II Lecture=50+14(Tutorial)

1. General Relativity & Cosmology

I. General Relativity : (22)
(a) Conceptual foundations of GR and curved spacetime (10)
Principle of equivalence; Connection between gravity and geometry; Form of metric in Newtonian limit; Metric tensor and its properties; Concept of curved spaces and spacetimes; Tensor algebra; Tensor calculus; Covariant differentiation; Parallel transport; Riemann curvature tensor; Geodesics; Particle trajectories in gravitational field. Symmetries: Killing equation and conserved charges.
(b) Dynamics of gravitational field (4)

Einstein's field equations; Definition of the stress tensor; Bianchi identities and conservation of the stress tensor; Einstein's equations for weak gravitational fields; The Newtonian limit.

(c) Schwarzschild metric and related topics (4)

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; Precession of perihelion; Deflection of ultra relativistic particles; Gravitational red-shift; Gravitational Lensing.

(d) Gravitational waves (4)

Wave equation in linearised theory; Plane waves; Transverse traceless gauge; Effect on test particles; Principles of detection and generation of gravitational waves; Types of detectors; Landau-Lifshitz formula; Hulse Taylor binary pulsar.

II. Cosmology: (28)

(a) Standard Model (13)

Hubble's law; Angular size; Source counts; Friedmann-Robertson-Walker models; Cosmological constant; Horizons; Relics of the big bang; The early universe; Thermodynamics of the early universe; Thermal equilibrium; temperature and entropy; entropy density; scale factor; radiation decoupling; Microwave background radiation; abundance of elements.

(b) Problems of the standard model (11)

Problems of the Standard model: flatness, horizon and inhomogeneity problem; idea of inflation and resolution of the problems; density inhomogeneity and its evolution; quantum origin of primordial fluctuations; dark energy; dark matter.

(c) Particle Astrophysics (4)

Particles and interactions; Ultra-high energy cosmic rays; Gamma ray bursts; Neutrino astronomy; dark matter candidates.

2. Solid State Electronics

I. Foundation of Solid State Electronics: (5)

Boltzmann transport equation, direct and indirect recombination, kinetics of traps and recombination centres, carrier concentration at equilibrium, temperature dependence of mobility, diffusion and drift of carriers, optical absorption, minority carrier mobility, Haynes-Shockley experiment, relaxation effects, ambipolar effects, magnetoresistance, quantum Hall effect.

II. Semiconductor Technology: (4)

Purification and preparation of semiconductor materials, bulk and epitaxial crystal growth techniques, diffusion and ion implantation, solid solubility, fabrication of IC, preparation of diodes, transistors and MOSFETS for monolithic circuits, heterostructures.

III. JFET and MESFET: (4)

Types of FET, basic device characteristics, pinch-off and saturation, gate control, current-voltage characteristics, GaAs MESFET, HEMT

IV. MOSFET and CCD: **(8)**

Basic operation, linear and saturation region, MOS capacitor, accumulation, depletion and inversion conditions, effects of real surfaces, threshold voltage, surface FET, capacitance effects, short channel effects and remedies, VMOS, charge coupled device, buried channel CCD.

V. Microprocessor and Microcontroller: **(7)**

Interrupt-driven I/O, DMA, demultiplexing the address bus, generating control signals, 8085 fetch cycle, execution cycle, machine cycle, fetch-execution overlap, timing diagram, delay routine, IC 8255 chip and its use,

Microprocessor vs. microcontroller, architecture of 8051 microcontroller, 8051 instruction syntax, addressing modes, arithmetic and logic operations, jump and call instruction.

VI. Optoelectronic Devices: **(6)**

LED: materials, light extraction, types of loss, construction, high frequency limit, diode laser, condition for population inversion, optical gain, threshold current, resonant cavity, heterojunction LED and laser.

VII. Advanced Analog and Digital Processes: **(8)**

Analog computation, waveform generation, multivibrators, digital MOS circuits, memory devices, D/A and A/D conversion, phase locked loop, digital image processing.

