Syllabus of M. Sc. in Physics

Semester I (Total 300 Marks)

Four General Theoretical Papers:

Paper 101:	Unit I - Mathematical Methods I	(23 Marks)
	Unit II - Classical Mechanics	(22 Marks)
Paper 102:	Unit I - Quantum Mechanics I	(23 Marks)
	Unit II - Classical Electrodynamics I	(22 Marks)
Paper 103:	Unit I - Solid State Physics I	(23 Marks)
	Unit II - Electronics I	(22 Marks)
Paper 104:	Unit I - Atomic Spectroscopy	(23 Marks)
	Unit II - Nuclear Physics I	(22 Marks)

General Practical Papers:

Paper 105: Electrical Practical for Group A of students
(75 Marks for Examinations + 25 Marks for Sessionals)
Paper 105: Non-electrical practical for Group B of students
(75 Marks for Examinations + 25 Marks for Sessionals)

Internal Assessment on Theoretical Papers:

Mid-semester Examinations/Class Test at the middle of the semester (20 Marks)

Semester II (Total 300 Marks)

Four General Theoretical Papers:

Paper 201:	Unit I - Mathematical Methods II	(23 Marks)
	Unit II - Relativity and Cosmology	(22 Marks)
Paper 202:	Unit I - Quantum Mechanics II	(23 Marks)
	Unit II - Classical Electrodynamics II	(22 Marks)
Paper 203:	Unit I - Solid State Physics II	(23 Marks)
	Unit II - Electronics II	(22 Marks)
Paper 204:	Unit I - Advanced Optics	(23 Marks)
	Unit II - Nuclear Physics II	(22 Marks)

Two General Practical Papers:

Paper 205: Electrical Practical for Group A of students
(75 Marks for Examinations + 25 Marks for Sessionals)
Paper 205: Non-electrical practical for Group B of students
(75 Marks for Examinations + 25 Marks for Sessionals)

Internal Assessment on Theoretical Papers:

Mid-semester Examinations/Class Test at the middle of the semester (20 Marks)

Question Patterns of all general papers will remain same as per previous years. Separate answer scripts will be needed for each unit of each paper.

SEMESTER III (TOTAL 300 MARKS)

Two General Theoretical Papers:

Paper 301:	Unit I - Statistical Mechanics I	(23 Marks)
	Unit II - Advanced Quantum Mechanics I	(22 Marks)
Paper 302:	Unit I - Group Theory	(23 Marks)
	Unit II - Computer Applications in Physics-I	(22 Marks)

Two Special Theoretical Papers:

Paper 303: Special paper – I (45 Marks)
Paper 304: Special paper – II (45 Marks)

One Special Practical Paper:

Paper 305: (40 Marks for Examination + 10 Marks for Sessional) (50 Marks)
Paper 306: One General (Computer) Practical (50 Marks)

Internal Assessment on Theoretical Papers:

Mid-semester Examinations/Class Test at the middle of the semester (20 Marks)

SEMESTER IV (TOTAL 300 MARKS)

Three General Theoretical papers:

Paper 401:	Unit I - Statistical Mechanics II	(23 Marks)
	Unit II - Advanced Quantum Mechanics II	(22 Marks)
Paper 402:	Molecular Spectroscopy	(45 Marks)
Paper 403:	Unit I - Astrophysics	(23 Marks)
	Unit II - Computer Applications in Physics-II	(22 Marks)

One Special Theoretical Paper:

Paper 404: Special Paper III (45 Marks)
(Radiophysics & Electronics, Nuclear Physics, Solid State Physics, Laser Physics, Materials Science)

One Special Practical Paper:

Paper 405: (40 Marks for Examination + 10 Marks for Sessional) (50 Marks)

Paper 406: Project/Term Paper: (50 Marks)
(40 Marks for preparation and presentation of project report and 10 Marks for viva-voce)

Internal Assessment on Theoretical Papers:

Mid-semester Examinations/Class Test at the middle of the semester (20 Marks)

Question Patterns of 401 & 403 general papers will be same as Sem-II General papers. For 402 & 404 eight questions to be set and five questions to be answered. Separate answer scripts will be needed for each unit of papers 401 & 403 only.

For 406 a Board of Examiners comprising faculty members of Department of Physics of BU and Dept of Physics of Asansol B B College will evaluate the term paper submitted by the Sem - IV students. One External Examiner should remain present in each Board during presentation & viva-voce.

SEMESTER I (Total 300 Marks)

Paper 101
Unit – I : Mathematical Methods – 1 **[23 Marks]**

1. a) Functions of a complex variable. Brief review of the topics included in the honours syllabus : analytic functions, Cauchy-Riemann equations, integration in the Complex plane, Cauichy's theorem, Cauchy's integral formula. Liouville's theorem. Moretra's theorem.
   b) Proof of Taylor and Laurent expansions. Singular Points and their classification. Branch Point and branch Cut. Riemann sheets. Residue theorem. Application of residue theorem to the evaluation of definite integrals and the summation of infinite series. Integrals involving branch point singularity. (5+8 lectures)

2. Linear vector spaces, subspaces, Bases and dimension, Linear independence and orthogonality of vectors, Gram-Schmidt orthogonalisation procedure. Linear operators. Matrix representation. The algebra of matrices. Special matrices. Rank of a matrix. Elementary transformations. Elementary matrices. Equivalent matrices. Solution of linear equations. Linear transformations. Change of Basis. Eigenvalues and eigenvectors of matrices. The Cayley-Hamilton theorem. Diagonalisation of matrices. Bilinear and Quadratic forms. Principal axis transformation. Functions of matrices. (10 lectures)

Books Recommended:

1. M. R. Spiegel (Schaum's outline series) – Theory and Problems of Complex Variables.
2. G. Arfken (Academic Press) – Mathematical Methods for Physicists.
3. J. Mathews and R. I. Walker (Benjamin) – Mathematical Methods of Physics.
4. P. Dennery and A. Krzywicki (Harper and Row) – Mathematics for Physicists.

Unit – II : Classical Mechanics **[22 Marks]**

Review of Lagrangian and Hamiltonian formalisms in different systems. Legendre transforms. Hamilton's canonical equations and their applications. Lagrangian and Hamiltonian for relativistic particles. Principle of least action. (5 lectures)

Canonical transformations and some applications. Infinitesimal Canonical transformation. Integral invariant of Poincare. Lagrange and Poisson brackets and their applications. Conservation theorems and angular momentum relation in Poisson brackets. Liouville's theorem. (6 lectures)

Hamilton-Jacobi equation for Hamilton's principle and characteristis function and their apllication. Separation of variables. Action and angle variable and their applications.Passage from classical to quantum mechanics. (6 lectures)
Rigid body motion. Heavy symmetrical top with one pont fixed on the axis. Fast and sleeping top. (2 lectures)
Deformable bodies. Strain and stress tensor. Energy of elastic deformation. (2 lectures)
Fluid dymnamis. Permanancy of vortices. Navier-Stokes theorem. (2 lectures)

Books Recommended:

1. Classical mechanics-Goldstein
2. Introduction to advances dynamics-McCuskey
3. Mechanics- Landau and Liftshitz.
4. Classical Mechanics- K.C. Gupta
5. Classical Mechanics- Rana and Jog

Paper 102

Unit – I: Quantum Mechanics I **[23 Marks]**

1. Linear vector space – State space, Dirac notation and Representation of State Spaces, Concept of Kets, Bras and Operators, Expectation Values, Superposition Principle, Orthogonality, Completeness, Expansion of State Vector, Non commutating Observables, Uncertainty Relations, Commutation and Compatibility, Change of basis, Unitary operators.
   State function and its interpretation, Expectation Values, Expansion of a State Function.... and Superposition of states.
   Matrix Representation of State Vectors and operators, Continuous Basis. Relation between a State Vector and its Wave function. Solution of the Linear Harmonic Oscillator with Operator Method, Coherent States. (10 lecturers)

2. Schrödinger equation and its applications-
   (i) *In one dimensional consideration-*
   Particle in one-dimensional potential well (finite and infinite depth) and its energy states; Linear harmonic oscillator; Solutions of different one-dimensional barriers (finite and infinite width) and penetration problems. (3 lectures)
   (ii) *In three dimensional consideration-*
   Free particle wave function; Motion of a charged particle in a spherically symmetric field; Angular momentum and the eigen functions; Energy states associated wave functions of Hydrogen atom; Expression of Bohr radius. (4 lectures)

3. Approximation methods - Time-independent perturbation theory for non-degenerate and degenerate states. Applications: Anharmonic oscillator, Helium atom, Stark effect in hydrogen atom, Variational methods: Helium atom. (6 lectures)

Books Recommended:

1) 'Quantum Physics' by Robert Eisberg and Robert Resnick (John Wiley and sons).
2) 'Quantum Theory' by D. Bohm (Prentice-Hall).
3) 'Quantum Mechanics: Theory and Applications' by A. K. Ghatak and S. Lokanathan (Macmillan India Ltd.).
4) 'Quantum Mechanics' by L. I. Schiff (McGraw-Hill Book, New York).
5) 'Quantum Mechanics' by Cohen and Tanandji.

Unit – II : Classical Electrodynamics I **[22 Marks]**

1. Inhomogeneous wave equation: it's solution. Lineard-Wiechert potentials. Field of a uniformly moving charge. Fields of an accelerated charge. Radiation from a charge at low velocity. Radiation from a charge at linear motion and circular motion or orbit. Bremsstrahlung- Cerenkov radiation. Relativistic electrodynamics. Covariant form of EM equations. Transformation law for the EM field. Lienard generalisation of Larmor formula; a uniformly moving charge from Coulomb field.

