Course Structure and Syllabus
for
5 year Integrated B.Sc. - M. Sc. in Physics

(Effective from 2015-16)

Semester-I

SUBJECT	Paper Code	L	T	P	Credit
Mathematical Physics I	**PH 101**	**4**	**2**	**0**	**4**
Classical Mechanics I and General Properties of Matter	**PH 103**	**4**	**2**	**0**	**4**
Physics Lab I	**PH 191**	**0**	**0**	**6**	**4**
Subsidiary Chemistry I		4	2	0	4
Subsidiary Mathematics I		4	2	0	4
Common English		4	2	0	4
			TOTAL		**24**
Subsidiary Physics I	**PH 131**	**4**	**2**	**0**	**4**
Engineering Physics	**PH 151**	**4**	**2**	**0**	**4**
Physics Laboratory	**PH 161**	**0**	**0**	**6**	**4**

Semester-II

SUBJECT	Paper Code	L	T	P	Credit
Mathematical Physics II and Acoustics	**PH 102**	**4**	**2**	**0**	**4**
Physical and Geometrical Optics	**PH 104**	**4**	**2**	**0**	**4**
Physics Lab II	**PH 192**	**0**	**0**	**6**	**4**
Subsidiary Chemistry II		4	2	0	4
Subsidiary Mathematics II		4	2	0	4
Elementary Arabic and Islamic studies		4	2	0	4
			TOTAL		**24**
Subsidiary Physics II	**PH 132**	**4**	**2**	**0**	**4**

Semester-III

SUBJECT	Paper Code	L	T	P	Credit
Electrostatics and Electronics	**PH 201**	**4**	**2**	**0**	**4**
Heat and Thermodynamics	**PH 203**	**4**	**2**	**0**	**4**
Subsidiary Chemistry III		4	2	0	4
Subsidiary Chemistry Lab I		0	0	6	4
Subsidiary Mathematics III		4	2	0	4
Subsidiary Mathematics IV		4	2	0	4
			TOTAL		**24**
Subsidiary Physics III	**PH 231**	**4**	**2**	**0**	**4**
Subsidiary Physics Lab I	**PH 261**	**0**	**0**	**6**	**4**

Semester-IV

SUBJECT	Paper Code	L	T	P	Credit
Electricity and Magnetism	**PH 202**	**4**	**2**	**0**	**4**
Physics Lab III	**PH 292**	**0**	**0**	**6**	**4**
Subsidiary Chemistry IV		4	2	0	4
Subsidiary Chemistry Lab II		0	0	6	4
Subsidiary Mathematics V		4	2	0	4
Subsidiary Mathematics VI		4	2	0	4
				TOTAL	**24**
Subsidiary Physics IV	**PH 232**	**4**	**2**	**0**	**4**
Subsidiary Physics Lab II	**PH 262**	**0**	**0**	**6**	**4**

Semester-V

SUBJECT	Paper Code	L	T	P	Credit
Quantum Mechanics I	**PH 301**	**4**	**2**	**0**	**4**
Statistical Mechanics I	**PH 303**	**4**	**2**	**0**	**4**
Solid State Physics I	**PH 305**	**4**	**2**	**0**	**4**
Digital Electronics	**PH 307**	**4**	**2**	**0**	**4**
Physics Lab IV	**PH 391**	**0**	**0**	**6**	**4**
Compulsory Environmental Science	*ES 331*	4	2	0	4
				TOTAL	**24**

Semester-VI

SUBJECT	Paper Code	L	T	P	Credit
Atomic and Molecular Physics I	**PH 302**	**4**	**2**	**0**	**4**
Classical Mechanics II & Special Theory of Relativity	**PH 304**	**4**	**2**	**0**	**4**
Nuclear and Particle Physics I	**PH 306**	**4**	**2**	**0**	**4**
Electrodynamics I and Modern Optics	**PH 308**	**4**	**2**	**0**	**4**
Physics Lab V	**PH 392**	**0**	**0**	**6**	**4**
Presentation Skill	**PS 332**	**0**	**0**	**6**	**4**
				TOTAL	**24**

Semester-VII

SUBJECT	Paper Code	L	T	P	Credit
Mathematical Physics II	**PH 401**	**4**	**2**	**0**	**4**
Classical Mechanics III	**PH 403**	**4**	**2**	**0**	**4**
Quantum Mechanics II	**PH 405**	**4**	**2**	**0**	**4**
Numerical Analysis & Computation	**PH 407**	**4**	**2**	**0**	**4**
Physics Lab VI	**PH 491**	**0**	**0**	**6**	**4**
Computer Lab	**PH 493**	**0**	**0**	**6**	**4**
				TOTAL	**24**

Semester-VIII

SUBJECT	Paper Code	L	T	P	Credit
Electrodynamics II	PH 402	4	2	0	4
Solid State Physics II	PH 404	4	2	0	4
Statistical Mechanics II	PH 406	4	2	0	4
Semiconductor Physics & Device	PH 408	4	2	0	4
Quantum Mechanics III	PH 410	4	2	0	4
Physics Lab VII	PH 492	0	0	6	4
				TOTAL	24

Semester-IX

SUBJECT	Paper Code	L	T	P	Credit
Quantum Mechanics IV	PH 501	4	2	0	4
Atomic Physics II	PH 503	4	2	0	4
Molecular Physics II	PH 505	4	2	0	4
Nuclear & Particle Physics II	PH 507	4	2	0	4
Physics Lab VIII	PH 591	0	0	6	4
Grand Viva	PH 593	0	0	6	4
				TOTAL	24

Semester-X

SUBJECT	Paper Code	L	T	P	Credit
Advanced Paper I	PH 502	4	2	0	4
Advanced Paper II	PH 504	4	2	0	4
General Theory of Relativity & Astrophysics	PH 506	4	2	0	4
Advanced Physics Lab	PH 592	0	0	6	4
Project work & Seminar presentation	PH 594	0	0	0	8
				TOTAL	24

- Subsidiary Physics I (PH 131), II (PH 132), II (PH 231) and IV (PH 232) (Theory papers) and Subsidiary Physics Lab I (PH 261) and II (PH262) are for Chemistry (H), Mathematics (H), Statistics (H) Computer Science (H) students

- Engineering Physics (PH 151) (Theory paper) and Physics Laboratory (PH 161) are for B.Tech students from all streams of Engineering.

- In the Semester-X, General Theory of Relativity & Astrophysics (PH 506) is the compulsory elective paper. Students can opt any one combination for the advanced papers I (PH 502) and II (PH 504) from the following:

  Option 1: Material Physics I (PH 502) + Material Physics II (PH 504)
  Option 2: Advanced Atomic and Laser physics (PH 502) + Advanced Nuclear and Particle Physics (PH 504)

FIRST YEAR

Semester- I

Paper PH 101 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Mathematical Physics I

1. **Vectors:** Scalars and vectors**,** vector in three dimension; axial and polar vectors; dot and cross product, scalar triple product and vector triple product; scalar and vector fields, gradient, divergence and curl; concept of line, surface and volume integrals; Stokes' theorem, Divergence theorem and Green's theorem, application to simple problems; Orthogonal curvilinear co-ordinate systems, unit vectors in such systems, illustration by plane, spherical and cylindrical co-ordinate systems only

2. **Differential equation:** Solution of first order linear differential equations, integrating factor, second order linear homogeneous differential equations with constant coefficients and its application in vibration and electrical circuits, Wornskian and general solution, particular inetgral

3. **Matrices:** Hermitian adjoint and inverse of a matrix, Hermitian, orthogonal and unitary matrices, Eigen values and Eigen vector, similarity transformation, Diagonalisation of real symmetric matrix with non-degenerative Eigen values.

4. **Fourier expansion:** Periodic functions, orthogonality of sine and cosine functions, Statement of Dirichlet's condition, analysis of simple periodic wave form with Fourier series and determination of Fourier co-efficient.

5. **Introduction to probability:** Independent random variables, probability distribution functions, binomial, Gaussian and Poisson with examples, Mean and variance; dependent events: conditional probability, Bayes' theorem and the idea of hypothesis testing.

Paper PH 103 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Classical Mechanics I and General Properties of Matter

Classical Mechanics I

1. **Mechanics of a single particle:** Velocity and acceleration of a particle in plane polar co-ordinates, radial & transverse components of velocity & acceleration, tangential & normal acceleration; time and path integral of force; work and energy; conservative force and concept of potential; conservation of energy, dissipative forces; conservation of linear and angular momentum; motion of variable mass.

2. **Mechanics of a system of particles:** Linear momentum, angular momentum and energy, center of mass decomposition; equation of motion, conservation of linear and angular momentum.

3. **Rotational Motion:** Rotational motions of rigid bodies, Energy and angular momentum of rotating rigid bodies, Moment of inertia and radius of gyration; Parallel and perpendicular axes theorem; calculation of moment of inertia for simple symmetrical system; rotational kinetic energy

4. **Central force problem:** Motion under central force, two constants of motion, nature of orbit under inverse square attractive field, Kepler's laws of planetary motion, Rutherford's scattering.

General Properties of Matter

1. **Gravitation:** Newton's law of Gravitation, Gravitational potential and intensity due to thin uniform

spherical shells and solid sphere, application of Gauss' theorem and Laplace's equation in simple symmetric problems.