VIII. Devices for the future: **(8)**

Physics of nanomaterials – general idea, nanoelectronic devices, electron confinement in two and one dimensional well, idea of quantum well structures, quantum wire and dot, density of states in quantum well, resonant tunneling, superlattice, different methods of preparation of nanomaterials: top-down and bottom-up approach, optical lithography and x-ray lithography, Molecular-beam epitaxy, Metal-organic chemical vapour deposition, cluster-beam evaporation, ion beam deposition, ball milling, molecular self-assembly, determination of particle size from x-ray diffraction pattern, tunneling electron microscopy, photoluminescence and light scattering characterizations, porous silicon, carbon nanotube.

3. Condensed Matter & Materials Physics-II

I. Electronic Quasiparticles in Solids: **[8]**

Quasiparticles, Effective Mass, Basic Behaviour of Semiconductors, Band Bending and Heterojunctions. Quantum Confinement: Density of States in Quantum-confined Systems (Low dimensional systems), Excitons in Quantum Structures, Superlattices, Disorder in Quantum-Confined Systems, Two Dimensional Electron Gas. Landau Levels and Quasiparticles in Magnetic Field: Density of States in Landau Levels, De Hass-van Alphen and Shubnikov-De Hass Oscillations, Integer Quantum Hall Effect, Fractional Quantum Hall Effect and Higher – Order Quasiparticles.

II. Ineractions of Quasiparticles & Transport Phenomena in Solids: **[8]**

Electron-Phonon Interactions: Deformation Potential Scattering, Piezoelectric Scattering, Fröhlich Scattering. Electron-Photon Interactions: Optical Transitions between

Semiconductor Bands, Direct & Indirect Transitions, Joint Density of States. Phonon-Phonon Interactions. Electron-Electron Interactions: Semiclassical Estimation of Screening Length. The Relaxation-Time Approximation and Diffussion Equation. The Boltzmann Transport equation. Thermal Conductivity, Electrical Conductivity and Magnetoresistance in Two - Band Model. Drift of Defects and Dislocations – Plasticity.

III. The Complex Susceptibility & Dielectric Properties of Materials: [6]

A Microscopic view of the Dielectric Constant. Kramers-Kronig Relation. The Quantum Mechanical Oscillator, Dielectric Functions. Polaritons. Nonlinear Optics and Photon-Photon Interactions: Second-Harmonic Generation and Three-Wave Mixing, Higher-Order Effects. Acousto-Optics and Phonon-Phonon Interactions. Raman Scattering.

IV. Growth, Characterization and Phase Diagrams of Materials: [9]

Classification of materials (crystalline, amorphous, nano-materials, ceramics, liquid crystals and polymers).

Growth: Processes for crystal growth, doping techniques of elemental and compound semiconductors; Growth processes (Physical and Chemical Vapor Deposition) and fundamentals of thin films; Recent developments in material processes.

Characterization: Diffraction techniques – X-ray Diffraction, Neutron Diffraction; Electron Microscopy – Transmission Electron and Scanning Electron Microscopy; Optical methods – FTIR, Raman Spectroscopy, UV – VIS – NIR – IR; Surface techniques – AFM, STM, Chemical ESCA, AES and RBS; Thermal methods – DTA, TGA, DSC; Other techniques – ESR, NMR, Mössbauer and Positron annihilation.

Phase Diagrams: Phase Rule, Single component, Binary systems and Lever Rule.

V. Liquid Crystals: [4]

Isotropic. Nematic and Cholesteric Phases. Smectics-A and –C. Hexatic Phases. Discotic Phases. Lyotropic Liquid Crystals and microemulsions.

VI. Non-Crystalline Materials; [7]

Microstructure and imperfections. Diffusion in solids and related phenomena.

Non-crystalline and glassy materials – Structure, Thermodynamics, Glass transition and related models, tunneling states, Specific heat estimation, Two – level system.

Amorphous semiconductors – Electrical properties, magnetic properties, switching and device applications.