2. Classical theory of electron: Radiation reaction from energy conversation: Lorentz theory. Self force. (22 lectures)

Books Recommended:

1. Marion- Classical Electrodynamics
2. Jackson- Classical Electrodynamics
3. Panofsky & Phillips- Classical Electrodynamics
4. Chen- Plasma Physics
5. Griffith-Electrodynamics

Paper – 103

Unit – I : Solid State Physics I **[23 Marks]**

1. Crystalline and amorphous solids. The crystal lattice. Basis vectors. Unit cell. Symmetry operations. Point groups and space groups. Plane lattices and their symmetries. Three dimensional crystal systems. Miller indices. Directions and planes in crystals. Inter-planar spacings. Simple crystal structures: FCC, BCC, Nacl, CsCl, Diamond and ZnS structure, HCP structure. (4 lectures)

2. X-ray diffraction by crystals. Laue theory. Interpretation of Laue equations. Bragg's law. Reciprocal lattice. Ewald construction. Atomic scattering factor. Experimental methods of x-ray diffraction. Neutron and electron diffraction (brief discussion). (3 lectures)

3. Types of bonding. The van der waals bond. Cohesive energy of inert gas solids. Ionic bond. Cohesive energy and bulk modulas of ionic crystals. Medelung constant. The covalent bond. Metallic bond. (3 lectures)
4. Vibrations of one-dimensional monatomic and diatomic lattices. Infrared absorption in ionic crystals (one-dimensional model). Normal modes and phonons. Frequency distribution function. Review of Debye's theory of lattice specific heat. Anharmonic effects. (4 lectures)
5. Magnetic properties of solids. Diamagnetism, Langevin equation. Quantum theory of paramagnetism. Curie law. Hund's rules. Paramagnetism in rare earth and iron group ions. Elementary idea of crystal field effects. Ferromagnetism. Curie-Weiss law. Heisenberg exchange interaction. Mean field theory. Antiferromagnetism. Neel point. Other kinds of magnetic order. Nuclear magnetic resonance. (9 lectures)

Books recommended:

1. F.C.Phillips: An introduction to crystallography (wiley)(3rd edition)
2. Charles A Wert and Robb M Thonson: Physics of Solids
3. J. P. Srivastava: Elements of solid state physics (Prentice Hall India; 2nd edition).
4. Christmaan-solid state physics (academic press)

Unit – II : Electronics I **[22 Marks]**

1. Passive Networks:
   Synthesis of two terminal reactive networks – Driving point impedance and admittance, Foster's reactance theorems, properties of poles and zeros of reactance function, canonic networks. (2 lectures)
   Four-terminal two-port network – parameters for symmetrical and unsymmetrical networks; image, iterative and characteristic impedances; propagation function; lattice network; Bisection theorem and its application. (2 lectures)
   L-C filters-LPF, HPF, BPF and BRF type constant-k prototype filters; m-derived filters (principle only). (3 lectures)
   Attenuators -T-type, Pi-type, Bridged-T type lattice attenuators. (1 lecture)

2. High Frequency Transmission Line:
   Distributed parameters; primary and secondary line constants; Telegraphers' equation; Reflection co-efficient and VSWR; Input impedance of loss-less line; Distortion of em wave in a practical line. (4 lectures)

3. Semiconductor Devices:
   (a) p-n junction physics- Fabrication steps; thermal equilibrium condition; depletion capacitance; current-voltage characteristics; charge storage and transient behavior; junction breakdown; heterojunction. (6 lectures)
   (b) Characteristics of some semiconductor devices- BJT, JFET, MOS, LED, Solar cell, Tunnel diode, Gunn diode and IMPATT. (6 lectures)

4. Active Circuits:
   Transistor amplifiers- Basic design consideration; high frequency effects; video and pulse amplifier; resonance amplifier; feedback in amplifiers. (5 lectures)
   Harmonic self-oscillators - Steady state operation of self-oscillator; nonlinear equation of self-oscillator; examples. (3 lectures)

Books Recommended:

1. J D Ryder, Networks line and fields.
2. Frazier, Telecommunications.
3. Zee, Physics of semiconductor devices.
4. Milman and Grable, Microelectronics. Tata mc hill.
5. Chattopadhyay and Rakshit, Electronics circuit analysis.

Paper –104 **[23 Marks]**

Unit – I : Atomic Spectroscopy

1. General discussion in Hydrogen spectra, Hydrogen-like systems, Spectra of monovalent atoms, quantum defect, penetrating and non-penetrating orbits, introduction to electron spin, spin-orbit interaction and fine structure, relativistic correction to spectra of hydrogen atom, Lamb shift, effect of magnetic field on the above spectra, Zeeman and Paschen-Back effect.

(7 lectrures)

2. Spectra of divalent atoms: Singlet and triplet states of divalent atoms, L-S and j-j coupling, branching rule, magnetic field effects, Breit's scheme, Spectra of Multi-valent atoms ideas only; complex spectra, equivalent electrons and Pauli exclusion principle. (6 lectrues)

3. Hyperfine structure in spectra of monovalent atoms, origin of X-rays spectra, screening constants, fine structure of X-ray levels, spin-relativity and screening doublet-laws, non-diagram lines, Auger effect. (4 lectures)

4. Lasers in Spectroscopy**:** Broadening of spectral lines, Doppler-free spectroscopy, excitation spectroscopy, ionization spectroscopy, Tera Hertz spectroscopy with innovative applications. (6 lectures)

Recommended books:

1. Introduction of atomic spectroscopy: White
2. Laser Spectroscopy: Allan Corney

Unit – II : Nuclear Physics I **[22 Marks]**

1. General properties of nuclei : Introduction, parity and isospin of nuclei, muonic atoms and electron scattering, charge form factor. Magnetic dipole moment electric quadrupole moment and nuclear shape. (6 lectures)
2. Two-nucleon problem and nuclear forces: Deuteron ground state, excited states, two-nucleon scattering, n-p scattering, partial wave analysis, phase-shift, scattering length, p-p scattering (qualitative discussion), charge symmetry and charge independence of nuclear forces. Exchange nature of nuclear forces, elementary discussion on Yukawa's theory. (6 lectures)
3. Nuclear models : Need for nuclear models, Fermi gas model, spherical shell model. (4 lectures)
4. Nuclear reactions : Direct and compound nuclear-reactions, experimental verification of Bohr's independence-hypothesis, resonance reactions, Breit-Wigner one-level formula, stripping and pick up reactions (qualitative discussion only), optical model. (4 lectures)
5. Particle accelerators : Pelletron, tandem principle, Synchrotron and synchrosyclotron, colliding beams, threshold energy for particle production. (5 lectures)

Two General Practical Papers:

Paper – 105 : Electronics Practicals for Group A Students

(75 marks for Examinations + 25 marks for Sessionals)

Paper – 105 : Non-Electronics Practicals for Group B Students

(75 marks for Examinations + 25 marks for Sessionals)

Internal Assessment on theoretical papers : 20 Marks

Semester II (Total 300 Marks)

Paper – 201

Unit – I : Mathematical Methods II **[23 Marks]**

1. Fourier and Laplace transforms. Inverse transforms. Covolution theorem. Solution of ordinary and partial differential equations by transform methods. (8 lectures)
2. Green's functions for ordinary and partial differential equations of mathematical physics. Integral equations. Fredholm and volterra equations of the first and second kinds. Fredholm's theory for non-singular kernel. (8 lectures)
3. Tensor analysis, Coordinate transformations, scalars, Covariant and Contravariant tensors. Addition, Subtraction, Outer product, Inner product and Contraction. Symmetric and antisymmetric tensors. Quotient law. Metric tensor. Conjugate tensor. Length and angle between vectors. Associated tensors. Raising and lowering of indices. The Christoffel symbols and their transformation laws. Covariant derivative of tensors. (9 lectures)

Books Recommended

1. G. Arfken (Academic Press) – Mathematical Methods for Physicists.
2. J. Mathews and R. I. Walker (Benjamin) – Mathematical Methods of Physics.
3. P. Dennery and A. Krzywicki (Harper and Row) – Mathematics for Physicists.
4. W. Joshi (Wiley Esstern) – Matrices and Tensors

Unit – II : Relativity and Cosmology **[22 Marks]**

1. **Review of special theory of relativity**:

Poincare and Minkowski's 4-dimensional formulation, geometrical representation of Lorentz transformations in Minkowski's space and length contraction, time dilation and causality, time-like and space-like vectors, Newton second law of motion expressed in terms of 4-vectors. (4 lectures)

2. **Review of tensor calculus:**

Idea of Euclidean and non-Euclidean space, meaning of parallel transport and covariant derivatives, Geodesics and autoparallel curves, Curvature tensor and its properties, Bianchi Identities, vanishing of Riemann-Christoffel tensor as the necessary and sufficient condition of flatness, Ricci tensor, Einstein tensor. (5 lectures)

3. **Einstein's field equations**

Inconsistencies of Newtonian gravitation with STR, Principles of equivalence, Principle of general covariance, Metric tensors and Newtonian Gravitational potential, Logical steps leading to Einstein's field equations of gravitation, Linearised equation for weak fields, Poisson's equation. (4 lectures)

4. **Applications of general relativity:**

Schwarzschild's exterior solution, singularity, event horizon and black holes, isotropic coordinates, Birkhoff's theorem, Observational tests of Einstein's theory. (4 lectures)

5. **Gravitational Collapse and Black Holes (Qualitative):**

Introduction: <u>Qualitative discussions on:</u> White Dwarfs, Neutron stars and Black Holes, Static Black Holes (Schwarzschild and Reissner-Nordstrom). Rotating Black Holes, Kerr Metric (derivation not required), Event Horizon, Extraction of energy by Penrose process, Kerr-Neumann Metric (no derivation). No hair theorem, Cosmic Censorship Hypothesis. (3 lectures)

6. **Cosmology:**

Introduction, Cosmological Principles, Weyl postulates, Robertson-Walker metric (derivation is not required), Cosmological parameters, Static Universe, Expanding universe, Open and Closed universe, Cosmological red shift, Hubble's law. Olber's Paradox.

<u>Qualitative discussions on:</u> Big Bang, Early Universe (thermal history and nucleosynthesis), Cosmic Microwave Background Radiation, Event Horizon, Particle Horizon and some problems of Standard Cosmology. (5 lectures)

Books Recommended:

1. J. V. Narlikar- General Relativity and Cosmology (MacMillion, 1978).
2. S. Weinberg- Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity (Wiley, 1972).
3. P. G. Bergmann- Introduction to Theory of Relativity (Pren tice-Hall, 1969).
4. J. V. Narlikar –Introduction to Cosmology (Cambridge Univ, Press, 1993).
5. A. K. Roychaudhuri, S. Banerjee and A. banerjee- General Relativity, Astrophysics and Cosmology (Springer-Verlag, 1992).
6. S. Banerji and A. Banerjee – General Relativity and Cosmology (Elsevier, 2007)
7. R. Resnick – Introduction to Special Theory of Relativity.
8. S. Banerji and A. Banerjee – The Special Theory of Relativity (Prentice Hall of India, 2002)
9. W.G.V.Rosser – Introduction to the Theory of Relativity.

Paper 202 :
Unit – I: Quantum Mechanics II **[23 Marks]**

1. Generalised angular momentum- Infinitesimal rotation, Generator of rotation, Commutation rules, Matrix representation of angular momentum operators, Spin, Pauli spin matrices, Rotation of spin states, Coupling of two angular momentum operators, Clebsch Gordon co-efficients, Applications. (6 lectures)

2. Symmetries- Symmetries, Invariance principle and Conservation laws, Space translation, Time translation, Space rotation, Irreducible spherical tensor operators, Wigner-Eckert theorem and its applications, Space inversion, Time reversal. (4 lectures)

3. Approximation methods- Time-independent perturbation theory for non-degenerate and degenerate states, Application: anharmonic oscillator, Helium atom, Stark effect in hydrogen atom, Variational methods: Helium atom. WKB method; Connection formulae. Time-dependent perturbation theory; Harmonic perturbation; Fermi's golden rule. Sudden approximation. (6 lectures)

4. Scattering theory- Scattering of a particle by a fixed centre of force. Scattering amplitude differential and total cross sections. Method of partial waves. Phase shifts. Optical theorem. Scattering by a hard sphere and potential well. Integral equation for potential scattering. Green's function. Born approximation. Yukawa and Coulomb potential. (7 lectures)

Unit – II :

Classical Electrodynamics II **[22 Marks]**

1. Scattering: free and bound electron. Dispersion and absorption: Lorentz electro magnetic theory. Kramers-Kronig relation.

