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, Cauchy’s theorem, Cauchy’s integral formula. Liouville’s theorem. Moretra’s theorem.


Books Recommended:

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 characteristic function and their application. 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 dynamics. Permanancy of vortices. Navier-Stokes theorem. (2 lectures)
**Books Recommended:**

1. Classical mechanics-Goldstein
2. Introduction to advances dynamics-McCuskey
5. Classical Mechanics- Rana and Jog

**Paper 102**

**Unit – I: Quantum Mechanics I**


2. Schrödinger equation and its applications-
   (i) *In one dimensional consideration*-粒子在一维考虑整个势垒（有限和无限深度）及其能量状态;线性谐振子;不同一维障碍物（有限和无限宽度）及穿透问题。 (3 lectures)
   (ii) *In three dimensional consideration*-自由粒子波函数;带电粒子在球形对称场中的运动;角动量和特征函数;氢原子的能量状态波函数;表达式玻尔半径。 (4 lectures)


**Books Recommended:**

2) ‘Quantum Theory’ by D. Bohm (Prentice-Hall).
3) ‘Quantum Mechanics: Theory and Applications’ by A. K. Ghatak and S. Lokanathan (Macmillan India Ltd.).
5) ‘Quantum Mechanics’ by Cohen and Tanandji.
Unit – II : Classical Electrodynamics I [22 Marks]


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]


Books recommended:
2. Charles A Wert and Robb M Thonson: Physics of Solids
4. Christmaan-solid state physics (academic press)

Unit – II : Electronics I

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.
5. Chattopadhyay and Rakshit, Electronics circuit analysis.
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 lectures)

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 lectures)

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. (4 lectures)

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

Unit – II : Nuclear Physics I

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]


Books Recommended
2. J. Mathews and R. I. Walker (Benjamin) – Mathematical Methods of Physics.
4. W. Joshi (Wiley Eastern) – 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: Qualitative discussions on: 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.

Qualitative discussions on: 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:

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)

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
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. Alfvén waves and velocity, Hartmann flow and Hartmann number.

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.  


Books recommended:

2. Ibach & Luth: Solid State Physics

Unit – II : Electronics II

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.

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

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.

4. Digital Circuits: Logic functions; Logic simplification using Karnaugh maps; SOP and POS design of logic circuits; MUX as universal building block. RCA, CLA and BCD adder circuits; ADD-SHIFT and array multiplier circuits. RS, JK and MS-JK flip-flops; registers and counters (principle only).
Books Recommended:
1. R P Jain, Modern digital electronics, Tata mac’Hill.
2. J.D.Ryder, Electronics fundamental and application.PHI.
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:

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
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)


Books Recommended:

1. R. K. Pathria, Statistical Mechanics
2. K. Huang, Introduction to Statistical Mechanics
4. F. Reif, Fundamentals of Statistical and Thermal Physics.
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 $\gamma^5$ 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-Wouthuysen transformations: Free particle transformation. The general transformation. (3 lectures)
8. The Hydrogen atom. (4 lectures)

Books Recommended:

Paper – 302
Unit I : Group Theory [23 Marks]

1. Abstract group theory:

2. Representation theory:

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
Books Recommended:
1. M. Hammermesh. ‘Group Theory’. Addison-Wesley
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.
3. Balaguruswamy, ANSI C. TMH.

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


2. Crystal elasticity – 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 $\text{Cu}^{2+}$ in tetragonal field, calculation of g-factros and susceptibilities of $\text{Ce}^{3+}$ in ethyl sulfate lattice, Kramer’s theorem, J-T effect. (8 lectures)

Books Recommended
4. J.M. Ziman: Principles of the theory of solids
5. A.L. Fetter and J.D. Walecka: Quantum theory of many particle systems
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
2. Thin Solid Films by K. L Chopra
4. Elements of crystallography by M. A. Azaroff

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**
2. R E Collin - Foundations of Microwave engineering.
4. J. Ryder – Networks, Lines and Field.
5. A. Papoulis – Signal Analysis

**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)
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- CO₂ laser & N₂
(ii) ionic gas laser – Ar⁺ laser
(iii) gas dynamic laser
(iv) high pressure pulsed gas laser
(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. Solid State Laser Engineering- W Koechner
3. Quantum Electronics- A Yariv
4. The Physics and Technology of Laser Resonator- D R Hall & P E Jackson
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]**

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
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**