VII. Nanostructure Materials and Carbon Nano-Tubes: [8]

Properties of Individual Nanoparticles. Quantum Wells, Wires and Dots. Size and Dimensionality Effects. Preparation and Characterization of Quantum nanostructures. Applications of nanostructures. Self-Assembly and catalysis. Carbon Nanostructures: carbon Clusters & Fullerenes. Carbon Nanotubes: fabrication, Structurs & Electronic Properties, Application of carbon Nanotubes. Nanostructured Ferromagnetism, Nanocarbon Ferromagnets, Giant and Colossal Magnetoresistance. Ferrofluids.

4. Nuclear Reaction

I. Nuclear decays: (18)

(a) β-decay (9)
Most general form of the interaction Hamiltonian, helicity, determination of neutrino helicity, reduction to the V – A form, lepton number conservation, parity non-conservation, qualitative discussions of Coulomb effects, Fermi and Gamow-Teller matrix elements, selection rules, allowed and forbidden transitions, log(f t) values.

(b) γ-decay (9)
Interaction of electromagnetic field with nuclei, multipole expansion, parity and angular momentum selection rules, transition probability within single particle model, angular distribution and directional correlation orientation ratio.

II. Nuclear Reactions: (32)

(a) Introduction: Survey of reactions of nuclei (3)
Strong, electromagnetic and weak processes, Types of reactions and Q-values, Reaction mechanisms: Energy and time scales for direct and compound reactions, Experimental observables: Angular distributions, Excitation functions.

(b) Models for nuclear reactions (14)
Direct reactions: Optical Model: From Hamiltonian to cross sections for elastic scattering; partial waves, phase shifts, scattering amplitudes, S-matrix and its symmetry and reciprocity; angular distributions, optical potential, Green functions methods: T-matrix expression, two potential formula, plane-wave and distorted-wave Born series. Connection with nuclear structure: reference to folded potential, nuclear density, inelastic excitation, electric B (Ek) and nuclear deformations, transfer reactions, spectroscopic factors, asymptotic normalization constant (ANC).
Compound nuclear reactions: Statistical model.

(c) Heavy Ion collisions (6)
Collisions near the Coulomb barrier: Semiclassical concepts, elastic scattering, Coulomb excitation, deep inelastic collisions, fusion, Collisions near the Fermi velocity, Collisions near the speed of light: Classifications of reactions and products, reaction kinematics. Ultra relativistic nuclear collisions: phase diagram of nuclear matter.

(d) Nuclear Fission (4)
Spontaneous fission, Mass energy distribution of fission fragments, Bohr-Wheeler theory, Fission isobars, Super-heavy nuclei.

(e) Nuclear reactions in stars (3)
H and He burning processes, Synthesis of heavy elements up to iron, Nucleosynthesis beyond iron.

(f) Reactions involving exotic nuclei (2)

5. Elementary Particle Physics

I. Preliminaries: (5)

Different types of symmetries and conservation laws. Noether’s theorem.

II. Symmetry groups and Quark model: (8)

SU(2) and SU(3): root and weight diagrams, Composite representation, Young’s tableaux, quark model, colour, heavy quarks and their hadrons.

III. Quantum Electrodynamics: (10)

Feynman rules, Example of actual calculations: Rutherford, Bhabha, Moeller, Compton, $e^+ e^- \rightarrow \mu^+ \mu^-$. Decay and scattering kinematics. Mandelstam variables and use of crossing symmetry.

IV. Hadron structure and strong interaction: (12)

Elastic e-p scattering, electromagnetic form factors, electron-hadron DIS, structure functions, scaling, sum rules, QCD, asymptotic freedom, gluons and jets in $e^+ e^- \rightarrow$ hadrons.

V. Weak interactions: (15)

Fermi theory, calculation of decay widths of muon and π^+.Quark mixing, absence of tree-level FCNC in the Standard Model, the CKM matrix, Glashow-Salam-Weinberg model, Gauge boson and fermion masses, Neutral current, Experimental tests. decay widths of W and Z. Higgs physics. Reasons for looking beyond the electroweak theory.

Practical, Seminar & Project Work

(For each Practical: Total No. of Lectures/Classes=96)

Computer Practical
(Practical-1)

1. FORTRAN Language

Constants and variables. Assignment and arithmetic expressions. Logical expressions and control statements, DO loop, array, input and output statements, function subprogram, subroutine.