2. Magnetohydrodynamic (MHD) equations, magnetic, viscosity, pressure, Reynold number, etc. MHD waves. Alfven waves and velocity, Hartmann flow and Hartmann number.

3. Orbit theory of drift motions in a plasma. Pinch effect. Instability in pinched plasma column. Plasma oscillations, short wavelength of plasma oscillation and Debye screening length.

4. Propagation of EM waves through plasma. Effect of external magnetic field on wave propagations: ordinary and extraordinary rays.

5. Multipole radiation.

(22 lectures)

Books Recommended:

1. Marion- Classical Electrodynamics
2. Jackson- Classical Electrodynamics
3. Panofsky & Phillips- Classical Electrodynamics
4. Chen- Plasma Physics
5. Griffith-Electrodynamics

Paper – 203

Unit – I : Solid State Physics II **[23 Marks]**

1. Quantized free electron theory. Fermi energy, wave vector, velocity and temperature, density of states. Electronic specific heats. Pauli spin paramagnetism. Sommerfeld's model for metallic conduction. AC conductivity and optical properties, plasma oscillations. Hall effects. (7 lectures)

2. Intrinsic and extrinsic semiconductors. carrier concentration and Fermi levels of intrinsic and extrinsic semi-conductors Bandgap. Direct and indirect gap semiconductors. Hydrogenic model of impurity levels. (3 lectures)

3. Energy bands in solids. The Bloch theorem. Bloch functions. Review of the Kroning-penney model. Brillouin zones. Number of states in the band. Band gap in the nearly free electron model. The tight binding model. The fermi surface. Electron dynamics in an electric field. The effective mass. Concept of hole. (elementary treatment) (8 lectures)

4. Superconductivity, Survey of important experimental results. Critical temperature. Meissner effect. Type 1 and type ii superconductors. Thermodynamics of superconducting transition. London equation. London penetration depth. Energy gap. Basic ideas of BCS theory. High-Tc superconductors. (5 lectures)

Books recommended:

1. John Singleton: Band theory and Electronic properties of Solids (Oxford University Press; Oxford Master Series in Condensed Matter Physics).
2. Ibach & Luth: Solid State Physics
3. M. Ali Omar: Elementary solid state physics (Addison-wesley)
4. C. Kittel: Solid-state physics (Wiley eastern)(5th edition).

Unit – II : Electronics II **[22 Marks]**

1. Op-Amp Circuits: Characteristics of ideal and practical op-amp; Nonlinear amplifiers using op-amps- log amplifier, anti-log amplifier, regenerative comparators; Active filters; precision rectifiers; ADC and DAC circuits; Op-amp based self oscillator circuits- RC phase shift, Wien bridge, non-sinusoidal oscillators. (7 lectures)

2. Voltage Regulators: Series op amp regulator, IC regulator, Switching regulators.(2 lectures)

3. Elements of Communication Electronics: Principles of analog modulation- linear and exponential types; comparison among different techniques; power, bandwidth and noise immunity consideration; Generation of transmitted carrier and suppressed carrier type AM signals; principles of FM and PM signal generation. (5 lectures)
   Principles of detection of different types of modulated signals (TC and SC types). (2 lectures)
   Modulation techniques in some practical communication systems: AM and FM radio, VSB AM and QAM technique in TV broadcasting. (4 lectures)

4. Digital Circuits: Logic functions; Logic simplification using Karnaugh maps; SOP and POS design of logic circuits; MUX as universal building block. (3 lectures)
   RCA, CLA and BCD adder circuits; ADD-SHIFT and array multiplier circuits. (3 lectures)
   RS, JK and MS-JK flip-flops; registers and counters (principle only). (2 lectures)

Books Recommended:

1. R P Jain, Modern digital electronics, Tata mac'Hill.
2. J.D.Ryder, Electronics fundamental and application.PHI.
3. Gaykwad, Operational Amolifier.
4. Roddy and Coolen, Electronic Communication systems. PHI.

Paper: 204

Unit-I : Advanced Optics **[23 Marks]**

1. Basic Laser Theory:
   Historical background of laser, Einstein coefficients and stimulated light amplification: population inversion, creation of population inversion in three level & four level lasers.
   (2 lectures)
2. Basic Laser Systems:
   Gas Laser: CO_2 laser, Solid State Laser: Host material and its characteristics, doped ions, Nd:YAG laser, Liquid laser: Dye laser, Semiconductor laser. (4 lectures)
3. Laser Beam Propagation:
   Laser beam propagation, properties of Gaussian beam, resonator, stability, various types of resonators, resonator for high gain and high energy lasers, Gaussian beam focusing.
   (3 lectures)
4. Nonlinear Optics:
   Origin of nonlinearity, susceptibility tensor, phase matching, second harmonic generation, methods of enhancement, frequency mixing processes, nonlinear optical materials.
   (2 lectures)
5. Holography:
   Importance of coherence, Principle of holography and characteristics, Recording and reconstruction, classification of hologram and application, non-destructive testing,
   (3 lectures)
6. Transient effect:
   Principle of Q-switching, different methods of Q-switching, electro-optic Q-switching, Pockels cell (2 lectures)
7. Fibre optics:
   Dielectric slab waveguide, modes in the symmetric slab waveguide, TE and TM modes, modes in the asymmetric slab waveguide, coupling of the waveguide (edge, prism, grating), dispersion and distortion in the slab waveguide, integrated optics components (active, passive), optical fibre waveguides (step index, graded index, single mode), attenuation in fibre, couplers and connectors, LED, injection laser diode (double heterostructure, distributed feedback) (5 lectures)
8. Detection of optical radiation:
   Human eye, thermal detector (bolometer, pyro-electric), photon detector (photoconductive detector, photo voltaic detector and photoemissive detector), p-i-n photodiode, APD photodiode (2 lectures)

Books recommended:

1. Principles of lasers- O Svelto
2. Solid State Laser Engineering- W Koechner
3. Laser- B A Labgyel
4. Gas laser- A J Boom
5. Methods of Experimental Physics Vol. 15B ed. By C L Tang
6. Industrial Application of Lasers – J F Ready
7. Handbook of Nonlinear Optics- R L Sautherland
8. Laser and electrooptics- C C Davis
9. Fibre optic communication- Joseph C Palais

Unit – II :

Nuclear Physics II **[22 Marks]**

1. Beta and Gamma decay : Fermi's theory of beta decay, allowed and forbidden transitions, selection rules, non-conservation of parity in beta decay, direct evidence for the neutrino, gamma–decay and selection rules (derivation of transition probabilities not required). (5 lectures)

2. Energy loss of charged particles and gamma rays : Mechanism, Ionization formula, Stopping power and range, radiation detectors – multiwire proportional counter, scintillation counter and Cerenkov detector. (5 lectures)

3. Reactor Physics : Slowing down of neutrons in a moderator, average log decrement of energy per collision, slowing down power, moderating ratio, slowing down density Fermi age equations, four-factor formula. (5 lectures)

4. High energy physics : Types of interaction in nature-typical strengths and time-scales, conservation laws, charge-conjugation, Parity and Time reversal, CPT theorem, Gell-Mann-Nishijima formula, intrinsic parity of pions, resonances, symmetry classification of elementary particles, quark hypothesis, charm, beauty and truth, gluons, quark-confinement, asymptotic freedom. (10 lectures)

Two General Practical Papers:

Paper – 205 : Electronics Practicals for Group B of students

(75 marks for Examinations + 25 marks for Sessionals)

Paper – 205 : Non-Electronics Practicals for Group A of Students

(75 marks for Examinations + 25 marks for Sessionals)

Internal Assessment on theoretical papers: 20 Marks

Question Patterns of all general papers will remain same as per previous years. Separate answer scripts will be needed for each unit of each paper.

SEMESTER III (Total 300 Marks)

Paper – 301
Unit – I : Statistical Mechanics I **[23 Marks]**

1. Scope and aim of statistical mechanics. Transition from thermodynamics to statistical mechanics. Review of the ideas of phase space, phase points, Ensemble, Density of phase points. Liouville's equation and Liouville's theorem. (2 lectures)
2. Stationary ensembles: Micro canonical, canonical and grand canonical ensembles. Partition function formulation. Fluctuation in energy and particle. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators. Para magnetism, concept of negative temperature. (10 lectures)
3. Density matrix: Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches, Properties. Pure and Mixed states.

   Density matrix for stationary ensembles. Application to a free particle in a box, an electron in a magnetic field. Density matrix for a beam of spin ½ particles. Construction of the density matrix for different states (pure and mixture) and calculation of the polarization vector. (8 lectures)
4. Distribution functions. Bose-Einstein and Fermi-Dirac statistics. General equations of state for ideal quantum systems. (3 lectures)

Books Recommended:

1. R. K. Pathria, Statistical Mechanics
2. K. Huang, Introduction to Statistical Mechanics
3. Silvio R. A. Salinas, Introduction to Statistical Mechanics.
4. F. Reif, Fundamentals of Statistical and Thermal Physics.
5. Kadanoff, Statistical Mechanics. World Scientific.
6. R. Kubo, Statistical Mechanics. (Collection of problems)

Unit – II :
Advanced Quantum Mechanics I **[22 Marks]**

1. The Klein Gordon equation. Covariant notations. Negative energy and negative probability density. (2 lectures)

2. The Dirac equation. Properties of the Dirac matrices. The Dirac particle in an external electromagnetic field. The non-relativistic limit of the Dirac equation and the magnetic moment of the electron. (3 lectures)

3. Covariant form of the Dirac equation. Lorentz covariance of the Dirac equation. Boost as hyper rotation Boost, rotation, parity and time reversal operation on the Dirac wave function. (5 lectures)

4. Conjugate Dirac spinor and its Lorentz transformation. The γ^5 matrix and its properties. Bilinear covariants and their properties. (1 lecture)
5. Boosting the wave function from the rest frame. Plane wave solutions of the Dirac equation and their properties. Energy and spin projection operators. (3 lectures)
6. Dirac's hole theory and charge conjugation. Feynman-Stuckelberg interpretation of antiparticles. (2 lectures)
7.Foldy-Wuthuysen transformations: Free particle transformation. The general transformation. (3 lectures)
8. The Hydrogen atom. (4 lectures)

Books Recommended:

1. Relativistic Quantum Mechanics – J.D.Bjorken and S.D.Drell, McGraw-Hill, New York (1964).
2. Advanced Quantum Mechanics – J.J.Sakurai, Addison-Wesley Publishing Company, Inc. (1967).
3. Relativistic Quantum Mechanics and Quantum Fields – T-Y Wu and W-Y Pauchy Hwang, Allied Publishers Limited (2001).