2. **Elasticity:** Hook's law, Elastic moduli and Poisson's ratio and their interrelations, Torsion of a cylinder, Bending of beams, Bending moment and shearing force; Stress and strain tensor in a continuous medium; Review of problems of cantilever and beam supported at both ends, strain energy of a bent beam.

3. **Viscosity:** Review of kinematics of fluid motion, Newton's law of viscous fluid, stream line and turbulent flow, Critical velocity, Reynold's number, Newtonian and non-Newtonian fluids, Poiseuille's equation**;** stoke's law' terminal velocity.

4. **Mechanics of Ideal fluids:** Equation of continuity, Euler's equation- Bernoulli's theorem and its application.

5. **Surface Tension:** Surface energy and surface tension, molecular theory, angle of contact, capillary rise, Excess-pressure inside a spherical bubble and drop.

Paper PH 191 (50 Marks; 4 Credit)

Physics Lab I

1. Determination of Young's Modulus of elasticity of a material of a bar by the method of flexure.
2. Verification of Jurin's law and hence the surface tension of a liquid by the capillary tube method.
3. Determination of the coefficient of viscosity of a liquid using Poissule's method.
4. Determination of rigidity modulus of a material of a wire by static method.
5. Determination of rigidity modulus of a material of a wire by dynamic method.
6. Determination of thermal conductivity of a bad conductor in the form of a disc by the Lees and Charlton method.
7. Determination of refractive index of a liquid by using a plane mirror and a convex lens.
8. Determination of focal length of concave lens by combination method.
9. Determination of focal length of convex lens by using optical bench.
10. Determination of the horizontal component of the earth's magnetic field with reflection and vibration magnetometer.
11. Determination of unknown frequency of a tuning fork by using a sonometer and drawing *n-l* cruve.

Paper PH 131 (50 Marks) LECTURES 45 + 15 Tutorial

Subsidiary Physics I

1. **Mathematical physics:** Vector in three dimension; Axial and polar vectors; dot and cross product, scalar triple product and vector triple product; scalar and vector fields, gradient, divergence and curl; concept of line, surface and volume integrals, statement of Stokes' theorem, Divergence theorem and Green's theorem; 1^{st} and 2^{nd} order differential equation and it's applications; Hermitian adjoint and inverse of a matrix, Hermitian and unitary matrices, Eigen values and Eigen vector, similarity transformation.

2. **Mechanics of a Single particle:** Velocity and acceleration of a particle in plane polar co-ordinates, radial & transverse components of velocity & acceleration, tangential & normal acceleration; time

and path integral of force; work and energy; conservative force and concept of potential; conservation of energy, dissipative forces; conservation of linear and angular momentum; motion of variable mass.

3. **Mechanics of a system of Particles:** Linear momentum, angular momentum and energy, center of mass decomposition; equation of motion, conservation of linear and angular momentum.

4. **Waves and Oscillations:** Simple harmonic motion, differential equation of S.H.M and it's solution, simple pendulum, damped harmonic oscillator, forced vibration, resonance, wave equation, longitudinal and transverse wave, standing waves, beats

Paper PH 151 (50 Marks) **LECTURES 45 + 15 Tutorial**

Engineering Physics

Mechanics

Classical mechanics: scalars and vectors, vector multiplication, central force, mechanics of system of particles, elastic properties, rotational motion, fluid dynamics: viscocity, Stoke's law, streamline flow, equation of continuity, Reynold's number, Bernoulli's theorem

Quantum mechanics: Photoelectric effect, de-Broglie's hypothesis, matter wave, Hysenberg's uncertainty principle, wave function, Schrodinger equation and simple problems

Statistical mechanics: Necessity of statistical mechanics, Maxwell-Boltzman, Bose-Einstein and Fermi-Dirac distribution formula

Optics

Huygen's principle, Interference of light, Young's double-slit experiment, Newton's ring; Diffraction: Fresnel and Fraunhofer class, Fresnel's half-period zones, zone plate, Fraunhofer diffraction due to single slit and plane transmission grating (elementary theory); Polarization: plane, circular and elliptically polarized light, Brewster's law, Polaroid, optical activity.
Coherence length and time; Einstein's A and B coefficients; spontaneous and induced emissions, condition for laser action, population inversion, He-Ne laser
Optical Fiber, core and cladding; total internal reflection; optical fiber and waveguide; communication through optical fiber, energy loss, attenuation and dispersion

Electrostatics & Electricity

Coulomb's law, intensity and potential of point charge, Gauss's theorem and simple applications, electric-dipole, Electric displacement, capacitor, parallel plates and cylindrical, Thermoelectricity, Magnetic effects of currents, Self-inductance, Mutual inductance, Transformer Electric circuit elements and AC, DC circuit analysis.

Solid State Physics

Crystalline nature of solid, diffraction of X-ray, Bragg's law, Mosley's law, explanation from Bohr's theory, Origin of the energy gap, band theory; metal, semiconductor and insulators; intrinsic and extrinsic semiconductors, dia, para and ferro magnetic materials, superconductivity

Nuclear Physics

Binding energy of nucleus, Binding energy curve and stability, Radioactivity, successive disintegration, radioactive equilibrium, radioactive dating, radioisotope and their uses, Nuclear transmutation, fission & fusion, nuclear reactor

Paper PH 161 (50 Marks; 4 Credit)

Physics Laboratory

1. Measurements of length (or diameter) using vernier scale, slide caliper, screw gauge and travelling microscope.
2. Determination of the radius of curvature of a spherical surface by using spherometer.
3. Determination of moment of inertia of (a) a cylinder and (b) a rectangular solid bar.
4. To determine the focal length of a concave lens by combination method and hence to determine the refractive index of the material of the lens by measuring the radii of curvature of both lenses
5. Determination of the average resistance per unit length of the meter bridge wire by Carey-Foster's method and hence to determine an unknown resistance
6. Determination of the horizontal component of the earth's magnetic field and the magnetic moment of a magnet by employing magnetometers
7. Determination of Young's Modulus of elasticity of a material of a bar by the method of flexure.
8. Determination of rigidity modulus of a material of a wire by static method.
9. Determination of rigidity modulus of a material of a wire by dynamic method.
10. Determination of unknown frequency of a tuning fork by using a sonometer.

Semester- II

Paper PH 102 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Mathematical Physics II and Acoustics

1. **Ordinary Differential Equations and Special functions:** Second order differential equations with variable co-efficient, solvability, regular and irregular singularities; Frobenius method of power series, Fuchs's theorem, The hyper geometric equation and functions; Confluent hyper geometric equation and functions; Representation of Legendre, Bessel, Hermite and Laguerre functions; Gamma and Beta functions.

2. **Partial differential equations:** Solution by the method of separation variables; Laplace's equation and its solution in Cartesian, Spherical polar and cylindrical polar co-ordinal systems; Wave equation, its plane and spherical wave solution.

3. **Vibrations:** Linear harmonic oscillator, differential equation and its solutions; Free and forced vibrations of a damped harmonic oscillator; resonance; sharpness of resonance; a pair of linearly coupled harmonic oscillators, eigenfrequencies and normal modes; Lissajous figure.

4. **Transverse vibration in stretched strings:** Wave equation, Plucked and struck strings, eigenfrequencies and eigenmodes, energy of transverse vibrations.

5. **Waves:** Linear equation of plane progressive wave motion in one dimension, and in three dimensions; plane wave and spherical wave solutions; intensity of a plane progressive wave; dispersion in wave propagation, group velocity and phase velocity.

6. **Sound:** Quality of sound, Noise and musical sound, Intensity and Loudness, Units of sound's intensity measurements, Acoustics of hall, Reverberation, Production, detection and application of ultrasonic waves, Doppler effect, shock waves.

Paper PH 104 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Physical and Geometrical Optics

Geometrical Optics

1. **Refraction:** Generalized Snell's Law of refraction, Refraction at single curved (Spherical surface), lens formula, combination of thin lens and equivalent lens.

2. **Fermat's Principle:** laws of reflection and refraction from Fermat's principle, both for plane and spherical surface.

3. **Cardinal points of an optical system:** Location of cardinal points of a single thick lens, hence to locate cardinal points of a thin lens; Cardinal points of system of two thin co-axial lenses separated by a distance, equivalent lens. Different type of magnification, Helmholtz and Lagrange's relation. Introduction of matrix methods in paraxial optics, simple application

4. **Dispersion:** Dispersive power of lens, prism. Chromatic aberration in lenses, methods of reduction of chromatic aberration in lenses, achromatic doublet.

5. **Aberration:** Qualitative discussions of monochromatic or siedal aberration in lenses and short discussion on reduction of siedal aberration in lenses.

6. **Optical instruments:** Field of view, entrance and exit pupil, compound eyepieces, Ramsden & Huygens type, working principle of Telescope and microscope.

Physical Optics

1. **Wave theory of light:** Electromagnetic nature of light. Definition and properties of wave front. Huygens' principle of wavefront propagation. Deduction of laws of reflection and refraction from wave theory.

2. **Coherence:** Concept of coherence, temporal coherence, spatial coherence, coherence time and length, coherent sources by division of wave front and by division of amplitude.

3. **Interference of light waves:** Principle of superposition, Young's double slit experiment: conditions of producing sustained interference of light, calculation of intensity distribution due to superposition of coherent waves & to find condition of constructive and destructive interference. Calculation of fringe width and fringe shape in Double Slit. Fresnel's biprism experiment and its application. Stokes' method to show change of phase due to reflection. Lloyd's mirror. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's rings: measurement of wavelength and refractive index.