2. Numerical analysis

Computer arithmetic and errors in floating point representation of numbers, different numerical methods for (i) finding zeroes of a given function (ii) solution of linear simultaneous equations (iii) numerical differentiation and integration (iv) solution of first-order differential equations (v) interpolation and extrapolation (vi) least square fitting. Random number generation, sorting.

PHYSICS (Practical : General)

(Practical-2, Practical-3)

1. Study of temperature dependence of resistivity for a given semiconductor using FOUR PROBE SETUP and determine its energy band gap.

2. Determination of Saturation Magnetization, Retentivity and Coercivity of given Ferromagnetic samples Using HYSTERESIS LOOP TRACER.

3. Determination of Hall Coefficient of a given semiconductor sample using variable DC magnetic field.

4. Determination of the specific charge of an electron by the SOLENOIDAL LENS METHOD / MODIFIED THOMPSON'S METHOD.

5. Study of LISSAJOUS FIGURES and calibrate an Audio Frequency Oscillator by PHASE CHANGE AND DIRECT METHOD.

6. Determination of the velocity of ultrasonic wave in a given liquid for a given frequency using MULTI - FREQUENCY ULTRASONIC INTERFEROMETER /LIQUID GRATING METHOD.

7. Determination of the Lande - g factor for the DPPH sample using ELECTRON SPIN RESONANCE SETUP.

8. Study of absorption spectrum of Iodine vapor using OPTICAL SPECTROMETER and determine its - (i) Dissociation energy and (ii) Anharmonicity constant.

9. Determination of the thickness of a given transparent plate with the help of JAMIN'S INTERFEROMETER.

10. Determination of the refractive index of a given transparent thin film using MICHELSON INTERFEROMETER.

11. Determination of the average wavelength and the difference between the wavelength of its two components of sodium light used as source employing MICHELSON INTERFEROMETER.

12. Study of atomic spectroscopy using ZEEMAN EFFECT.

13. Study of Polarization of light using LASER BEAM.

14. Study of Photoconductivity of semiconductors.

PHYSICS (Practical : Electronics)
(Practical-4, Practical-5)

1. Construct a saw-tooth wave generator using UJT for different frequencies. Determine V_P, V_V and η, symbols having the usual meanings. For a fixed C, vary

R (5 values) and Draw the T-R graph. Plot the theoretical T-R graph on the same graph paper. Obtain two such sets.

2. Construct a saw-tooth wave generator using UJT for different frequencies. Determine V_P, V_V and η, symbols having the usual meanings. For a fixed R, vary C (5 values) and Draw the T-C graph. Plot the theoretical T-C graph on the same graph paper. Obtain two such sets.

3. Design an astable multivibrator with two transistors for a fixed given frequency (1.0 KHz). Assume $V_{c(sat)}$=0.2 volt, $I_{c(sat)}$=5 mA, $h_{FE(min)}$=100 and $V_{BE(sat)}$=0.6 volt. Compare the experimentally obtained frequencies with the required theoretical values.
Using this multivibrator design a VCO and draw its transfer characteristics. From this plot calculate the VCO sensitivity.

4. Design the following RC active filters:
   (a) Low Pass, having cut off frequency 10 KHz.
   (b) Band Pass, having Centre frequency 2.8 KHz and bandwidth 3.2 KHz. Draw separate frequency response curves and compare the theoretical and experimental results.

5. Design the following RC active filters:
   (a) High Pass, having cut off frequency 5 KHz.
   (b) Band Stop, having Centre frequency 3.4 KHz and bandwidth 3.0 KHz. Draw separate frequency response curves and compare the theoretical and experimental results.

6. Design the following using NAND gates only:
   (a) S-R Flip-Flop with the provision of clock (enable input). Study the output for different combinations of S and R.
   (b) Convert the above to clocked D Flip-Flop.
   (c) Design a clocked J-K Flip-Flop and study the results of different combinations of J, K and clock. Note the drawback of the experimental circuit, if any and suggest a suitable circuit to remove the drawback with proper explanation.