Paper – 302

Unit I : Group Theory [23 Marks]

1. Abstract group theory:

Definition. Group postulates. Finite and infinite groups, order of a group, subgroup; rearrangement theorem, multiplication table. Cosets, Lagrange's theorem. Order of an element.. Conjugate elements and classes. Invariant subgroups, factor groups. Generators. Isomorphism and homomorphism. Cyclic and other distinct groups. Permutation and alternating groups. Cayley's theorem. (7 lectures)

2. Representation theory:

Definition of representation. Faithful and unfaithful representations. Invariant subspaces and reducible representations. Reducible and irreducible representations. Schur's lemmas, great orthogonality theorem and its geometrical interpretation. Character. First and second orthogonality theorems of characters and its geometrical interpretation. Regular representation, celebrated theorem and its implication. Projection operators; determination of basis functions. Direct product groups and their representations Direct product representations and their reduction. Construction of character tables of simple groups. (7 lectures)

3. Continuous group:

Infinite groups. Discrete and continuous groups, mixed continuous group. Topological and Lie groups. Axial rotation group SO(2). Rotation group SO(3). Special Unitary groups SU(2) and SU(3) and their application in Physics. (5 lectures)

4. Application in Physics

Group of Schrodinger equation. Reduction due to symmetry. Perturbation and level splitting. Selection rules. Zeeman effect. (4 lectures)

Books Recommended:

1. M. Hammermesh. 'Group Theory'. Addison-Wesley
2. M. Tinkham. 'Group Theory and Quantum Mechanics;. McGraw-Hill.
3. G. G. Hall. 'Applied Group Theory'. Longmans, Green.
4. A. W. Joshi. 'Group Theory'. Wiley Eastern Ltd..
5. F. A. Cotton. 'Chemical Application to Group Theory'. Wiley Eastern Limited.
6. N. Deo : Group Theory (Tata McGraw Hill)

Unit – II :
Computer Applications in Physics-I **[22 Marks]**

1. **Computer fundamentals**:

   Functional units-CPU, Memory, I/O units; Information representation- integral and real number representation; Character representation: Alphanumeric codes; BCD, Gray, ASCII codes; Error detection and error correcting codes; Hamming codes; CRC codes. (4 lecturers)

2. **Computer Software and Operating Systems**:

   System software and application software; Translator programs; Loaders and linkers; Operating systems- classification; Elements of DOS and Windows- basic commands. (3 lectures)

3. **Elements of C Programming Language**:

   Algorithms and flowchart; Structure of a high level language program; Features of C language; constants and variables; expressions; Input and output statements; conditional statements and loop statements; arrays; functions; character strings; structures; pointer data type; list and trees. (15 lectures)

Books Recommended:

1. Tanenbaum, Operating system. Prentice Hall.
2. Gottfried, Programming with C. Schaum series.
3. Balaguruswamy, ANSI C. TMH.

Paper – 303 (Solid State Physics special) **[45 marks]**

1. Diffraction of x-rays by crystals – scattering of x-rays by an atom and by a three dimensional crystal. Laue interference function, Bragg equation. Ewald construction. Width of diffraction maxima. Crystal structure factor. Space group extinctions. Patterson function. Effect of temperature on the intensity of Bragg reflections. Debye-Waller factor.(10 lectures)

2. Crystal elastivity – Generalised Hooke's law strain energy function cauchy relations. Propagation of elastic waves through cubic crystals. Determination of elastic constants. (5 lectures)

3. Language and use of second quantization formalism: application to the free electron gas, Band electrons in a magnetic field, Fermi surface and its experimental determination, Pauli spin paramagnetism, Landau diamagnetism, Azbel-Kaner Cyclotron resonance, the de Haas-van Alphen effect. (6 lectures)

4. Energy bands: Different methods of calculation of energy bands in solids viz., Nearly free electron model, orthogonalised plane wave (OPW) method and pseudo-potential methods, Phillops-Kleiman's cancellation, qualitative discussions of band structures of semiconductor, semi-metal and insulator, dynamics of an electron in a crystal, Effective mass tensor. (8 lectures)

5. General magnetism: Magnetic susceptibility tensor, quadratic representation, correlation of principal susceptibilities with crystallographic axes in different crystal systems using magnetic ellipsoid, correlation of magnetic anisotropy of molecules and ions in a unit cell with those of crystals, measurements of principal anisotropies of crystals belonging to different systems, Derivation of quantum mechanical expression of diamagnetic susceptibility, structural information from measurement of magnetic anisotropy.(8 lectures)

6. Paramagnetism: Van Vleck expressions of susceptibility, quantum mechanical derivation of Langevin, Debye formula, Crystal field Hamiltonian, Steven's operators, Operator equivalent method, splitting of 3d ions in octahedral and tetrahedral field, Orgel diagram, Stark inversion, Lower symmetry field and computation of principal susceptibility of Cu^{+2} in tetragonal field, calculation of g-factros and susceptibilities of Ce^{3+} in ethyl sulfate lattice, Kramer's theorem, J-T effect. (8 lectures)

Books Recommended

1. B.E.Warren – X-ray Diffraction.
2. A. Maradudin – Solid State Physics (Supplement 3) (Academic Press).
3. O. Madelung – Introduction of Solid State Theory (Springer).
4. J.M. Ziman: Principles of the theory of solids
5. A.L. Fetter and J.D. Walecka: Quantum theory of many particle systems
6. D. Pines: Elementary excitations in solids
7. Raimes: Wave mechanics of electrons

Paper – 303 (Materials Science Special) [45 Marks]

Section I: Applied crystallography in materials science

Noncrystalline and semicrystalline states, Lattice. Crystal systems, unit cells. Indices of lattice directions and planes. Coordinates of position in the unit cell, Zones and zone axes. Crystal geometry. Symmetry classes and point groups, space groups. Glide planes and screw axes, space group notations, Equivalent points. Systematic absences, Determination of crystal symmetry from systematic absences. Stereographic projections. Standard projection of crystals.

(10 lectures)

Section II: Introduction to materials

Classification of materials: Crystalline & amorphous materials, high T_c superconductors, alloys & composites, semiconductors, solar energy materials, luminescent and optoelectronic materials, Polymer, Liquid crystals and quasi crystals, Ceramics. (10 lectures)

Section III: Preparation techniques of materials

Preparation of materials by different techniques: Single crystal growth, zone refining, epitaxial growth. Melt-spinning and quenching methods, sol-gel, polymer processing. Preparation of ceramic materials; Fabrication, control and growth modes of organic and inorganic thin films: different technique of thin film preparations: Basic principles. (10 lectures)

Section IV: Synthesis of nanomaterials

Top down and bottom up approaches of synthesis of nano-structured materials, nanorods, nanotubes/wire and quantum dots. Fullereness and tubules, Single wall and multiwall nanotubes. (5 lectures)

Section V: Phase transition in materials

Solid solutions, Phases, Thermodynamics of solutions, Phase rule, Binary phase diagrams, Binary isomorphous systems, Binary eutectic systems, ternary phase diagrams, kinetics of solid reactions. Order disorder phenomenon in binary alloys, long range order, super lattice, short range order. (10 lectures)

Reference Books

1. Materials science and Engineering by *V. Raghavan*, Prentice-Hall Pvt. Ltd.
2. Thin Solid Films by *K. L Chopra*
3. Elements of X-ray diffraction by *B. D. Cullity*, Addison-Wesley Publishing Co.
4. Elements of crystallography by *M. A. Azaroff*
5. Engineering Materials by *Kenneth G. Budinski*, Prentice-Hall of India Pvt. Ltd.

Paper – 303 (Radiophysics & Electronics special) [45 marks]

1. Microwave Devices: Klystron, magnetrons, Travelling wave tubes, Gunn, Impatt, transistors, GaAs-InP FET, HEMT. (7 lectures)
2. Optical Devices: Laser and Laser resonator, LEDs, Photodiodes, APD, Photo conductor. (6 lectures)
3. Microwave measurements (Frequency, power, impedance). (3 lectures)
4. Optical modulator: Electro optics modulation (amplitude and phase). (3 lectures)
5. Optical coupler: Coupling of light from one fiber to other with the use of evanescent wave. (2 lectures)
6. Integrated optics: basic idea. (2 lectures)
7. Analysis of networks and systems: Sample data system. Z- transform, Fourier and Laplace transforms. (7 lectures)
8. Wave Guide and transmission networks: Wave guides coaxial, rectangular and cylindrical; resonators; filters; couplers; branching networks. Antennas-dipole, array; reflectors, steering strip, microstrip and coplanar structure. (10 lectures)

9. Feed back control systems: Feed back system, stability, performance criteria, servo systems, automatic control principle. (5 lectures)

Books Recommended

1. P. Bhattacharya - Semiconductor opto electronics devices.
2. R E Collin - Foundations of Microwave engineering.
3. S.Y.Liao – Microwave Devices on circuits.
4. J. Ryder – Networks, Lines and Field.
5. A. Papoulis – Signal Analysis
6. Electronic and Radio Engineering – F. E Terman.

Paper – 303 (Nuclear & Particle Physics special) [45 marks]

1. Two body bound state problem-deuteron ground state, singlet state, magnetic dipole and electric quadrupole moment of deuteron. Photodisintegration of deuteron. (8 lectures)

2. Nucleon-nucleon force-charge-symmetry and charge independence, concept of isospin. Probable form of nucleon-nucleon potential from general symmetries, exchange forces, meson theory of nucleon forces, phenomenological potentials-effective of nucleon-nucleon interaction in nuclei. (10 lectures)

3. Low-energy nucleon many body problems-Hartree-Fock theory, angular momentum projection. Second quantization, quasi-particles- Hartree-Fock-BCS and Hartree-Fock-Bogoliouv theories. (7 lectures)

4. Shell model-nucleons in a harmonic oscillator potential, radial density distribution, estimate of oscillator frequency, spin-orbit potential, magic numbers, spin, magnetic and electric quadrupole moment of nuclei, residual interaction, single particle model, odd-odd nuclei, Nordheim's rules, many particle shell model. (8 lectures)

5. Collective model-Collective Hamiltonian, vibrational spectra, ellipsoidally deformed nuclei, total deformation parameter and non- axiality parameter, Moment of inertia –rigid and irrotational values. Rotational models of even-even and odd A nuclei. High Spin states,qualitative explanation, coriolis anti-pairing, cranking formula for the moment of inertia of deformable nucleus, Bohr-Wheeler's theory of nuclear fission. Fission isomers. (8 lectures)

6. Electromagnetic interactions with the nucleus and the nucleon, elastic form factors multipole moments in elastic form factors. (4 lectures)

Paper – 303 (Laser Physics special) [45 marks]

1. **Basic Laser Principle:**
   Summary of black body radiation, Quantum theory for evaluation of the transition rates and Einstein coefficients-allowed and forbidden levels-metastable state; population inversion; rate equations for three level and four level lasers, threshold of power calculation, various broadening mechanism, homogeneous and inhomogeneous broadening. (8 lectures)
2. **Basic Laser System**:
   Basic concept of construction of laser system, various pumping system, pumping cavities for solid state laser system, characteristics of host materials and doped ions. (3 lectures)

3. **Optical beam propagation:**
Paraxial ray analysis, wave analysis of beams and resonators, propagation and properties of Gaussian beam, Gaussian beam in lens like medium, ABCD law-Gaussian beam focusing
(6 lectures)

4. **Resonators:**
Stability of resonators-'g' parameter, various types of resonators, evaluation of beam waist of such combination, design aspect of resonator for various types of lasers, unstable resonator and their application. (8 lectures)