4. **Interferometers:** Michelson Interferometer: idea of form of fringes (No theory required), determination of wavelength, wavelength difference, refractive index, and visibility of fringes. Fabry-Perot interferometer and its applications.

5. **Diffraction of light waves:** Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula. (Qualitative discussion only). *Fraunhofer diffraction:* single slit, circular aperture, resolving power of a telescope, double slit, multiple slits, diffraction grating, resolving power of grating. *Fresnel Diffraction:* Fresnel's assumptions. Fresnel's half-period zones for plane wave, explanation of rectilinear propagation of light, theory of a zone plate, multiple foci of a zone plate. Fresnel's

integral, Fresnel diffraction pattern of a straight edge, a slit and a wire.

6. **Polarization of waves:** Different states of polarization, Double refraction, Huygens construction for propagation through uni-axial crystals. Polaroid's and their uses. Nicole prism & its use as polarizer and analyzer. Production and analysis of plane, circularly and elliptically polarized light by retardation plates (half wave & quarter wave plate). Optical activity, Fresnel's explanation of optical activity, Biquartz and half-shade polarimeter

Paper PH 192 (50 Marks; 4 Credit)

Physics Lab II

1. To construct two-input OR and AND gates using diode logic and to obtain truth tables. To construct the NOT gate using transistor logic and obtain truth table.
2. To verify the truth tables of NOR, NAND and XOR gates using ICs. To construct AND, OR and NOT gates using IC NOR and IC NAND gates.
3. Verification of De-Morgan's theorem and different relationship in Boolean algebra using IC logic gates.
4. Determination of the value of Plank's constant by using LED.
5. Determination of moment of inertia by using a flywheel
6. Experiment on action due to gravity.
7. Determination of unknown resistance by carry fosters bridge.
8. To draw the angle of incidence vs. Deviation curve of a prism with the help of a spectrometer and hence to find the angle of minimum deviation and refractive index of the material of the prism
9. Calibration of a polariometer and hence to determine the specific rotation and the concentration of the sugar solution.
10. Determination of the radius of curvature of the lower surface of a plano-convex lens by using Newtown's ring apparatus.

Paper PH 132 (50 Marks) LECTURES 45 + 15 Tutorial

Subsidiary Physics II

Optics

1. **Geometrical optics:** Fermat's principles; Laws of reflection and refraction at plane surface, Refraction at spherical surface, lens formula, combination of thin lenses – equivalent focal length. Dispersion and dispersive power; chromatic aberration and its remedy. Different types of seidal aberration (qualitative) and their remedies, Eye-pieces, Principles of telescope and microscope.

2. **Physical optics:** Light as an electromagnetic wave, full electromagnetic spectrum, properties of electromagnetic waves, Huygen's principle, explanation of the laws of reflection and refraction.

   A. **Interference of light:** Young's double-slit experiment, calculation of intensity distribution and fringe width, conditions of interference in thin films, Newton's ring.

B. **Diffraction:** Fresnel and Fraunhofer class, Fresnel's half-period zones, zone plate. Fraunhofer diffraction due to single slit and plane transmission grating (elementary theory), resolving power.

C. **Polarization:** different sets of polarization, Brewster's law, double refraction, retardation plate, Polaroid, optical activity.

Heat and thermodynamics

1. **Kinetic theory of gases:** Basic assumptions of kinetic theory, Ideal gas approximation, deduction of perfect gas laws. Interpretation of temperature. Maxwell's distribution law, r.m.s, mean and most probable velocity, collision probability, distribution of free path and mean free paths from Maxwell's distribution, principle of equipartition of energy.

2. **Real Gases:** Nature of intermolecular interaction: isotherms of real gases. Equation of states, defect of ideal gas laws, Van der-Waals equation of state, Other equations of state (mention only), critical constants of a gas, law of corresponding states; Virial Coefficients, Boyle temperature.

3. **Concept of thermodynamics: T**hermodynamic variables of a system, state function, exact and inexact differentials. Isolated system, closed system, open system, extensive and intensive properties.

4. **Laws of Thermodynamics:** Thermal equilibrium, Zeroth law and the concept of temperature; Thermodynamic equilibrium, internal energy, external work,1st law of thermodynamics and it's simple applications, Reversible and irreversible processes, second law of thermodynamics, Carnot-cycle, and it's efficiency, Carnot's theorem, Clausius inequality, entropy, change of entropy in simple reversible and irreversible processes, Third law of thermodynamics.

5. **Thermodynamic Functions:** Enthalpy, Helmholtz and Gibbs' free energies; Maxwell's relations and simple deductions using these relations; thermodynamic equilibrium and free energies, Joule-Thompson effect, Clausius-Clapeyron equation, expression for (C_p-C_v), C_p/C_v, TdS equations

SECOND YEAR

Semester-III

Paper PH 201 (50 Marks; 4 Credit) **LECTURES 45 + 15 Tutorial**

Electrostatics and Electronics

Electrostatics

1. Coulomb's law of electrostatics, intensity and potential, continuous charge distribution, delta function, Gauss' theorem and its application; Poisson and Laplace's equations; Superposition theorem (statement only), Application of Laplace's equation to simple cases of symmetric spherical charge distribution.

2. **Dipoles:** Multipole expansion of scalar potential- monopole, dipole, quadrapole terms; Potential and field due to an electric dipole, work done in deflecting a dipole, dipole-dipole interaction (for both electric and magnetic dipoles); force on dipole in a non-homogeneous field.

3. **Dielectrics:** Polarization, electric displacement vector (D), Gauss's theorem in dielectric media; boundary conditions, electrostatic field energy; computation of capacitance in simple cases (parallel plates); spherical and cylindrical capacitors containing dielectrics, uniform and non-uniform.

4. **Electrical Images:** Uniqueness theorem, Solution of field problems in case of a point charge near a grounded conducting infinite plane.

5. **Boundary value problem:** in uniform external field for (a) conducting spherical shell and (b) dielectric sphere, problems on earthed conducting sphere and insulated conducting sphere.

Electronics

1. **Semiconductor diodes:** P and N type semiconductors, electrons and holes, Fermi level, Temperature dependence of electron and hole concentrations, doping, impurity states, n and p type semiconductors, conductivity, mobility, p-n junction diode, Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Barrier Formation in P-N Junction Diode, Derivation for Barrier Potential, Barrier Width and Current for Step Junction.

2. **Two-terminal Devices and their Applications:** Rectifier Diode: Half-wave Rectifiers. full-wave rectifiers and Bridge rectifier Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, avalanche and Zener breakdown, Zener diode and its applications, load regulation, line Regulation.

3. **Bipolar junction transistors (BJT):** p-n-p and n-p-n transistor; active, cut-off and saturation regions, Characteristics of CB, CE and CC Configurations, input and output characteristics, α and β of a transistor and their interrelation, load line analysis of Transistors and Q point concept, Transistor biasing and Stabilization Circuits, stability factor, biasing methods, fixed bias, Collector to base bias, Self bias or potential divider bias.

4. **Hybrid parameters:** Transistor as 2-port Network, definition of h-parameters, h-parameter equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Two port analysis of a transistor, low frequency model analysis, voltage gain, current gain, power gain, input resistance, output resistance comparison of CB, CC and CE amplifiers.

5. **Feedback Amplifier:** Principle of feedback amplifier, Voltage feedback and current feedback, negative and positive feedback, Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. Calculation of voltage gain of feedback amplifier, advantages of negative feedback.

6. **Oscillators:** Barkhausen criterion for sustained oscillation, Determination of Frequency of L-C (Hartley, Colpitt), Weinbridge and crystal oscillators.

Paper PH 203 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Heat and Thermodynamics

Heat

1. **Kinetic theory of gases:** (i) Basic assumptions of kinetic theory, Ideal gas approximation, deduction of perfect gas laws. Interpretation of temperature. Maxwell's distribution law, r.m.s, mean and most probable velocity, (ii) Maxwell's distribution law both in terms of velocity and energy, finite size of molecules, collision probability, distribution of free path and mean free paths from Maxwell's distribution, (iii) principle of equipartition of energy: application to specific heat, Dulong and Petit's law.

2. **Real Gases:** Nature of intermolecular interaction: isotherms of real gases. Equation of states, defect of ideal gas laws, Van der-Waals equation of state, Other equations of state (mention only), critical constants of a gas, law of corresponding states; Virial Coefficients, Boyle temperature.

3. **Transport Phenomenon:** Viscosity, thermal conductivity and diffusion in gases, Brownian motion: Einstein's theory, Determination of Avogadro number (Perrin's work).

4. **Conduction of Heat:** Thermal conductivity, diffusivity. Fourier's equation for heat conduction – its solution for rectilinear and radial (spherical and cylindrical) flow of heat.

5. **Classical theory of radiation:** Properties of thermal radiation, Blackbody radiation, Kirchhoff's law, Stefan-Boltzmann law, Radiation pressure, Wein's displacement and distribution law, Saha's Ionization formula, Rayleigh Jeans law, Ultraviolet catastrophe.

Thermodynamics

1. **Concept of thermodynamics:** Microscopic and Macroscopic points of view: thermodynamic variables of a system, state function, exact and inexact differentials. Isolated system, closed system, open system, extensive and intensive properties.