7. Design a transistor CE amplifier of mid-band gain 50 and study its performance in the following way:
   (a) Test the linearity of input-output variations of a voltage signal of suitable fixed frequency and show it graphically.
   (b) For fixed amplitude of input ac signal within the linear region, study the frequency response with an external bypass capacitor at the output. Plot the gain-frequency graph and determine the bandwidth of the amplifier.

8. (a) Study the performance of AM modulator circuit by considering three different values of modulating signal amplitude and frequency. Determine modulation index in each case.
   (b) Study the performance of AM demodulator circuit by considering three different values of modulating signal amplitude and frequency.
   Write down your observations clearly.

9. Study the performance of Passive T type Low Pass and High Pass filters considering three different values of load. Draw separate frequency response curves for Low Pass and High Pass filters.

Advanced Experiments (Electronics)

(Practical-6 & Practical-7)

A. Experiments with OP-AMP and timer IC

1. Waveform generators – square, triangular, saw-tooth
2. Solution of simultaneous algebraic equations
3. Astable and monostable multivibrator with variable frequency and duty cycle using 555 IC.
4. Voltage-controlled oscillator with 555 IC

B. Simple microprocessor programs, for example:

1. Average of some numbers
2. Testing even/odd
3. Addition of 2-byte numbers
4. Multiplication of two 8-bit numbers
5. Division of two 8-bit numbers with (a) quotient only (b) both quotient and reminder
6. Testing for A=B, A>B and A<B conditions for two given numbers A and B
7. Sum of 10 even (odd) numbers
8. Factorial of a given number
9. To check the parity of a given number
10. To sort out the largest/smallest of a given set of numbers
11. To arrange a given set of numbers in ascending/descending order
12. Configuring delay programs for prescribed period
13. Display programs – displaying in address field, data field and both

C. Experiments on optoelectronics

1. Characteristics of solar cell with variation in
   (i) waveband
   (ii) distance and
   (iii) area of exposure and calculation of parameters
2. Optical communication with LED, photodiode and optical fibers

A. Experiments on digital electronics

1. Fabrication of shift register with JK master-slave flip-flops and study of series and parallel in/out operations

2. Fabrication of counters of different modulus using JK master-slave flip-flops. Use of 7490 counter chip
3. R-2R ladder D/A converter (4-bit and 8-bit)
4. Use of 7483 adder chip as adder, subtractor and both
5. Diode ROM with decoder
6. Use of 7-segment display

B. Microprocessor Interfacing

1. Configure port A/port B/port C as output ports
2. Generate square waves (symmetric, asymmetric and variable amplitude) using 8255 IC and display in CRO
3. Generate triangular wave/saw tooth wave using 8255 IC and display in CRO
4. Control system, such as:
   (i) Stepper motor controller
   (ii) Use of relay module
5. Use of D/A and A/D converters
6. Introductory use of microcontroller

C. Experiments on microwave

1. Familiarity with microwave components and assembling those
2. Gunn diode characteristics
3. Use of waveguide and horn antenna in microwave communication.

Advanced Experiments (Astrophysics)

(PRACTICAL-6 & PRACTICAL-7)

A. Experiments

1. To study the solar limb darkening effect.
2. To study the power pattern of various antennae.
3. To study the Faraday rotation effect and to determine the Verdet constant of lead silicate glass for a given wavelength of light.
4. To study the characteristics of a CCD camera.
5. To determine the effective temperature of a halogen source using a photometer.
6. To perform gamma ray spectrometry with scintillation counting system using single and multichannel analysers
7. To estimate the night sky brightness with a photometer.
8. To polar align an astronomical telescope.
9. Differential photometry of a program star w.r.t a standard star.
10. To study the effective temperature of stars by B-V photometry.
11. To estimate the temperature of an artificial star by photometry.
12. To estimate the relative magnitudes of a group of stars by a CCD camera.