5. **Q-switching:**
Giant pulse theory, different Q-switching techniques: mechanical Q-switching, electrooptic Q-switching, acoustooptic Q-switching, dye Q-switching, Raman-Nath effect. (5 lectures)

6. **Ultrafast Phenomenon**:
Principle of generation of ultrafast pulses (mode locking), basic concepts for measurement of fast processes, Streak technique, Stroboscopy, sampling technique, nonlinear optical methods for measuring ultrashort pulses. (3 lectures)

7. **Different laser systems:**
Gas Lasers:
(i) Molecular gas lasers- CO_2 laser & N_2
(ii) ionic gas laser – Ar^+ laser
(iii) gas dynamic laser
(iv) high pressure pulsed gas laser
Solid State Laser: (i) Nd:YAG laser, (ii) Nd:Glass laser, comparison of performances
(iii) Tunable solid state laser: Ti:sapphire laser; Alexandrite laser
Chemical Laser: HF laser, HCl laser, COIL
Excimer laser; Color centre laser; Free electron laser; semiconductor diode laser
(12 lectures)

Books Recommended:

1. Principles of lasers- O Svelto
2. 2. Solid State Laser Engineering- W Koechner
3. 3. Quantum Electronics- A Yariv
4. 4. The Physics and Technology of Laser Resonator- D R Hall & P E Jackson
5. 5. Introduction to optical electronics- K A Jones
6. Laser- B A Langyel
7. Gas laser- A J Boom

Paper – 304 (Solid State Physics special) **[45 marks]**

1. Transport properties of solids – Boltzmann transport equation and its linearisation. The relaxation time approximation. Variational method for the solution of the linearised Boltzmann equation. Electron-phonon interaction. Ideal resistance in metals. Mattheissen's rule. Transport coefficients of metals and semiconductors in presence of magnetic field. Limitations of the Boltzmann transport equation. Kubo formula for electrical conductivity. (10 lectures)

2. Ferromagnetism and Spin wave - Spontaneous magnetic orders, Alignment of spins through Heisenberg exchange, Thermal variation of spontaneous magnetization, Spin waves, Magnons, Magnon dispersion relation, Derivation of Bloch $T^{3/2}$ Law, Magnon heat capacity. (5 lectures)

3. Magnetic domains and interactions - Origin of domains, anisotropy energy density, Bloch wall, Indirect exchange, RKKY interaction, Spin glass. (3 lectures)

4. Electron Paramagnetic Resonance (EPR) - Phenomenon of magnetic resonance, Bloch equation, Adiabatic fast passage and slow passage solution, Rate of absorption, Saturation, linewidth, Spin lattice relaxation, Spin-Spin relaxation, Exchange interaction, EPR set up. (5 lectures)

5. Nuclear Magnetic Resonance (NMR) - Nuclear moments-Overview, Nuclear induction and absorption experiment, Rate of absorption, Line width, Motional narrowing in liquids, Chemical shift, High resolution spectroscopy, Knight shift (4 lectures)

6. Mössbauer Spectroscopy and Hyperfine interactions - Mössbauer effect, Recoil-less fraction and its temperature dependence, Isomer shift, Application of Mössbauer effect to solid state physics, Quadrupole interaction, EFG tensor, Splitting of nuclear levels. (5 lectures)

7. Alloys and Solid Solutions - Structure of metals and solid solutions. Order-disorder phenomena in binary alloys, Long-range and short-range order, Brag-Williams theory, Superlattice lines. (4 lectures)

8. Crystal defects - Lattice imperfections, Vacancies and interstitial defects, Dislocations, Crystal growth, Colour centers. (4 lectures)

9. Introduction to experimental Techniques in condensed matter physics-Measurement of resistance, Measurement of dc and ac susceptibility (squid, VSM0, Atomic force microscope, (AFM), Scanning tunneling microscope (STM). (5 lectures)

Books recommended:

1) Solid State Physics: Mattis
2) Electron Paramagnetic Resonance: Pake
3) Molecular spectroscopy: Banwell.
4) Solid State Physics: C. Kittle
5) Magnetism in Condensed Matter: Stephen Bludell
6. O. Madelung – Introduction of Solid State Theory (Springer).
7. J.M. Ziman: Principles of the theory of solids

Paper – 304 (Materials Science Special) [45 Marks]

Section I: X-ray scattering from crystalline, nanocrystalline and noncrystalline materials

X-ray energy level schemes, diagram and non-diagram lines, Absorption of X-rays and theory of filters.

X-ray scattering: General description of scattering process, coherent and incoherent scattering, total scattering from a spherically symmetric electron cloud, Quantum mechanical treatment of scattering in outline. Perfect crystal theory: Intensity form a small single crystal, Integrated intensity from a small perfect crystal (no deduction), integrated reflection from Mosaic and powder crystal. (10 lectures)

Section II: Lattice Imperfections

Point defect, line defect, plane defect, volume defect, dislocation, stacking faults, application, Burger vectors. (5 lectures)

Section III: Structure of metals, semiconductors and ceramics

Difference between structures of metals and ceramics, close-packed structures: BCC, FCC & HCP metals. Structure of semiconductors: Si, Ge, ZnS, pyrites, chalcopyrite's, ZnO etc.; structure of ceramics: metal oxides, nitrides, carbides, borides, ferrites, perovskites, etc. (10 lectures)

Section V: Microstructure characterization by direct & indirect methods

Diffraction techniques: interpretation of x-ray powder diffraction patterns, Identification & quantitative estimation of unknown samples by X-ray powder diffraction technique and fluorescent analysis. Theory and method of particle size analysis. Integral breadth method, Warren-Averbach's Fourier method, profile fitting method, Rietveld Method. (10 lectures)

Section VI: Characterization techniques related to nanomaterials

Electron Microscopy techniques: TEM, SEM & STEM. AFM, XPS, EDX. Electron and neutron diffraction (10 lectures)

Reference Books

1. X-ray diffraction by *B. E. Warren*, Addison-Wesley Publishing Co.
2. The Optical principles of the Diffraction of X-rays by *R. W. James*, G. Bell & Sons Ltd.
3. An Introduction to Metallurgy by *Sir Alan Cottrell*, University Press
4. The Structure & Properties of Materials (Volume II) by *J. H. Brophy, R. M. Rose and J. Wulff*, Wiley Eastern Ltd.
5. Structure of Metals, *C. S. Barrett & T. B. Massalski*, McGraw-Hill Book Company.

Paper – 304 (Radiophysics & Electronics special) [45 marks]

1. IC Technology : Hybrid and monolithic IC; Semiconductor processing diffusion, implanation, oxidation, epitaxy, lithography; Si IC technology-MOS and Bipolar; Packaging and testing. (3 lectures)

2. Analog Integrated Circuits. Differential amplifier, OP-AMP comparator; continuous time filters, switched capacitance implementation of sample data filters; analog multiplexers, PLL and frequency synthesizer. (10 lectures)

3. Digital Integrated Circuits: Logic families – TTL, ECL, MOS, MESFET; design of combinational and sequential circuits – MUX, decoder/ encoder, registers, counters, gate arrays; programmable logic devices – PAL, GAL, PLA, Programmable gate arrays. (7 lectures)

4. Special purpose ICs: ICs for analog communication; Digital signal processing ICs; Basic concepts of MIC, MMIC and OELC; GaAs technology; (3 lectures)

5. Memories: Sequential and Random access memories; RAM bipolar and MOS static and dynamic memories; programmable memories PROM, EPROM, EEPROM. (5 lectures)

6. Microprocessor and their applications: Architecture of 8 bit (8085) and 16 bit (8086) microprocessors; addressing modes and assembly language programming of 8085 and 8086. 8086 machine cycles and their timing diagrams; Interfacing concepts memory and I/O interfacing; Interrupts and interrupt controllers; microprocessor based system design; comparison of different microprocessors. (13 lectures)

7. Fundamentals of speech synthesis and recognition, Image processing and biomedical signal processing. (4 lectures)

Books Recommended:

1. Geiger, Allen and Strader – *VLSI – Design Techniques for Analog and Digital Circuits*.
2. Gray and Meyer – *Analysis and Design of Analog Integrated Circuits*.
3. A P Mathur – *Microprocessors.*
4. R S Gaonkar – *Microprocessor Architecture, Programming and Applications with 8085/ 8085A* (2^{nd} Ed.).
5. D V Hall – *Microprocessor and Interfacing*.
6. Lin and Gibson – *Microprocessor*.
7. S Soelof – *Applications of Analog Integrated Circuits*.

Paper – 304 (Nuclear & Particle Physics special) [45 marks]

1. Two-nucleon scattering-partial wave analysis, effective range theory, coherent scattering, spin-flip and polarization, comparison of n-n and p-p scattering. (10 lectures)

2. Nuclear reactions-reaction and scattering cross sections, compound nuclear reactions, resonance reactions, Breit-Weigner formula, experimental determination of resonance widths and shapes, statistical theory, optical model, transfer reactions, pick-up and stripping reactions, spectroscopic factors. (12 lectures)
Heavy ion reactions-salient features at low, intermediate and high energies, classical dynamical model, heavy ion fusion, fusion excitation function, deep inelastic collision. (8 Lectures)

3. Some aspects of nuclear measurement techniques:
(i) Detectors and electronics for high resolution gamma and charge particle spectroscopy;
(ii) Fast neutron, detection
(iii)Neutrino detection,
(iv)Drift chambers, RICH, calorimeter (15 lectures)

Books Recommended:

1. Nuclear Physics: L.R.B Elton
2. Nuclear reactions: Blatt and Weisskopf
3. Nuclear Theory- Roy and Nigam

4. Nuclear Physics- B. Cohen
5. Nuclear Physics- Preston and Bhaduri
6. Nuclear structure- Bohr and Mottelson
7. Nuclear structure- M. K. Pal
8. Techniques in experimental nuclear physics- Leo
9. Techniques in experimental nuclear physics- Knoll
10. Techniques in experimental nuclear physics-S. S. Kapur

Paper – 304 (Laser Physics special) **[45 marks]**

1. **Laser Safety:**
   Various hazards due to laser radiation-eye, skin, chemical etc., safety measures and standard ANSI. (2 lectures)

2. **Nonlinear Optics**:
   Introduction, nonlinearities of the polarization, generation of second harmonic, D.C., sum and difference frequency generation, anharmonic oscillator model, Miller's rule, crystal symmetry, coupled amplitude equations, Manley-Rowe relation. (8 lectures)

3. **Phase Matching**:
   Basic idea of phase matching, quasi-phase matching method, various methods of phase matching (angle, temperature, birefringence etc.) critical and noncritical phase matching, collinear and non-collinear phase matching, expression of angle band-width ($\Delta\theta$) and wavelength band-width ($\Delta\lambda$) in phase matched second harmonic generation, idea of tangential phase matching. (8 lectures)

4. **Second Harmonic Generation**:
   Basic equation, conversion efficiency and parameters affecting doubling efficiency, various methods of enhancing conversion efficiency, second harmonic generation with Gaussian beam, intra-cavity second harmonic generation. (8 lectures)