2. **Zeroth law and First Law of Thermodynamics:** Thermal equilibrium, Zeroth law and the concept of temperature; Thermodynamic equilibrium, internal energy, external work, review of 1st law of thermodynamics and it's applications. Perpetual motion of first kind.

3. **Second Law of Thermodynamics:** Reversible and irreversible processes, Indicator diagram, Spontaneous process, review of various statement of second law of thermodynamics. Carnot-cycle, and it's efficiency, Carnot's theorem, Kelvin or thermodynamic scale of temperature and it's relation with perfect gas scale, Clausius inequality, entropy, change of entropy in simple reversible and irreversible processes, entropy change in gases and mixture of gases, entropy and disorder, equilibrium and entropy principle, principle of degradation of energy, temperature entropy diagram.

4. **Thermodynamic Functions and Maxwell's relation:** Enthalpy, Helmholtz and Gibbs' free energies; Legendre transformations, Maxwell's relations and simple deductions using these relations; thermodynamic equilibrium and free energies.

5. **Change of State:** Equilibrium between phases, triple point, Gibb's phase rule (statement only) and simple applications, First and higher order phase transitions, Ehrenfest criterion. Clausius-Clapeyron's equation, Calculation of Joule-Thomson cooling and temperature of inversion.

6. **Heat Engines:** External combustion engine, Rankine cycle, Otto and Diesel cycle.

Paper PH 231 (50 Marks) **LECTURES 45 + 15 Tutorial**

Subsidiary Physics III

Electrostatics & Electricity

Quantization of charge, Millikan's oil drop experiment, Coulomb's law, intensity and potential of point charge, Gauss's theorem and simple applications, potential and field due to an electric-dipole, mechanical force on the surface of the charged conductor. Electric displacement, capacitor, parallel plates and cylindrical, energy stored in parallel plate capacitor. Thermoelectricity, Magnetic effects of currents, Self-inductance, Mutual inductance, Transformer Electric circuit elements and AC, DC circuit analysis.

Electronic Devices

Intrinsic semiconductors, electrons and holes, Fermi level, Temperature dependence of electron and hole concentrations, doping, impurity states, n and p type semiconductors, conductivity, mobility, Hall effect, hall coefficient. Metal semiconductor junction, p-n junction, majority and minority carriers, diodes, Zener and tunnel diodes, transistor and solar cell.

Introduction to relativity

Postulates of special theory of relativity, inertial and non-inertial frames of reference, Length contraction, time dilation, velocity addition, mass variation and mass-energy equivalence

Introduction to Quantum Mechanics

Quantum theory of radiation, Planck's concept, radiation formula (statement only), qualitative discussion of photo-electric effect and Compton effect in support of quantum theory, Raman effect, wave nature of material particle, wave-particle duality, wavelength of deBroglie wave, Heisenberg's uncertainty principle, Schrodinger equation, particle in an one-dimensional infinite well, energy eigen value, wave function and its probabilistic interpretation

Paper PH 261 (50 Marks; 4 Credit)

Subsidiary Physics Lab I

1. To determine the focal length of a concave lens by combination method and hence to determine the refractive index of the material of the lens by measuring the radii of curvature of both lenses
2. Determination of the radius of curvature of the lower surface of a Plano-covex lens by using Newton's ring apparatus
3. Determination of the average resistance per unit length of the meter bridge wire by Carey-Foster's method and hence to determine an unknown resistance
4. Determination of the horizontal component of the earth's magnetic field and the magnetic moment of a magnet by employing magnetometers
5. To study the characteristics of curve of *p-n* junction diode and A.C and D.C resistance
6. Verification of truth tables of "OR", "AND", "NOT" gates using diode and transistor
7. Determination of Planck's constant using light emitting diode

Semester-IV

Paper PH 202 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Electricity and Magnetism

1. **Steady current:** (a) Differential form of Ohm's law, Kirchhoff's laws, Thevenin and Norton's theorem, Maximum power transfer theorem, Superposition principle, T and Π networks. (b) Wheatstone bridge, qualitative discussion on sensitivity of Wheatstone bridge, Application in P.O. Box, Meter Bridge, working principle of potentiometer. (c) Thermoelectricity*:* Seebeck, Peltier, and Thomson effects, laws of thermoelectricity, thermoelectric curve, neutral and inversion temperature, thermoelectric power .

2. **Magnetic effect of steady current:** Lorentz force and concept of magnetic induction; force on linear current element; Biot-Savart's law, $\nabla.\mathbf{B}=0$; magnetic vector potential; calculation of vector potential and magnetic induction in simple cases– straight wire, magnetic field due to small current loop; magnetic dipole; field due to a dipole; magnetic shell; Ampere's theorem; Ampere's circuital law, simple illustrations; force between long parallel current carrying conductors; $\nabla\times\mathbf{B} = \mu\mathbf{J}$; comparison between static electric and magnetic fields, moving coil galvanometer- Dead beat and Ballastic galvanometer, Ammeter and voltmeter.

3. **Properties of Magnetic materials:** Free current and bound current; surface and volume density of current distribution; magnetisation, non-uniform magnetisation of matter; $\mathbf{J}_b = \nabla\times\mathbf{M}$; Ampere's law in terms of free current density and introduction of **H**; line integral of H in terms of free current; boundary conditions for **B** and **H**, magnetic scalar potential; application of Laplace's equation to the

problem of a magnetic sphere in uniform magnetic field; hysteresis and energy loss in ferromagnetic material, magnetic circuit; energy stored in magnetic field, magnetic circuits and it's applications.

4. **Electromagnetic induction:** Faraday's and Lenz's law; motional e.m.f.-simple problems calculation of self and mutual inductance in simple cases, inductances in series and parallel; reciprocity theorem, energy stored in an inductance.

5. **Transient D.C.:** Series L-R circuits, charging and discharging of a condenser in C-R circuits, L-C-R circuits.

6. **Alternating current :** Mean and r.m.s. values of current and emf with sinusoidal wave form; L-R, C-R and series L-C-R circuits, reactance, impedance, phase-angle, power dissipation in AC circuit power factor, vector diagram, resonance in a series and parallel circuit, Q-factor, principle of ideal transformer, A-C bridge- principle of generalized A.C. bridge, Anderson's bridge, theory of rotating magnetic field, induction motor.

Paper PH 292 (50 Marks; 4 Credit)

Physics Lab III

1. Investigation of inductance by using a series LR circuit.
2. Investigation of capacitance by using a series CR circuit.
3. Investigation on a series resonant LCR circuit.
4. Determination of self-inductance of a coil by using Anderson's bridge.
5. Determination of the thermoelectric power at a given temperature by using a thermocouple
6. Estimation of temperature a torch bulb filament from resistance measurement for the verification of Stefan's law.
7. Thevenin's, Norton's and Maximum power transfer theorem.
8. Study of the forward and reverse characteristics of a Zenor diode and it's use in load and line regulation.
9. Study of I-V characteristics of a p-n junction diode and its performance as a half and full wave rectifier.
10. To draw the output and transfer characteristics of a transistor in the common-emitter configuration for different base currents and to determine the ac current gain and the output admittance from the active region of the characteristics.

Paper PH 232 (50 Marks) **LECTURES 45 + 15 Tutorial**

Subsidiary Physics IV

Basic Statistical Physics

Phase space distribution functions, microcanonical, canonical and grand canonical ensembles. Boltzmann statistics and its applications to ideal gas. Bose-Einstein (BE) statistics, blackbody radiation (no-deduction), Fermi-Dirac (FD) statistics, Fermi gas and applications

Laser and Fiber Optics

Purity of spectral lines; coherence length and coherence time; time and spatial coherence of a source; Einstein's A and B coefficients; spontaneous and induced emissions, condition for laser action, population inversion, He-Ne laser; pulse laser and tunable laser, spatial coherence and directionality, laser applications.
Optical Fiber, core and cladding; total internal reflection; optical fiber and waveguide; communication through optical fiber, energy loss, attenuation and dispersion

Atomic and Molecular Physics

Bohr's theory of hydrogen spectra, concept of quantum number, Pauli exclusion principle, diatomic molecules, rotational and vibrational energy levels, basic ideas on molecular spectra

Solid State Physics

Crystalline nature of solid, diffraction of X-ray, Bragg's law, Mosley's law, explanation from Bohr's theory. Origin of the energy gap, band theory; metal, semiconductor and insulators; intrinsic and extrinsic semiconductors, Direct and indirect bandgap semiconductor

Nuclear Physics

Binding energy of nucleus, Binding energy curve and stability, Radioactivity, successive disintegration, radioactive equilibrium, radioactive dating, radioisotope and their uses, Nuclear transmutation, fission & fusion, nuclear reactor, elementary idea on particle physics

Paper PH 262 (50 Marks; 4 Credit)

Subsidiary Physics Lab II

1. Drawing the characteristics for a Zener diode and to study it as a voltage regulator
2. Study of transfer characteristics (collector-current and collector-voltage) characteristics of transistor in CE mode (*p-n-p*/*n-p-n*) and determination of current gain and hybrid parameters
3. To study the characteristics of half wave and full wave rectifier
4. Investigation of an inductance in an a.c circuit
5. Investigation of capacitance of an a.c. circuits
6. Investigations on a series resonant circuits
7. Study the temperature dependence of total radiation and hence verify the Stefan's law

THIRD YEAR

Semester-V

Paper PH 301 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Quantum Mechanics I

1. **Elementary quantum mechanics:** Black-body radiation, Planck's quantum postulates, Planck's law of blackbody radiation. Deduction of Wein's displacement and distribution law, Rayleigh Jeans law, Stefan-Boltzmann law from Planck's law, Photoelectric effect, Compton effect, de-Broglie hypothesis, Electron double-slit experiment, Davisson-Germer experiment. Heisenberg's

uncertainty principle (statement) with some applications, Gamma-Ray Microscope. Concept of wave function as describing the dynamical state of a single particle. Group and phase velocities, classical velocity of a particle and the group velocity of the wave representing the particle. Principle of superposition. Schrodinger equation. Probabilistic interpretation; equation of continuity, probability current density. Boundary conditions on the wave function.