B. Computational Astrophysics Experiments

1. To draw a H-R diagram and study the same by selecting the stars from the image of a Globular Cluster, choosing the cluster from any Globular Clusters(ra,dec from Harris catalogue, 2003 update) from sdss.
2. To solve Lane Emden equations numerically for n=3 by variational iterative scheme and study the density, temperature and pressure profile for a hot and cool star.
3. To find the regression lines as well as variances of the estimates for Black Hole Mass and Velocity Dispersion using measuremental errors and compare it with OLS. Also to find the other symmetric regression lines.
4. To calculate the Christoffel symbols, Riemann tensor, Ricci tensor and curvature for a given spacetime using gRtensor - a computer algebraic package for tensor analysis.

Advanced Experiments (Condensed Matter And Materials Physics)
(PRACTICAL-6 & PRACTICAL-7)

1. Determination of Space Group and Crystal Structure of a Single Crystal Material by Laue Diffraction Method.
2. Determination of Crystal Structure and Lattice Parameters of a Polycrystalline Material by Powder Diffraction (Debye-Scherrer) Method.
3. Determination of Hall Effect & Magnetoresistance of Polycrystalline Bismuth Sample.
4. Determination of Magnetic Susceptibility of Paramagnetic Salts by Guoy Balance Method.
5. Determination of AC Conductivity and Dielectric Constants of Composites Materials by LCR Bridge.
6. Study of Dielectric Constants of Ferroelectric Crystals at Elevated Temperatures and determine the Curie -Temperature.
7. Study of F-Centers of X-ray Irradiated Alkali Halides (KCl & KBr) Samples.
8. Study of the Nature of Band Gap and Determination of Optical Constants (n, k) of Semiconductor (Crystalline and Amorphous) Thin Films using UV-VIS (Dual and Single beam) Spectrophotometer.
9. FTIR Study of Si Based Oxide/ Carbon Nano- Composites.
10. Study of the variation of Hall Coefficient of a given extrinsic semiconductor as a function of temperature using Temperature dependence Hall – effect setup.
11. Study of the electrical properties of given thin films of different materials (metal, insulator and semiconductor) using Four – Probe Setup.

Advanced Experiments (Nuclear Physics & High Energy Physics)
(PRACTICAL-6 & PRACTICAL-7)

1. Determine Using given G.M. counter, the mass absorption coefficient of lead and aluminium for the gamma rays from Co-60. Hence with the given calibration curve curves, determine the average energy of these gamma rays.
2. Study with the help of the given G.M. counter the probability distribution of count values accumulated within a given interval of time, in a given environment, and compare with what is expected from theory.
3. Using the given G.M. counter, take data for thickness of aluminium sheet versus count rate for the given reference source of beta-rays (RaD-E; $T_{\beta, max}$= 1.17 MeV) also take similar data for the unknown source of beta rays. Hence, taking recourse to Feather's analysis, find $T_{\beta, max}$ for the unknown source.
[Formula for the range R(in gm/cm^2) of beta -rays in aluminium:
$R=0.407 (T_{\beta, max})^{1.38}$, for $0.15 < T_{\beta, max} < 0.8$ MeV
$R=0.542. T_{\beta, max} - 0.133$, for $0.8 < T_{\beta, max} < 3$ MeV]
4. Taking Co-60 and Cs-137 as reference gamma-sources and using the given scintillation spectrometer, draw a calibration curve between E_γ and V_{LLD} for the corresponding photopeak. Hence determine the energy(-ies) of the gamma- rays emitted by the given unknown source. Also determine from the data for Cs-137 the resolution and the photopeak efficiency of the detector at E_γ = 0.662 MeV.
5. Determine with the help of the given magnetic spectrometer, the spectrum of beta-rays emitted by RaD-E.
6. Activate the given silver foils with slow neutrons. Then determine the half-life(half-lives) of the isotopes of the silver so produced with the help of the given G.M. counter. The operating voltage of the G.M counter should be ascertained at the begaining of the experiment.
7. Find the mass stopping power of air for alpha-particles of three different energies between 1MeV and 5 MeV using the given alpha-spectrometer and an Americium-241 alpha source. Apply 35 V bias across the detector. [Given that 5.484 MeV. be the maximum energy of the alpha-particles emitting from Americium-241]