5. **Higher Order Nonlinear Processes**:
   Four wave mixing processes-third harmonic generation, resonance enhancement of nonlinear susceptibilities, different phase matching techniques, generation of tunable deep UV and IR radiation, stimulated Raman scattering, inverse Raman scattering, anti-stokes coherent Raman scattering, application in spectroscopy, self focusing. (8 lectures)

6. **Chemical Application**:
   Selective excitation reaction, different separation processes, principle of isotope separation, uranium enrichment. AVLIS. (3 lectures)

7. **Laser speckle:**
   Spatial frequency filtering- theory and its application (2 lectures)

8. **Lasers in Spectroscopy:**
   (i) Saturation spectroscopy-Doppler free spectroscopy-Lamb dip, (ii) femtosecond spectroscopy, (iii) Terahertz spectroscopy (iv) Photo-acoustic spectroscopy, (v) Opto-galvanic spectroscopy. (6 lectures)

Books Recommended:

1. Methods of Experimental Physics Vol. 15B ed. By C L Tang
2. Industrial Application of Lasers – J F Ready
3. Solid State Laser Engineering- W Koechner
4. The Principle of Nonlinear Optics- Y R Shen
5. Handbook of Nonlinear Optics- R L Sautherland
6. Laser and electrooptics- C C Davis

Paper – 305 (Special Practical Paper) [50 marks]
(40 Marks for Examinations + 10 Marks for Sessionals)

Solid State Physics Special Practical Experiments:

1. To study the temperature dependence of Hall coefficient of a given semiconductor.
2. Preparation of single crystals of copper sulfate using slow evaporation technique and identification of the c-axis of the newly grown triclinic crystal. Determination of magnetic field with different magnetizing current from the measurements of anisotropy with 'c-axis vertical' modes of suspension.
3. Determination of Band gap of a given semiconductor material by four probe technique.
4. Design/fabrication of a temperature controller and to study the performance of the designed controller using PID Controlled Oven.
5. Determination of Lattice parameters, particles sizes etc. of different powder samples of bulk-/nano-systems (ferrite, α-Fe2O3, γ-Fe_2O_3) using X-ray diffractograms.

Materials Science Special Practical Experiments:

1. Determination of Miller indices and lattice parameter of an unknown powder material by X-ray diffraction.
2. Phase identification of an unknown sample by x-ray diffraction.
3. Determination of particle size and lattice strain of an unknown powder specimen applying marq2 software and Scherrer equation.
4. Preparation of nanocrystalline powder specimen by ball milling: analysis of their x-ray spectra and particle size estimation by Scherrer formula.
5. Preparation of nanocrystalline powder specimen by chemical route: analysis of their x-ray spectra and particle size estimation by scherrer formula.
6. Study of porosity and grain size of thin film and powder sample by SEM.

Radio physics and Electronics special Practical Experiments:

Expt. No.	Name of the Experiment
1.	Design and study of an ECL OR-NOR circuit.
2.	Design and study of an active band pass filter.
3.	Design and study of an active phase sifter.
4.	Design and study of a current controlled oscillator.
5.	Design and study of a RC phase oscillator.

Nuclear Physics Special Practical Experiments:

1. Determination of half-life of a long-lived radioisotope of K^{40}.
2. Study of Gamma ray spectrum of radioactive nuclides with a NaI (Tl) scintillator and single channel analyzer.
3. To study the efficiency of a NaI (Tl) detector for gamma rays of different energies and to draw the efficiency calibration curve and the strength of the unknown source from this curve.
4. Using two channel coincidence analyzer with scintillation detectors,
   (a) Study of gamma ray spectra,
   (b) Measurement of resolving time by random co-incidence method
   (c) Study of the angular resolution of the two coincidence detectors.

Laser Physics Special Practical Experiments:

1. Determination of spot size and the angle of divergence of a given laser source.
2. Measurement of absorption coefficient of a material (supplied) using laser light.
3. Determination of numerical aperture of a fibre by measuring the diameter of laser beam.
4. To study the effect of magneto-striction of a given material.
5. To study the Faraday effect and Verdert constant of the given material.

Paper – 306: One General (Computer) Practical (50 marks)

Internal Assessment on theoretical papers : (20 Marks)

SEMESTER IV (Total 300 Marks)

Paper – 401
Unit – I : Statistical Mechanics II **[23 marks]**

1. Ideal quantum systems:

   a. Properties of ideal Bose gas: Bose-Einstein condensation: Transition in liquid He^4, Superfluidity in He^4. Photon gas: Planck's radiation law. Phonon gas: Debye's theory of specific heat of solids.

   b. Properties of ideal Fermi gas: Review of the thermal and electrical properties of an ideal electron gas. Landau levels, Landau diamagnetism. White dwarf and Neutron stars. (10 lectures)

2. Strongly interacting systems:

   Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian.

   Exact solution of one-dimensional Ising system (Matrix methods). Bragg-William's approximation (Mean field theory) and the Bethe-Peierls approximation. (6 lectures)

3. Phase transition: General remarks. Phase transition and critical phenomena. Critical indices. Landau's order parameter theory of phase transition. (3 lectures)

4. Fluctuations. Thermodynamic fluctuations. Spatial correlations in a fluid. Brownian motion: Einstein-Smoluchowski's theory. (4 lectures)

Books Recommended

1. Sanchez Bowley, Introductory Statistical Mechanics, Oxford University Press
2. R. K. Pathria, Statistical Mechanics
3. K. Huang, Introduction to Statistical Mechanics
4. Silvio R. A. Salinas, Introduction to Statistical Mechanics.
5. F. Reif, Fundamentals of Statistical and Thermal Physics.
6. Kadanoff, Statistical Mechanics. World Scientific.
7. R. Kubo, Statistical Mechanics. (Collection of problems)

Unit – II : Advanced Quantum Mechanics II **[22 marks]**

1. Concepts of fields. Lagrangian dynamics of Classical fields. Derivation of the Euler-Lagrange equation from Hasmilton's variational principle. Lagrangians and equations of motion of fundamental fields. (1 lecture)

2. Noether's theorem. Invariances. Conserved currents and charges. Energy-momentum tensors and energy of fields. (2 lectures)

3. Canonical quantization and particle interpretation of the real Klein-Gordon field. Fock space of bosons. Energy of the real Klein Gordon field. Normal ordering. (2 lectures)

4. Introduction of antiparticle. Charge of quantum complex Klein-Gordon field. (1 lecture)

5. Canonical quantization and energy of the Dirac field. Anti-commutators. Pauli principle. Equal time anti-commutator between the Dirac field and the canonically conjugate momentum field. (2 lectures)

6. Coulomb gauge quantization and energy of the Electromagnetic field. (4 lectures)

7. A comparison between non-covariant and covariant quantization of the electromagnetic field. Features of covariant quantizations : Derivation of equal-time commutators between the components of fields and canonically conjugate momentum fields, (Derivation of energy operator not needed) special properties of time-like photons. Gupta-Bleuler formalism. (4 lectures)

8. Basic ideas of the path integral formalism in quantum mechanics and quantum field theory. (1 lecture)

9.Interacting fields (mainly electromagnetic interaction). Lagrangian and equations of motion of a system of interacting electrons and photons. Covariant perturbation theory. Derivation of the s-matrix operator. Time-ordering. Application to Compton scattering. Wick's theorem (statement only). Enumeration of terms of s-matrix element and corresponding Feynman diagrams. Statement of Feynman rules of graphs in quantum electrodynamics. Vacuum polarization diagram in Hydrogen atom, Charge renormalization and Lamb shift. (Detailed derivations of integrals not needed). Drawing of diagrams and statement of anomalous magnetic moment of electron. (5 lectures)

Books recommended:

1. Relativistic Quantum Fields - J. D. Bjorken and S. D. Drell, McGraw-Hill Book Company (1965)
2. Quantum Field Theory - Lewis H Ryder, Cambridge University Press (1985)
3. Quantum Field Theory - Claude Itzyksen and Jean-Bernard Zuber, McGraw Book Co. (1985)
4. Quantum Field Theory in a nutshell - A. Zee, Princeton University Press (2003).
5. A First Book of Quantum Field Theory – A. Lahiri and P. B. Pal, Narosa Publishing House (2001).

Paper – 402 : Molecular Spectroscopy [45 marks)]

1. Born-Oppenheimer approximation and separation of electronic and nuclear motions in molecules. Band structures of molecular spectra. (2 lectures)

2. Microwave and far infrared spectroscopy : Energy levels of diatomic molecules under rigid rotator and non-rigid rotator models. Selection rules. Spectral structure. Structure determination. Isotope effect. Rotational spectra of polyatomic molecules. Stark effect. (5 lectures)

3. Infrared spectra : Energy levels of diatomic molecules under simple harmonic and anharmonic (no deduction necessary for this one) models. Selection rules and spectral structures. Morse potential energy curves. Dissociation energies. Isotope effect. Rotational – vibrational coupling. Parallel and perpendicular modes. Symmetry properties of molecular wave functions and nuclear spins. (7 lectures)

4. Raman spectroscopy. Rotational, Vibrational, Rotational-Vibrational Raman spectra. Stokes and anti stokes Raman lines. Selection Rules. Spectral structures. Nuclear spin and its effect on Raman spectra. (3 lectures)
5. Vibrational spectra of poly atomic molecules. Normal modes. Selection rules for Raman and infrared spectra. Complementarity of Raman and infrared specra. Normal modes of CO_2 molecule. Normal modes of other simple triatomic molecules. (4 lectures)
6. Electronic spectra of diatomic molecules:
   (a) Vibrational band structure. Progressions and sequences. Isotope shifts. Deslandres tables. Molecular constants in the ground and excited electronic states and crude idea of molecular bonding.
   (b) Rotational structure of electronic spectra. P-, Q- and R- branches. Band head formation and shading of bands.
   (c) Intensity distribution in the vibrational structure of electronic spectra and Franck-Condon principle.
   (d) Hund's coupling.
   (e) Experimental determination of dissociation energy. (5 lectures)

7. Hydrogen molecule ion and molecular orbitals. Valence Bond approach in hydrogen molecule. Coulomb and exchange integrals. Electronic structures of simple molecules. Chemical bonding. Hybridizations. (5 lectures)
8. Basic aspects of photo physical processes: radiative and non-radiative transitions; fluorescence and phosphorescence; Kasha's rules. Nuclear Magnetic resonance spectroscopy. Electron spin resonance spectroscopy. Fourier transform spectroscopy. Photo acoustic spectroscopy. Photo electron spectroscopy. Mossbauer spectroscopy. (8 lectures)
9. Application of group theory to spectroscopy. (6 lectures)

Books Recommended:

!. G. Herzberg. 'Molecular Spectroscopy (Diatomic Molecules)' Van-Nostrand.
2. G. M. Barrow. 'Molecular Spectroscopy'. McGraw-Hill.
3. J.Michael Hollas. ' Modern spectroscopy'. John-Wiley & sons.
4. C. L. Banwell and E. M. McCash. 'Fundamentals of Molecular Spectroscopy' Tata- McGraw-Hill..
5. G.Aruldhas 'Molecular Spectroscopy'.
6. Bransden and Joachin. 'Atoms and Molecules'
7. F.A.Cotton. 'Chemical application to Group theory'.