2. **Postulates of quantum mechanics:** Dynamical variables as linear hermitian operators and eigen value equations, Momentum, energy and angular momentum operators. Measurement of observables, expectation values, Compatible observables and simultaneous measurements, Ehrenfest theorem.

3. **Time-independent and Time-dependent Schrodinger's equation:** Separation of variables in one dimension, stationary states, time evolution and expectation values of stationary and non-stationary states, Eigenstates, normalization and orthonormality, completeness

4. **Applications of Quantum Mechanics:** Free particle in one dimensional box, box normalization, momentum eigen functions of a free particle. One dimensional potential well and barrier, boundary conditions, bound and unbound states. Reflection and transmission coefficients for a rectangular barrier in one dimension, explanation of alpha decay. Linear harmonic oscillator, energy eigen values from Hermite differential equation, wave function for ground state, parity of wave function.

5. **Schrodinger equation in spherical polar coordinates:** Angular momentum operators and their commutation relations; eigenvalues and eigenfunctions of L^2 and L_z; theorem of addition of angular momenta [statement with examples]. The hydrogen atom problem, stationary state wavefunctions as simultaneous eigenfunctions of H, L^2 and L_z; radial Schrodinger equation and energy eigenvalues [Laguerre polynomial solutions to be assumed]; degeneracy of the energy eigenvalues.

Paper PH 303 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Statistical Mechanics I

1. **Basic probability concepts:** Elementary statistical concepts and examples, Microscopic and macroscopic systems, Basic probability concepts and relations among probabilities, Binomial distribution, Calculation of mean values, Probability density.

2. **Statistical descriptions of systems of particles:** Specification of state of a system, Statistical postulates and probability calculations, density of states, equilibrium and irreversibility, Interactions between two systems – thermal, mechanical and diffusive, statistical definition of temperature, pressure, entropy and chemical potential.

3. **Classical Statistics:** Macrostate & microstate, Classical description of state in terms of phase space and quantum description in terms of wave functions, Phase space: density of states in phase space (phase cells), Principle of equal a priori probability, Ergodic hypothesis, Classical Liouville's theorem, Elementary concept of ensemble: micro canonical, canonical and grand canonical ensembles, Entropy and thermodynamic probability, Maxwell-Boltzmann distribution law, Partition function and its properties, Calculation of thermodynamic functions (entropy, free energy) of an ideal monatomic gas, Classical entropy expression, Gibbs Paradox, Sackur-Tetrode equation, Law of equipartition of energy (with proof)-applications to specific heat and its limitations, Thermodynamic functions of a two-energy levels system, Negative temperature.

4. **Bose-Einstein Statistics:** B-E distribution law, Thermodynamic functions of a strongly degenerate Bose gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and thermodynamic functions of photon gas. Bose derivation of Planck's law.

5. **Fermi-Dirac Statistics:** Fermi-Dirac distribution Law, Thermodynamic functions of a completely and strongly degenerate Fermi gas, Fermi energy, Electron gas in a metal, Specific heat of metals, Relativistic Fermi gas, White dwarf stars, Chandrasekhar mass limit.

Paper PH 305 (50 Marks; 4 Credit) **LECTURES 45 + 15 Tutorial**

Solid State Physics I

1. **Crystallography:** Definition of crystal and amorphous; crystal translation vector, Space lattice, Bravais lattice, Lattice constant calculation: SC, BCC, FCC, HCP, Diamond, sodium chloride, cesium chloride, zinc blend, perovskite structure, lattice planes and Miller indices, inter-planer spacing crystal crystal structure, symmetry operation, point groups.

2. **Crystal Structure analysis by X-rays:** Diffraction of X-rays by crystals, reciprocal lattice, Brillouin zones, Bragg's law, The von Laue equations, Bragg's law in reciprocal lattice, Brillouin zones, atomic and geometrical structure factor, and experimental diffraction methods.

3. **Lattice Vibration:** Vibration of linear monatomic and diatomic lattices, excitation of optical branch in ionic crystals- the infrared absorption, localized vibrations, quantization of lattice vibrations, experimental determination of the dispersion relations, inelastic scattering on neutrons, inelastic scattering of X-rays.

4. **Free electron theory of metals:** Free electron gas model in metals, free electron gas in one dimensional box, free electron gas in three dimensional box, filling up of energy levels, density of states, the Fermi energy, average kinetic energy of an electron, average velocity of an electron, heat capacity of the electron gas, Boltzman transport equation, electrical conductivity, Drude Lorentz theory, Sommerfield theory, Hall effect, thermal capacity of metals, ratio of thermal to electrical conductivity, field emission.

5. **Band theory of solids:** Wave functions in a periodic lattice and the Bloch theorem, the Kronig-Penny model, approximate solution near a zone boundary and band gap, the tight binding approximation, band theory of insulators and semiconductors, intrinsic semiconductors, band model, Extrinsic semiconductors, impurity states and band model.

Paper PH 307 (50 Marks; 4 Credit) **LECTURES 45 + 15 Tutorial**

Digital Electronics

1. **Integrated Circuits** (Qualitative treatment only): Active & Passive components. Discrete components. Wafer. Chip. Advantages and drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification of ICs. Examples of Linear and Digital ICs.

2. **Digital Circuits:** Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers.

3. **Boolean algebra:** De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products, Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by Sum of Products (SOP), Products of Sum (POS) Method and Karnaugh Map.

4. **Arithmetic Circuits:** Binary Addition. 1’s and 2’s complement. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor.

5. **Data processing circuits**: Basic idea of Multiplexers, De-multiplexers, digital comparator (4 & 8 bit), Decoders, Encoders.

6. **Sequential Circuits:** SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop.

7. **Introduction to CRO:** Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference.

8. **Timers**: IC 555: block diagram and applications: Astable multivibrator and Monostable multivibrator.

9. **Shift registers:** Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-

10. Parallel-out Shift Registers (only up to 4 bits).

11. **Counters (4 bits):** Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counte, MOD-N counter

12. **Intel 8085 Microprocessor Architecture:** Main features of 8085. Block diagram. Components. Pin-out diagram. Buses. Registers. ALU. Memory. Stack memory. Timing & Control circuitry. Timing states. Instruction cycle, Timing diagram of MOV and MVI.

13. **Communication principles:** Modulation and demodulation – elementary theory of AM, FM and PM, their relative advantage/disadvantage, demodulation of AM (diode detector) and FM (slope detector) waves.

14. **Operational amplifier:** Characteristics of an Ideal and Practical Op-Amp (IC 741), Input bias current, offset voltage, concept of virtual ground, differential amplifiers, CMRR, gain-band width product, Applications of Op-Amps: inverting and non-inverting amplifiers, Adder, Subtractor, Integrator, differentiator.

Paper PH 391 (50 Marks; 4 Credit)

Physics Lab IV

1. To design a series regulated power supply with a power transistor as a pass element, a second transistor as a feedback element and Zener diode as a reference voltage source
2. B-H curve using ballistic galvanometer
3. Measurement of the wavelength separation of sodium D-lines using diffraction grating
4. Determination of the refractive index (μ) of the material of a prism by using spectrometer and hence the study of dispersion curve
5. To design a CE amplifier with a given midband gain and to study its performance
6. To determine the Hybrid parameters of a bipolar junction transistor in CE mode by using an ac source.
7. To find the temperature coefficient of resistances for platinum, using a platinum resistance thermometer and a Callender and Griffith's bridge
8. To determine the speed of ultrasonic waves in a liquid medium.
9. To determine the self inductance of a given coil by Rayleigh method.
10. To determine the wavelength of sodium light by sing bi-prism diffraction experiment.
11. Determination of mechanical equivalent of heat (J) by Callendar and Barne's method.

Semester-VI

Paper PH 302 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Atomic and Molecular Physics I

1. **Atomic Spectrum:** Spectrum of light, Bohr model for hydrogen like ions, experimental evidences, Rydberg atoms, Franck-Hertz experiment and its improvements, Bohr-Sommerfeld model, Bohr-Sommerfeld quantization rule and fine structure of H atom, spectra of alkali atoms.

2. **Vector Atom Model:** Magnetic moment of an electron for orbital motion, space quantization, Stern-Gerlach experiment, electron spin, vector model, Lande-g factor, interpretation of Stern-Gerlach experiment and spin as an intrinsic quantum number, Incompatibility of spin with classical ideas. Study of fine structure by Michelson interferometer, doublet lines of alkali spectra, spin-orbit interaction, Zeeman effect (normal & anomalous), Paschen-Back effect.

3. **Many Electron Atoms:** Pauli Exclusion Principle, Periodic table, Fine structure, Spin orbit coupling. Spectral Notations for Atomic States, Total Angular Momentum, Vector Model, L-S and J-J couplings, Hund's Rule, Term symbols of many electron atoms in the ground state, LS and JJ coupling. Spectra of Hydrogen and Alkali Atoms (Na etc.)