**Section VI: Characterization techniques related to nanomaterials**

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

**Reference Books**

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

**Paper – 304 (Radiophysics & Electronics special)**

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:
3. A P Mathur – Microprocessors.
4. R S Gaonkar – Microprocessor Architecture, Programming and Applications with 8085/8085A (2nd Ed.).
5. D V Hall – Microprocessor and Interfacing.
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-Weignuer 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) Optogalvanic spectroscopy. (6 lectures)
Books Recommended:
2. Industrial Application of Lasers – J F Ready
4. The Principle of Nonlinear Optics- Y R Shen
5. Handbook of Nonlinear Optics- R L Sauterland
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-Fe2O3) 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.
3. Determination of particle size and lattice strain of an unknown powder specimen applying marq2 software and Scherrer equation.
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:

<table>
<thead>
<tr>
<th>Expt. No.</th>
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<tbody>
<tr>
<td>1.</td>
<td>Design and study of an ECL OR-NOR circuit.</td>
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<td>2.</td>
<td>Design and study of an active band pass filter.</td>
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<td>3.</td>
<td>Design and study of an active phase sifter.</td>
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<tr>
<td>4.</td>
<td>Design and study of a current controlled oscillator.</td>
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<tr>
<td>5.</td>
<td>Design and study of a RC phase oscillator.</td>
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</tbody>
</table>

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.
3. Determination of numerical aperture of a fibre by measuring the diameter of laser beam.
4. To study the effect of magnetostriction 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)
Paper – 401
Unit – I : Statistical Mechanics II [23 marks]

1. Ideal quantum systems:

2. Strongly interacting systems:
   Exact solution of one-dimensional Ising system (Matrix methods). Bragg-William’s approximation (Mean field theory) and the Bethe-Peierls approximation. (6 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
5. F. Reif, Fundamentals of Statistical and Thermal Physics.
7. R. Kubo, Statistical Mechanics. (Collection of problems)

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


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)


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


Books recommended:

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)


6. Electronic spectra of diatomic molecules:
   (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)


9. Application of group theory to spectroscopy. (6 lectures)

Books Recommended:
5. G.Aruuldas ‘Molecular Spectroscopy’.
6. Bransden and Joachin. ‘Atoms and Molecules’
7. F.A.Cotton. ‘Chemical application to Group theory’.
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:**
3. Theoretical Astrophysics (Vols.I,II,III) – T. Padmanavan (CUP)

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)


Books Recommended:
1. Sastry, Introductory Methods of Numerical Analysis. PHI

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


3. Many body techniques: The basic Hamiltonian, Jelium Model, Hatree and Hatree-Fock equation, interacting electron gas, Hatree-Fock approximations for the electron gas, Exchange 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, Piezoelectricity, Pyroelectricity. (4 lectures)

7. Advanced materials / Phenomenon
   Spintronics, Multiferroics, Gain 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,
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

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
2. D Roddy and J Coolen – *Electronic Communications.*
5. Gulati – *Monochrome and Color TV.*

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)


7. Neutrino mass and neutrino oscillation. Derivation of intensity of \( \nu_e - \nu_\mu \). Atmospheric, solar and Supernova neutrinos. Solar neutrino problem. (2 lectures)

Books recommended:

Paper 404 (Laser Physics Special paper):

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:**
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 Satherland
6. Laser and electrooptics- C C Davis
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$_2$O$_3$, 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.
5. Variation of grain size and porosity of sintered/thin film specimens sintered at different temperatures by optical microscope.

Radio physics and Electronics Special Practical Experiments:

<table>
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<tbody>
<tr>
<td>1.</td>
<td>Studies on timer circuits (using 555 timer).</td>
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<tr>
<td>2.</td>
<td>Design and study of Wien-Bridge oscillator.</td>
</tr>
<tr>
<td>3.</td>
<td>Studies on LED and LED based circuits.</td>
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<tr>
<td>4.</td>
<td>Problems on assembly language programming using 8085 microprocessor.</td>
</tr>
<tr>
<td>5.</td>
<td>Experiments on Microprocessor interfacing.</td>
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</tbody>
</table>
Nuclear Physics Special Practical Experiments:

1. Study of the $\beta$-ray absorption and determination of the end point energy of the $\beta$-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 $\beta$-ray spectrometer,
   (a) study of $\beta$-ray momentum spectrum and its internal conversion electron peak,
   (b) Fermi-Kurie plot of the $\beta$-ray spectrum and determination of end-point energy
4. Using thin lens $\beta$-ray spectrometer,
   (a) Estimation of absolute intensity ratio of the total $\beta$ radiation and the internal conversion peak of the electron,
   (b) Study of $\beta$ 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.
3. Determination of numerical aperture of a fibre by measuring the diameter of laser beam.
4. To study the magnetostriction of a given material.
5. To study the Faraday effect and Verdett 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.