Paper – 403 :
Unit – I : Astrophysics **[23 marks]**

1. **Introduction:**
   Astrophysics and Astronomy, Celestial coordinate systems (Sun-Earth system, Galactic Coordinate system). (1 lecture)

2. **Stellar Structure and Evolution:**
   i) Star formation, Stellar Magnitudes, Classification of stars, H-D classification, Saha Equation of ionization, Hertzsprung-Russel (H-R) diagram. (2 lectures)
   ii) Gravitational energy, Virial theorem, Equations of stellar structure and evolution. (2 lectures)
   iii) Pre-main sequence evolution, Jeans criteria for star formation, fragmentation and adiabatic contraction, Evolution on the main sequence, Post main sequence evolution, Polytropic Models: Lane-Emden equation, simple stellar models: Eddington's model and Homologous model, Convective and Radiative stars, Pre-main sequence contraction: Hayashi and Henyey tracks. (6 lectures)

3. **Nuclear Astrophysics:**

   Thermonuclear reactions in stars, pp chains and CNO cycle, Solar Neutrino problem, subsequent thermonuclear reactions, Helium burning and onwards, nucleosynthesis beyond iron, r- and s- processes. (3 lectures)

4. **Stellar Objects & Stellar Explosions:**
   Qualitative discussions on: Galaxies, Nabulae, Quasars, Brown dwarfs, Red Giant Stars, Nova, Supernova. (2 lectures)

5. **Gravitational Collapse and relativistic Astrophysics:**
   Newtonian theory of stellar equilibrium, White Dwarfs, Electron degeneracy and equation of States, Chandrasekhar Limit, Mass-Radius relation of WD. Neutron Stars, Spherically symmetric distribution of perfect fluid in equilibrium. Tolman-Oppenheimer-Volkoff (TOF) equation, Mass-Radius relations of NS. Pulsars, Magnetars, Gamma ray bursts.
   Black holes, Collapse to a black hole (Oppenheimer and Snyder), event horizon, singularity. (7 lectures)
6. **Accretion disks:**
   Formation of Accretion Disks, Differentially rotation systems in Astrophysics, Disk dynamics, Steady Disks, Disk formation in close binary systems through mass transfer, Accretion onto compact objects (Black Holes and Neutron Stars). (3 lectures)

Books Recommended:

1. Textbook of astronomy an astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2. Astrophysics – Stars and Galaxies, K. D. Abhyankar, University Press, 2001.
3. Theoritical Astrophysics (Vols.I,II,III) – T. Padmanavan (CUP)
4. Black Holes, White Dwarfs and Neutron Stars – S.L.Shapiro and S.A.Teukolsky (John Wiley, 1983)

5. The Early Universe – E.W.Kolb and M.S.Turner (Addision-Wesley Reading, 1990)
6. Introduction to Cosmology – J.V.Narlikar (Cambridge University Poress)
7. General Relativity, Astrophysics and Cosmology – A.K.Raychaudhuri, S.Banerji and A.Banerjee (Springer-Verla, 1992)
8. General Relativity and Cosmology – S. Banerji and A. Banerjee (Elsevier, 2007)
9. The Structure of the Universe – J.V.Narlikar (OUP, 1978)

Unit II :
Computer Applications in Physics II **[22 marks]**

1. CPU- programmers model; instruction set and addressing modes of a generic CPU; RISC and SISC; Storage System- primary and secondary memory; semiconductor, magnetic and optical memory; cache memory; virtual memory; memory management; IO Units – keyboard, mouse, VDU, printers; (principle of operation only). Computer Networks- motivation, classification, topology, technology (qualitative description); Internet- structure, TCP/IP protocol, internet services; Introduction to WWW. (7 lectures)

2. Representation of integers and real numbers; Accuracy, range, overflow and underflow of number representation; error propagation and instability.
   Solution of polynomial equations- bisection, Newton-Raphson algorithm.
   Solution of system of simultaneous equations- Gauss elimination, Gauss-Seidel, LU decomposition algorithms. Interpolation- Newton interpolation formula. Numerical integration – trapezoidal formula, Simpson's formula, Romberg formula. Numerical solution of differential equations- Euler, Runge-Kutta formula. Numerical solution of partial differential equations- description of algorithms only. Monte Carlo technique of numerical integration. (15 lectures)

Books Recommended:

1. Sastry, Introductory Methods ofNumerical Analysis. PHI
2. Kyayszig, Advance Engineering Mathematics. John Willey, 9th Ed.
3. Tanenbaum, Computer Network, Prentice Hall.

Paper – 404 (Solid State Physics Special) **[45 marks]**

1. Lattice dynamics – Equation of motion of a vibrating lattice, Harmonic approximation. Atomic force constants. Dynamical matrix. Central and non-central forces. Dispersion relation. Vibrational properties of square and cubic lattices, Acoustic and optical modes. Quantisation of lattice vibration. Optical modes in ionic crystals. The Lyddane-Sachs-Teller relation. Polaritons. Localised lattice vibrations. Frequency distribution function, Van Hovesingularities. Thermodynamic functions of a vibrating solid in the harmonic approximation. An harmonic interaction. Gruneisen constant, Mie-Gruneisen equation of state. Slow neutron scasttering in solids, Elastic/inelastic and Coherent/incoherent scattering. (12 lectures)

2. Optical properties of solids – Kramers-Kronig relations sum rule for oscillator strengths. Direct and indirect interband transitions. Optical absorption in Semi-conductors and Mott-Wannier excitations. (4 lectures)

3. Many body techniques: The basic Hamiltonian, Jelium Model, Hatree and Hatree-Fock equation, interacting electron gas, Hatree-Fock approximations for the electron gas, Excahnge hole, exchange energy, Density Functional Theory, Static screening, Thomas Fermi approximation, Plasma Oscillations, Bohm Pines theory-Random Phase Approximation, plasma oscillations, dielectric function of an electron gas, Linhard dielectric function. (7 lectures)

4. Superconductivity**:** Phenomenology: signatures of superconductivity in resistivity, susceptibility, heat capacity, IR reflectivity etc., fluxoid quantization, Cooper pairing: instability of the Fermi sea, BCS Hamiltonian and its diagonalization by Bogoliubov-Valatin transformation, ground state energy, gap equation, critical temperature, isotope effect, magnetic mechanisms of pairing, Ginzburg-Landau theory: H_{c2}, Abrikosov vortex lattice, Josephson junction and Josephson effect, exotic symmetries of the order parameter. Coexistence of superconductivity and magnetism, applications of high T_c superconductors. (8 lectures)

5. Ferrimagnetism and Antiferromagnetism

   Ferrites, two sublattice model, Curie temperature and susceptibility, super exchange, magnetic bubbles. Exchange Hamiltonian, Dispersion relation, Zero-point sublattice magnetization, Thermal behaviour of sub-lattice magnetization. (5 lectures)

6. Dielectric and Ferroelectrics
   Ionic crystals, Polarization catastrophe, nature of phase transitions, Ferroelectricity, Piezo-electricity, Pyroelectricity. (4 lectures)

7. Advanced materials / Phenomenon
   Spintronics, Multiferroics, Gaint magnetoresistance (GMR), Colossal magnetoresistance (CMR), La-based Perovskite, C_{60}. (5 lectures)

Books recommended:

1. Solid State Physics: C. Kittle
2. Ferrites: J. Smith & P.J. Wijn
3. Introduction to Magnetic Materials: B. D. Cullity
4. Solid State Physics: Askrof and Mermin
5. Magnetism in Condensed Matter: Stephen Bludell
6. Theory of Superconductivity, J. Robert Schrieffer,
7. Introduction to Superconductivity, 2nd Edition, by *Michael Tinkham*
8. O. Madelung – Introduction of Solid State Theory (Springer).
9. J.M. Ziman: Principles of the theory of solids

Paper 404 (Material Science Special Paper) (45 Marks)

Section I: Optical and dielectric properties of materials

Theory of electronic polarization and optical absorption, ionic polarization, orientational polarization. Optical phonon model in an ionic crystal; Interaction of electromagnetic waves with optical modes, polariton, Dispersion curves of transverse optical (TO) phonon and optical photon in a diatomic ionic crystal, LST relation; Metal-insulator transition.

UV-VIS, IR, FTIR and Raman spectroscopy. Optical properties of metals & nonmetals-Luminescence, photoconductivity. (15 lectures)

Section II: Electrical properties of crystalline, nanocrystalline and polymeric materials

Resistivity variation in metals, alloys, semiconductors and nanocrystalline materials, electrical conduction in ionic ceramics, clay materials and conducting polymers. Two-probe and four probe techniques, DC and AC conductivity measurements. (10 lectures)

Section III: Mechanical Properties of metals and ceramics

Concepts of stress & strain, stress-strain behavior, anelasticity, Plastic deformation, Hardness-Knoop & Vicker's hardness test. (5 lectures)

Section IV: Thermal properties of metals & alloys

Temperature effects on the intensities of Bragg reflections. Influence of temperature on diffraction of X-rays: Normal coordinates of lattice vibration and X-ray scattering from a vibrating lattice and origin of thermal diffuse spots. First order TDS. Debye-Waller factor' Debye's method of calculating isotropic temperature factor for a cubic crystal. DTA, TGA, DSC (Outline only).

Annealing processes, Heat treatment of steels, mechanism of hardening. Quenching, thermal stresses. (10 lectures)

Section V: Structure - Property correlation, application aspects of material

Correlation of structure with physical properties of materials, application prospects of materials in different areas. (5 lectures)

Reference Books

1. Introduction to Ceramics by *W. D. Kingery, H. K. Bowen and D. R. Uhlmann*, John Wiley & Sons
2. Diffraction analysis of the microstructure of materials by *E. J. Mittemeijere and P. Scardi*, Springer
3. Materials Science & Engineering by *William D. Callister*, John Wiley & Sons, Inc.
4. Modern techniques of surface science by *D. P. Woodruff & T. A. Delchar*, Cambridge University Press
5. X-ray spectroscopy by *B. K. Agarwal*, Springer-Verlag.