4. **Effects of external electric fields on one-electron spectra:** Linear and quadratic Stark effects, atomic polarizability

5. **X-ray:** continuous X-ray spectrum and its dependence on voltage, Duane and Haunt's law. Characteristics X-rays, Moseley's law, doublet structure and screening parameters in X-ray spectra, X-ray absorption spectra

6. **Molecular spectroscopy:** Diatomic molecules, rotational and vibrational energy levels, Basic ideas about molecular spectra. Raman effect and its application to molecular spectroscopy (qualitative discussion only).

Paper PH 304 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Classical Mechanics II & Special Theory of Relativity

1. **Rigid body rotational dynamics:** Moment of inertia about any axis – ellipsoid of inertia and inertia tensor, location of principal axes in simple symmetric cases. Angular momentum and kinetic energy; Inertial and non-inertial frame, Rotating frame of reference, Coriolie's and centrifugal force, illustration with simple examples. Foucault's pendulum, Euler's theorem, Euler's equation of motion, Force free motion of rigid bodies, Eulerian angles, free spherical top and free symmetric top.

2. **Lagrangian and Hamiltonian formulation of Classical Mechanics:** Generalised coordinates, constraints and degrees of freedom; D'Alembert's principle; Lagrange's equation for conservative systems (from D'Alembert's principle; variational principle not required) and its application to simple cases; Generalised momentum; Idea of cyclic coordinates, its relation with conservation principles; Definition of Hamiltonian, Hamilton's equation (derivation by Legendre transformation) and its application to simple cases.

3. **Special Theory of Relativity:** Concept of inertial frame and non-inertial frame, Galilean transformation and invariance of Newton's laws of motion, non-invariance of Maxwell's equations. Michelson-Morley experiment and explanation of the null result. Postulates of special theory of relativity; simultaneity; Lorentz transformation along one of the axes, length contraction, time dilation, Twin paradox and velocity addition theorem, Fizeau's experiment, Four vectors. Relativistic dynamics: variation of mass with velocity; energy momentum relationship, Doppler effect.

4. **Vectors and Tensors:** Covariant and contravariant vectors. Contraction. Covariant, contravariant, and mixed tensors of rank-2, transformation properties. The metric tensor (flat space-time only).

Raising and lowering of indices with metric tensors. (Consistent use of any one convention, diag(-1,1,1,1) or diag(1,-1,-1,-1).) Example of common four-vectors: position, momentum, derivative, current density, four-velocity.

5. **Invariant intervals:** Concept of space-time: Euclidean and Minkowski. Invariant intervals in 1+1 and 3+1 dimensions (use Minkowski space-time). Space like, time-like and light like four vectors. Light cone. Causality and simultaneity in different frames. Four Force and energy equations, Lagrangian and Hamiltonian of relativistic particles.

6. **Relativistic electrodynamics:** Transformation equation for momentum, current density and vector potential, transformation equations for field vectors and covariance of Maxwell equations in 4 vector form, covariance and transformation law of Lorentz force, self energy of electron.

Paper PH 306 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Nuclear and Particle Physics I

1. **Nuclear Properties:** Nuclear mass, charge, size, binding energy, spin and magnetic moment. Isobars, isotopes and isotones; mass spectrometer (Bainbridge).

2. **Structure of Nucleus:** Nature of forces between nucleons, nuclear stability and nuclear binding, the liquid drop model (descriptive) and the Bethe-Weizsacker mass formula, application to stability considerations, extreme single particle shell model (qualitative discussion with emphasis on phenomenology with examples).

3. **Unstable nuclei:** (i) Alpha decay: alpha particle spectra, velocity and energy of alpha particles. Geiger-Nuttal law. (ii) Beta decay: nature of beta ray spectra, the neutrino, energy levels and decay schemes, positron emission and electron capture, selection rules, beta absorption and range of beta particles, Kurie plot. (iii) Gamma decay: gamma ray spectra and nuclear energy levels, isomeric states. Gamma absorption in matter, photoelectric process, Compton scattering, pair production (qualitative).

4. **Nuclear reactions:** Conservation principles in nuclear reactions. Q-values and thresholds, nuclear reaction cross-sections, examples of different types of reactions and their characteristics. Bohr's postulate of compound nuclear reaction, Ghoshal's experiment.

5. **Nuclear fission and fusion:** Discovery and characteristics, explanation in terms of liquid drop model, fission products and energy release, spontaneous and induced fission, transuranic elements. Chain reaction and basic principle of nuclear reactors. Nuclear fusion: energetics in terms of liquid drop model.

6. **Particle Accelerator and Detector:** Cyclotron: basic theory, synchrotron, GM counter, Proportional counter, scintillation counter.

7. **Elementary particles:** Four basic interactions in nature and their relative strengths, examples of different types of interactions. Quantum numbers: mass, charge, spin, isotopic spin, intrinsic parity, hypercharge. Charge conjugation. Conservation laws.

Paper PH 308 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Electrodynamics I and Modern Optics

Electrodynamics I

1. **Basics:** Generalization of Ampere's Law, Equation of continuity, Displacement Current, Maxwell's Field Equations, Wave equation for electromagnetic (EM) field and its solution – plane wave and spherical wave solutions, transverse nature of field, relation between E and B, energy density of

field, Poynting vector and Poynting's theorem, boundary conditions.

2. **EM Waves in an isotropic dielectric**: Wave equation, reflection and refraction at plane boundary, reflection and transmission coefficients, Fresnel's formula, change of phase on reflection, polarization on reflection and Brewster's law, total internal reflection.

3. **Electromagnetic Waves in Conducting medium**: Reflection and transmission at metallic surface-skin effect and skin depth, Propagation of electromagnetic waves between parallel conducting plate-wave guides (rectangular only).

4. **Dispersion**: Normal and anomalous, Equation of motion of an electron in a radiation field: Lorentz theory of dispersion Sellmeier's and Cauchy's formulae, absorptive and dispersive mode, half power frequency, band width.

5. **Scattering**: Scattering of radiation by a bound charge, Rayleigh's scattering (qualitative ideas), blue of the sky, absorption.

Modern Optics

1. **LASER**: Historical background of LASER; Characteristics of Laser light; Einstein's A and B coefficients; Stimulated absorption, Spontaneous and Stimulated Emissions; Light amplification; Optical pumping and Population inversion; Rate equations: two-level, three-level and four-level systems; Optical Resonator, Modes of resonators; Metastable states; Solid State Laser- Ruby laser; Gas Laser- He-Ne and CO_2 lasers; Liquid laser- Dye laser; Semiconductor laser; Application of laser.

2. **Fiber Optics:** Physical nature of optical fiber: core, cladding and jacket; Critical angle, Acceptance angle, Total internal reflection and Numerical aperture; Classification of optical fibers: step index and graded index fiber, single and multimode fibers; TE and TM modes; Attenuation and dispersion in optical fiber; Analog and digital communication through optical fibers.

3. **Holography:** Importance of coherence in holography; Principle of holography and characteristics; Recording (construction) and reconstruction of hologram; classification of hologram and applications.

4. **Nonlinear optics:** Linear and nonlinear medium, Harmonic generation, Second and Third harmonic generation (SHG, THG), optical mixing, parametric generation of light.

Paper PH 392 (50 Marks; 4 Credit)

Physics Lab V

1. To study the use of OP-AMP as (i) an inverting amplifier (ii) a non-inverting amplifier (iii) a unity gain buffer (iv) an adder and (v) a differential amplifier
2. To study the use of OP-AMP as (i) logarithmic amplifier (ii) antilog amplifier (iii) simple voltage comparator and (iv) Schmitt trigger
3. Determination of the Fourier spectrum of certain complex wavefroms by using a parallel resonant circuit.
4. To design and construct a Wein bridge oscillator using OPAMP and diodes as amplitude stabilizer; also to study the performance of the oscillator and lead-lag network by using a CRO.
5. Resistance by half deflection method and half deflection method
6. To determine wavelength of spectral lines using plane-transmission grating

7. Measuring wavelengths of a LASER with a diffraction grating
8. To determine high resistance by the method of leakage of a condenser.
9. Verification of state tables of R-S flip-flop, J - K flip-flop, T Flip-Flop, D Flip-Flop Using NAND and NOR gates.
10. Experiments with Half adder and full adder.

FOURTH YEAR

Semester- VII

Paper PH 401 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Mathematical Physics II

1. **Complex Variable:** Analytic functions, Cauchy-Riemann equation; Cauchy's integral formula; Taylor's expansion, Laurent's expansion; singularities, poles and branch points; Residue formulae.

2. **Set and Group Theory:** Definitions and operations involving sets, algebra of sets, union and inter section, Cartesian product of sets, mapping, closed and open sets, convergence and completeness. Definition of groups, multiplication table, conjugates elements and classes, subgroups; direct product of groups; isomorphism & homomorphism, Permutation groups.

3. **Linear vector space and operators:** Vector space, inner product space, Schmidt's orthogonalisation method, Schwart inequality. Linear operators, matrix representation of operators. Special operators-conjugate operators, adjoint and self adjoint operators, unitary operators, orthogonality.

4. **Tensors:** General definition, contravariant, covariant and mixed tensors and their ranks; outer product of tensors, contraction of tensors, inner product of tensors; Symmetric and antisymmetric tensors; Kronecker delta. Metric tensor, raising and lowering of indices; Cartesian tensors.

5. **Integral transformation:** Laplace transformation and inverse Laplace transformation; Solution of differential equation using Fourier transforms and Laplace transformation; Dirac delta function and its FT.

Paper PH 403 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Classical Mechanics III

1. **Lagrangian Mechanics:** Review of D'Alembert's principle, Lagrange's equations, concept of symmetry, homogeneity and isotropy, conservation principles, Lagrange's equations for non holonomic systems, Lagrange's equations for impulsive forces.

2. **Hamiltonian Formulation:** Calculus of variations, Hamilton's principles, Lagrange's and Hamilton's equations from Hamilton's principles. Canonical transformations, generating functions, example of canonical transformation. Poisson Bracket, relations of P.B., Conservation theorems in P.B. Formulation. Hamilton-Jacobi equation, separation of variables, cyclic variables and the Kepler problem, Action angle variables, harmonic oscillator and Kepler problem in action-angle variables.

3. **Rigid Body Dynamics:** Euler angles, finite and infinitesimal rotations, inertia tensor, motion of a heavy symmetric top rotating about a fixed point in the body under gravity.

4. **Small oscillations:** condition of stability near equilibrium, the eigenvalue equation & principal axes transformation, frequencies of free vibrations and normal coordinates, vibrations of molecules.

5. **Continuous systems and fields:** Lagrangian and Hamiltonian formulation for continuous systems, symmetry and conservation principles, Noether's theorem, classical field theory

Paper PH 405 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Quantum Mechanics II

1. **Operator and Matrix method in Quantum Mechanics:** Linear vector space; Linear operators; Hilbert space; Hermitian and unitary operators; Completeness; Matrix representation, change of basis; Formulation of Quantum Mechanics in vector space language; Uncertainty principle for two arbitrary operators; co-ordinate and momentum representation.

2. **Quantum dynamics:** Equation of motion in Schrödinger, Heisenberg and interaction picture; One dimensional harmonic oscillator by operator method, time development of the oscillator, coherent state.

3. **Angular momentum**: Angular momentum operators, spherical harmonics, commutation relations between angular momentum operators, angular momentum by operator method, raising and lowering operators, matrix representation for j=1/2 and j=1, Pauli spin matrices, addition of two angular momenta, Clebsch-Gordan coefficients; Construction of spin eigen-functions

4. **Approximation methods for bound states-I**

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

Paper PH 407 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Numerical Analysis & Computation

1. **Computational Language (FORTRAN 77/90)**

a) Basic Linux commands and vi editor commands.
b) Constants and variables; variable types and declarations.
c) Assigment and arithmatic expressions.
d) Read and write statements, logical expression.
e) IF, Arithmatic IF, IF THEN ELSE statements.
f) GO TO, Computed GO TO statements.
g) DO loops, nested DO loops.
h) Functions and subroutines.
i) Arrays, 1 2 3 dimensionals.
j) Formatted input / output statements.
k) Precision: single, double, quadruple

l) xmgrace and gnuplot.

2. **Numerical Techniques**

a) Error in computation: definition and source of errors, propagating and control of errors.
b) Root finding for polynomial equations: Bisection method and Newton Raphson method, or use any other two methods.
c) Interpolation, extrapolation: Polynomial interpolation or any other method.
d) Numerical integration: Mid point rule and Trapezoidal rule or any two other methods.
e) Solving linear equations: Gauss elimination methods and Iterative solution methods.
f) Solving first order linear differential equations: Euler's method and Runge-Kutta method.

Paper PH 491 (50 Marks; 4 Credit)

Physics Lab VI

1. Interferometry with Michelson interferometer
2. Measurement of the Hall coefficient of a given sample and its temperature dependence using four probe method
3. Determination of Lande-g factor using ESR spectroscopy
4. Study of Amplitude Modulation and demodulation
5. Experiment with FET and MOSFET
6. Design and characterization of a stable multi-vibrator
7. Performance of Passive pi type and T type high pass and low pass filters

Paper PH 493 (50 Marks; 4 Credit)

Computer Lab

Simple Problems to Practice the Language

1. Finding the largest number in a set of numbers
2. Sum of some numbers except one of them.
3. Arranging numbers in increasing / decreasing order.
4. To test if the given number is prime; generating all prime numbers up to a given number.
5. Mean, variance standard deviation of a given set of numbers.
6. Factorial of a given number.
7. Generating the Fibbonaci series.
8. N atoms, each has two spin states. Enumerate all possible microstates, estimation of the energy of each of these states, distribution of magnetization and energy.
9. Converting a decimal number into a binary.
10. Matrix operations (addition, subtraction, multiplication, transpose).
11. Solution of 1st order differential equation etc.

12. Sum of a G.P. series term by term
13. Solution of a quadratic equation with real/complex roots.
14. Solution of a quadratic equation with real/complex roots.

Semester-VIII

Paper PH 402 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Electrodynamics II

1. **Recapitulation of electrodynamics:** Recapitulation of field equations, scalar & vector potentials, Lorentz and Coulomb gauge, Conservation laws, electromagnetic field tensor, covariance of electrodynamics, transformation of electromagnetic fields, relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

2. **Field of moving charges and radiations:** Retarded potentials, Lienard Wichert potentials, Field produced by arbitrary moving charged particle at low velocity and at high velocity, Angular distribution of radiation emitted by an accelerated charge, Total power radiated by an accelerated charge, synchrotron radiation

3. **Radiating System:** Oscillating electric dipole, radiation from an oscillating dipole, radiation from a linear antenna.

4. **Radiation in material media:** Cherenkov radiation, Thomson and Rayleigh Scattering, dispersion and absorption, Kramer Kroning dispersion relation.

Paper PH 404 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Solid State Physics II

1. **Imperfections in Crystals:** Lattice defects, Point defects, Schottky defects, Frenkel defects, Dislocation, Surface imperfections, Volume defects

2. **Theory of Semiconductors:** Intrinsic and Extrinsic semiconductors; Compound semiconductors; direct and indirect semiconductors; drift velocity, mobility and conductivity of Intrinsic semiconductors; Carrier concentration in N and P type semiconductors; Charge nutrality equation; Carrier transport in semiconductors

3. **Dielectrics:** Electronic, Ionic and Orientation Polarization, Internal field, Clausius-Mosotti equation, Ferro and Piezo electricity, Frequency dependence of dielectric constant, temperature dependence of dielectric constants and permanent molecular dipole moment, response of dielectric to an alternating fields.

4. **Magnetism**: Dia, para and ferro-magnetic properties of solids. Langevin's theory of diamagnetism and paramagnetism. Quantum theory of paramagnetism, Curie's law. Ferromagnetism : spontaneous magnetization and domain structure; temperature dependence of spontaneous magnetisation; Curie-Weiss law, explanation of hysteresis. Magnetic exchange interaction-Ferro, antiferro & ferrimagnetism. ESR and NMR

5. **Superconductivity** : Basic phenomenology, Meissner effect, London's phenomenological theory and penetration depth, critical magnetic field, coherence length, type-I and type-II

superconductors, magnetic flux quantization, entropy and specific heat, isotope effect, BCS theory, ac and dc Josephson effects, high temperature superconductors.

Paper PH 406 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Statistical Mechanics II

1. **Introduction:** Macrostate, microstate, phase space, volume in phase space, phase cells, density of states, counting the number of microstates in phase space, principle of equal priori probability, ensembles, partition function, MB, BE, FD distribution function.

2. **Microcanonical ensemble:** Microcanonical distribution, entropy, calculation of internal energy, entropy and chemical potential of a perfect gas.

3. **Canonical Ensemble:** System in contact with a heat reservoir, canonical distribution, canonical partition function and its correlation with thermodynamic quantities- expression of entropy, Helmholtz free energy, total energy, specific heat (C_v), fluctuation of internal energy. Canonical partition function for perfect monatomic gas and calculation of entropy, Helmholtz free energy and internal energy.

4. **Grand Canonical Ensemble:** System in contact with a particle reservoir, grand canonical distribution, grand canonical partition function, grand potential, fluctuation of particle number, chemical potential of ideal gas.

5. **Classical non-ideal gas:** Mean field theory and Van der Wall's equation of state; Cluster integrals and Mayer-Ursell expansion.

6. **Quantum statistical mechanics:** Indistinguishability and quantum statistics, exchange symmetry of wave functions, symmetric and anti-symmetric wave functions, average value in quantum statistics. Density matrix, density operator in statistical mechanics, quantum Liouville's theorem. Density matrices for equilibrium microcanonical, canonical and grand canonical ensembles, simple examples of density matrices- One electron in a magnetic field, A particle in a box, A linear harmonic oscillator. Statistics of identical and indistinguishable particles, Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics- a comparison, Pauli's exclusion principle.

7. **Ideal Bose and Fermi gas:** Calculation of energy and pressure of ideal Bose gas, gas degeneracy, Bose-Einstein condensation, calculation of entropy and specific heat of Bose gas, superfluidity. Calculation of energy and pressure of ideal Fermi gas, weak and strong degeneracy, Fermi gas at finite T, calculation of entropy, specific heat, free energy. Pauli's theory of paramagnetism.