Paper – 404 (Radiophysics & Electronics Special) (45 marks)

1. Review of CW Modulation Technique: Linear modulation DSB, SSB, VSB, QAM techniques, Exponential modulation FM and PM; AM and FM modulators and demodulators. (4 lectures)

2. Pulse Modulation and Demodulation Techniques : Sampling the rein PAM, PWM, PPM, Pulse code modulation – coding technique modulation and demodulation. (5 lectures)

3. Digital Modulation Techniques : ASK, FSK, PSK, DPSK, QPSK, MSK, Principle, modulators and demodulators. (5 lectures)

4. Effect of Noise on Communication System: Characteristics of additive noise; Performance of AM, FM and PCM receivers in the face of noise; Multi-path effect. (5 lectures)

5. Elements of Information Theory: Information, average information, information rate, Effect of coding on average information per bit; Shanon's theorem; Channel capacity, an optimum modulation system. (4 lectures)

6. TV Systems: Color TV standards – NTSC, PAL, SECAM; Transmission format of intensity and color signal; Transmitter and receiver systems of broadcast TV; Advanced TV; Cable TV. (4 lectures)

7. RADAR System: Basic pulsed radar system – modulators, duplexer indicators, radar antenna CW radar; MTI radar FM radar; chirped pulse radar. (4 lectures)
8. Optical Communication: Fibre optic communication systems; Power budget equation; Multiplexing; Quantum limit; Incoherent reception; signal-to-noise ratio calculation; Basics of coherent techniques in FOC. (4 lectures)

9. Satellite Communication: Orbits, Station keeping; Satellite attitude; Path loss calculation; Link calculation; Multiple access techniques; Transponders; Effects of nonlinearity of transponders. (3 lectures)

10. Specialised Communication Systems: Mobile Communication – Concepts of cell and frequency reuse description of cellular communication standards; Pagers. Computer communication – Types of networks; Circuit message and packet switched networks; Features of network, design and examples of ARPANET, LAN, ISDN, Medium access techniques – TDMA, FDMA, ALOHA, Slotted ALOHA, CSMA/CD; Basics of protocol. (7 lectures)

Books Recommended

1. A B Carlson – *Communication Systems.*
2. D Roddy and J Coolen – *Electronic Communications.*
3. Franz and Jain – *Optical Communication Systems.*
4. A M Dhake – *Television and Video Engineering*.
5. Gulati – *Monochrome and Color TV*.
6. Kennedy and Davis – *Electronic Communication Systems*.
7. Taub and Schilling – *Principle of Communication Systems*.

Paper – 404 (Nuclear & Particle Physics special) (45 marks)

1. Basic objectives of high energy physics. Brief overview of four fundamental interactions and their characteristics, elementary particles and their characteristics. (1 lecture)

2. Static model ($SU(3)_f$) of quarks. Baryon and meson supermultiplets. Spin-flavour state functions of baryon decouplets, baryon octets and meson nonets. Colour wave functions. Magnetic moments of baryons. Principles of discoveries of heavy flavours: Charm, bottom and top.(Detailed experimental techniques not needed). Summary of quantum numbers of all quark flavours. Vector mesons and their decays. Zweig rule. (8 lectures)

3. Gauge theories of fundamental interactions. Internal symmetries. Global and local gauge invariances. U(1) and $SU(3)_c$ symmetries. Comparison between Quantum Electrodynamics and Quantum Chromodynamics. Running coupling constants (derivations not required). Ultraviolet breakdown. Asymptotic freedom. Infrared slavery. (8 lectures)

4. High energy electron-proton scattering. Bjorken variable. Elastic, deep-inelastic régimes. Derivation of inclusive scattering cross section in terms of structure functions. Bjorken scaling. Scaling violation. Concepts of Mandelstam variables. Compton scattering and gluon emission scattering amplitudes and cross-sections in terms of Mandelstam variables. Altarelli-Parisi evolution equation. (10 lectures)

5. Weak interaction. Analogy with electromagnetic interaction. Four-fermion point interaction of Fermi. Weak interaction amplitude in terms of bilinear covariants. Parity violation. τ-θ paradox, Wu's experiment. Correlation data. V-A form of weak interaction amplitude. Parity violations in Λ^0, K^0 decays. Strangeness oscillation. Regeneration phenomenon. CP violation in K^0 decay. CPT theorem (statement only). Strangeness-conserving and strangeness-violating weak interactions. Cabbibo theory. (8 lectures)

6. Gauge theory of weak interaction. Spontaneous symmetry breaking and Higgs mechanism. Electroweak unification. Glashow-Weinberg-Salam model of electroweak symmetry breaking. $W^{\pm}$, Z^0 masses. Basic ideas of a Grand Unified Theory, SU(5) theory and its predictions. Inclusion of gravity. Planck scale. Brief chronology of events in the early universe. (8 lectures)

7. Neutrino mass and neutrino oscillation. Derivation of intensity of ν_e - ν_μ . Atmospheric, solar and Supernova neutrinos. Solar neutrino problem. (2 lectures)

Books recommended:

1. Introduction to High Energy Physics – D.H.Perkins, Addison Wesley, Reading, Mass (1982)
2. Quarks and Leptons: An Introductory Course in Modern Particle Physics – F. Halzen and A.D.Martin, John Wiley & Sons (!983)
3. The ideas of Particle Physics:An introduction for Scientists - G.D.Coughlan, J.E.Dodd and B.M.Gripaios, Cambridge University Press(1984).
4. Facts and Mysteries in Elementary Particle Physics – Martinus Veltman, World Scientific (2003).

Paper 404 (Laser Physics Special paper): (45 lectures)

1. **Upconversion and down conversion:**
   Sum frequency generation, limitation to upconversion, introductory theory, infrared detection, effect of phase matching, noise properties, image conversion, experimental status, difference frequency generation, optical parametric oscillation. (6 lectures)

2. **Optical communication:**
   Optical fibre waveguide, modes in optical fibres, pulse distortion and information rate in optical fibre, distortion in single mode fibre, fibre losses, connector principle, lateral and angular misalignment, end separation, splices, dispersion characteristics: intra and inter modal dispersion, dispersion modified fibre, coupling of source with fibre, modulation, PCM, multiplexing, WDM, TDM, solitons. (6 lectures)

3. **Nonlinear materials:**
   UV-VIS_NIR crystals, assessment of nonlinear crystals (Kurtz powder method, Maker fringe method), chalcopyrites, derivation and characteristics. (4 lectures)

4. **Methods of semiconductor crystal growth:**
   Outline of bulk crystal growth method, phase diagram analysis, Bridgemann-Stockberger, Czochralsky and Kyropoulous methods, liquid phase epitaxy, vapour phase epitaxy, metal organic chemical vapour deposition, chemical beam epitaxy, molecular beam epitaxy. (6 lectures)

5. **Laser instrumentation:**
   Principle of measurement with laser beam, distance, rotation and fluid velocity measurement, laser range finder. (5 lectures)

6. **Remote monitoring:**
   Advantages of remote monitoring of the atmosphere by laser, principles of remote monitoring, different lidar systems, sources of noise and its remedial measures, Raman back scattered lidar (4 lectures)

7. **Material processing:**
   Laser in drilling, cutting, welding, marking, annealing (5 lectures)

8. **Optical disability:**
   Principle of optical disability, different optical logic gates, optical computer, optical phase conjugation, production of phase conjugated beam. (3 lectures)

9. **Laser cooling:** Principle of laser cooling, BE condensation. (2 lectures)

10. **Laser in medical science:**
    Superiority of Laser, Laser tissue interaction, physical effects on human skin of laser beam reflection, absorption, scattering), different interaction mechanism (photodynamic therapy), Lasers in Surgery: different surgical treatments. (4 lectures)

Books Recommended:

1. Methods of Experimental Physics Vol. 15B ed. By C L Tang
2. Industrial Application of Lasers – J F Ready
3. Laser remote Sensing:- R M Measures
4. Optical bistability- H M Gibbs
5. Handbook of Nonlinear Optics- R L Sautherland
6. Laser and electrooptics- C C Davis

Paper – 405 One Special Practical Paper (50 Marks)
(40 Marks for Examinations + 10 Marks for Sessionals)

Solid State Physics Special Practical Experiments:

1. Determination of magnetoresistance of a given semiconductor for different magnetic field.
2. Determination of the spectroscopic splitting factor of a given sample using electron spin resonance spectrometer.
3. Preparation of single crystals of copper potassium sulfate using slow evaporation technique and measurements of magnetic anisotropy of the single crystals of copper potassium sulfate with b-axis vertical modes of suspension using Krishnan-Banerji's flip angle method.
4. Measurements of magnetic anisotropy of hexagonal single crystals of dysprosium phosphate with c-axis parallel modes of suspension OR Measurements of magnetic anisotropies of monoclinic single crystals of copper potassium sulfate with c-axis vertical / (001) plane horizontal using Krishnan-Banerji's flip angle method.
5. Determination of Curie temperature of a given ferroelectric material.
6. Calibration of Mössbauer spectrometer and hence the determination of the hyperfine parameters of some given samples (alpha-iron, alpha-Fe_2O_3, Stainless Steel etc.)

Materials Science Special Practical Experiments

1. Two-probe DC conductivity and carrier density evaluation of a semiconductor.
2. Two-probe DC conductivity and carrier density evaluation of a pellet prepared through cold pressing.
3. Preparation of thin film by chemical deposition technique and determination of film thickness by fiber optic spectrophotometer.
4. Determination of band gap of a semiconductor sample using UV-VIS spectroscopy.
5. Variation of grain size and porosity of sintered/thin film specimens sintered at different temperatures by optical microscope.
6. Measurement of variation of microhardness of sintered specimens with sintering temperatures.

Radio physics and Electronics Special Practical Experiments:

Expt. No.	Name of the Experiment
1.	Studies on timer circuits (using 555 timer).
2.	Design and study of Wien-Bridge oscillator.
3.	Studies on LED and LED based circuits.
4.	Problems on assembly language programming using 8085 microprocessor.
5.	Experiments on Microprocessor interfacing.

Nuclear Physics Special Practical Experiments:

1. Study of the β-ray absorption and determination of the end point energy of the β-ray spectra of the given source by the Feather's method.
2. Study of gamma ray absorption and determination of gamma ray energy.
3. Using thin lens β-ray spectrometer,
   (a) study of β-ray momentum spectrum and its internal conversion electron peak,
   (b) Fermi-Kurie plot of the β-ray spectrum and determination of end-point energy
4. Using thin lens β-ray spectrometer,
   (a) Estimation of absolute intensity ratio of the total β radiation and the internal conversion peak of the electron,
   (b) Study of β ray spectrum with end point energy.

Laser Physics Special Practical Experiments:

1. Determination of spot size and angle of divergence of a given laser source.
2. Measurement of absorption coefficient of a material (supplied) using laser light.
3. Determination of numerical aperture of a fibre by measuring the diameter of laser beam.
4. To study the magneto-striction of a given material.
5. To study the Faraday effect and Verdert constant of a given material.
6. To determine the distance between the grooves of a compact disk.
7. To find the wavelength of an unknown light source using compact disk.
8. Determination of the particle size of a material (supplied).
9. Measurement of Brewster angle of a substance and hence determine the refractive index.
10. To verify the Malus law.

Paper – 406

Project/Term Paper (50 Marks)
(40 Marks for preparation and presentation of project report and 10 Marks for viva-voce)

Internal Assessment on theoretical papers : 20 Marks

Mid-semester Examinations/Class Test at the middle of the semester (20 Marks)

Question Patterns of 401 & 403 general papers will be same as Sem-II General papers. For 402 & 404 eight questions to be set and five questions to be answered. Separate answer scripts will be needed for each unit of papers 401 & 403 only.

For 406 a Board of Examiners comprising faculty members of Department of Physics of BU and Dept of Physics of Asansol B B College will evaluate the term paper submitted by the Sem. - IV students. One External Examiner should remain present in each Board during presentation & viva-voce.