8. **Phase Transition and critical phenomena:** General theory of phase transition, examples of phase transition and critical phenomena, magnetic phase transitions. Ising model: partition function for one dimensional case and exact solution in one dimension; Bragg-Williams theory; Critical exponents, calculation of exponents from Mean Field Theory and Landau's theory, upper critical dimension.

9. **Non-equilibrium Statistical Mechanics**: Time dependent correlation functions, Fluctuation and thermodynamic properties, Brownian motion, Langevin theory, Fokker-Planck Equation, Fluctuation-Dissipation Theorem.

Paper PH 408 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Semiconductor Physics & Device

1. **Fundamentals of semiconductor:** Idea of energy band, the Fermi level and energy distribution of carriers inside bands, temperature dependence of carrier concentration, carrier transport in

semiconductors, generation and recombination process of excess carriers in semiconductor and idea of quasi Fermi levels, basic equation of semiconductor device operations.

2. **P-N junction devices:** Majority carrier diodes: Tunnel diodes: principle of operations & I-V characteristics. Schottky barrier diodes: Metal semiconductor contacts, Schottky-Mott theory & surface states, Schottky effect, current flow mechanism, I-V characteristics, Ohmic contacts.

3. **Field effect transistors (FET):** Classification of various types of FETs, construction of junction FET, Principle of operation drain characteristics, biasing, operating region, pinch-off voltage. Structure and principle operation of MOSFET, depletion & enhancement type, I-V characteristics.

4. **Optoelectronic devices:** Photoconductor, Solar cell, Photodiode, LED, Semiconductor laser, Phototransistor, Thyristor.

5. **Power Amplifier:** Multistage amplifier, frequency response of a two stage R-C coupled amplifier, gain and band width and their product, operating point of class A,B, AB and C amplifier, analysis of single tuned voltage amplifier, requirement of power amplifiers, class B push-pull amplifier.

6. **Coupled Amplifier:** RC-coupled amplifier and its frequency response.

Paper PH 410 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Quantum Mechanics III

1. **Approximation methods for bound states-II**

   Time-dependent Perturbation Theory: interaction picture; Constant and harmonic perturbations; Fermi's Golden rule; Sudden and adiabatic approximations; Radiative transitions and Einstein's A & B coefficients

   Variational method: trial wavefunction, application to He atom as example, Exchange degeneracy; Ritz principle for excited states for Helium atom, Hylleraas-Undheim theorem

   WKB Approximation: Quantization rule, tunneling through a barrier, qualitative discussion of alpha-decay and related problems

2. **Symmetric in quantum mechanics:** conservation principles and degeneracy associated with symmetry, Continuous symmetries- spatial translation, rotation and time evolution, Discrete symmetries- Parity, time reversal and permutation, Rotation matrices, Spherical tensor operators, Wigner-Eckart theorem, Symmetry group and group representation.

3. **Identical Particles:** Meaning of identity and consequences, symmetric and antisymmetric wavefunctions, Slater determinant, symmetric and antisymmetric spin wavefunctions of two identical particles, collisions of identical particles.

4. **Quantum theory of potential scattering**: Laboratory and centre of mass frames, scattering cross-section amplitude, partial wave analysis, phase shift and resonance, scattering length, optical theorem, scattering by attractive square well and hard sphere, integral equation of scattering, Green's function, Lippmann-Schwinger equation, Born approximation, scattering by Yukawa potential, Coulomb scattering, introduction to S and T matrices

Paper PH 492 (50 Marks; 4 Credit)

Physics Lab VII

1. Interferometry with Fabry Perrot interferometer
2. To verify Fresnel's equations for reflection of electromagnetic waves
3. To find the e/m of an electron
4. Photoelectric effect: Measurement of Planck's constant
5. Dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibration
6. Determination of dielectric constant of different materials
7. Square and Triangular wave generator

FIFTH YEAR

Semester-IX

Paper PH 501 (50 Marks; 4 Credit) **LECTURES 45 + 15 Tutorial**

Quantum Mechanics IV

1. **Relativistic Quantum Mechanics**: Klein-Gordon equation and its inadequacies, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles, free particle Dirac equation, Dirac matrices, plane wave solution and its interpretation, negative energy states and hole theory, spin, helicity, chirality and magnetic moment of a Dirac particle, Dirac particle in central potential, relativistic angular momentum, radial Dirac equation and its solution for H-atom, non-relativistic limit of the Dirac equation, covariant formulation of Dirac equation, properties of gamma matrices, charge conjugation, normalization and completeness of spinors, bilinear covariants and their transformations under parity and infinitesimal Lorentz transformation, Weyl representation and chirality projection operators

2. **Field quantization:** Basic ideas, construction of conjugate momentum from Lagrange density, commutation relations for bosonic and anti-commutation relations for fermionic fields in terms of field and momentum or creation and annihilation operators, quantization of scalar and complex scalar fields, Quantization of non relativistic Schrodinger equation, Occupation number representation, Radiation field theory- electromagnetic field as oscillators, and vacuum quantization and its application in Lamb shift, energy and momentum of field quantum, interaction of atom with quantized radiation field, spontaneous and induced emission.

3. **Interacting field theory:** Interaction picture, covariant perturbation theory, S-matrix, Wick's theorem, Feynman diagrams

4. **Quantum electrodynamics:** Fourier decomposition of the field, Feynman propagator, divergent amplitudes, Canonical quantization of the photon field, Feynman rules of quantum electrodynamics

Paper PH 503 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Atomic Physics II

1. **One electron atom**: Introduction of quantum states; Atomic orbital; Parity of the wave function; Angular and radial distribution functions.

2. **Interaction of one-electron atoms with electromagnetic radiation:** Charge particles in an e.m. field, transition rates, absorption, stimulated emission, spontaneous emission, density of states, Einstein's coefficients, selection rules, allowed and forbidden transitions, spectrum of one electron atoms. Atomic life-time and metastable states, line shapes and line width- natural line width, Doppler broadening, pressure broadening.

3. **Fine and hyperfine structure of one electron atoms:** Fine structure of hydrogen atom- relativistic corrections to the kinetic energy, spin-orbit term and Darwin corrections, fine structure splitting, selection rules and spectral lines, Lamb shift. Hyperfine interaction and isotope shift; hyperfine splitting of spectral lines and selection rules. Effect of external magnetic field- Strong, moderate and weak field.

4. **Spectra of two-electron atoms**: Exchange force, singlet and triplet states, para and ortho states. Schrodinger equation of two electron atoms, spin wave functions and role of Pauli's exclusion principle, level scheme of two electron atom (He atom). Independent particle model, quantum mechanical calculation of ground state energy of He atom- perturbation theory. Excited states of two electron atoms. L-S and j-j coupling schemes for two electron atoms.

5. **Many-electron theory:** Identical particles, symmetric and anti-symmetric wave function, wave functions for bosons and fermions, Pauli's exclusion principle, Slater determinant. Central field approximation for many electron atom; electron states in central field- configurations, shells and subshells. LS and j-j couplings for many electrons, equivalent and nonequivalent electrons, spectroscopic terms, Hunds rule, Lande interval rule, energy levels and spectra for many electron atoms. *Theoretical model for many-electron atoms*: Model of independent electron, Hartree method, Hartree-Fock method and Thomas-Fermi model.

6. **Spectra of alkali and alkaline earth atoms**: Effective model potential, spin-orbit interaction and fine-structure, hyperfine structures, examples with Na and Be atoms.

Paper PH 505 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Molecular Physics II

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

2. **Spectra of Diatomic Molecules:** Solution of nuclear equation; Molecular rotation: rigid and Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential. Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra.

3. **Raman spectroscopy:** Rotational, Vibrational, Rotational-Vibrational , electronics Raman spectra. Stokes and anti stoke Raman lines. Selection Rules. Spectral structures. Nuclear spin and its effect on Raman spectra.

4. **Vibration of polyatomic molecules:** Molecular symmetry, matrix representation of the symmetry elements of a point group, reducible and irreducible representation, character tables for C_{2v} and C_{3v} point groups, normal co-ordinates and normal modes, application of group theory to molecular vibration.

Paper PH 507 (50 Marks; 4 Credit) **LECTURES 45 + 15 Tutorial**

Nuclear & Particle Physics II

1. **Nuclear Interactions and Nuclear Reactions**: Nucleon interaction, exchange forces and tensor forces, Meson theory of nuclear forces, nucleon-nucleon scattering, effective range theory, spin dependence of nuclear forces, charge independent and charge symmetry of nuclear forces, isospin formalism, Yukawa interaction

2. **Direct and compound nuclear mechanisms**: Cross-sections in terms of partial wave amplitudes, compound nucleus, scattering matrix, reciprocity theorem, Breit-Wigner one level formula, resonance scattering

3. **Alpha decay**: Gamow's theory

4. **Beta decay**: Angular momentum and parity selection rules, allowed and forbidden transitions, selection rules, parity violation, two component theory of neutrino decay, detection and properties of neutrino, Gamma decay, multiple transitions in nuclei, angular momentum and party selection rules, internal conversion, nuclear isomerism

5. **Two-body nuclear problem:** deuteron ground state, nuclear scattering, sources on neutrons, its detection, measurement of energy, neutron diffraction application, interaction of neutron with matter

6. **Elementary Particle Physics**: Symmetry and conservation laws, elementary ideas of CP and CPT invariance, classification of hadrons, Lie algebra, SU(2), SU(3) multiplets, quark model, Gell-Mann-Okubo mass formula for octet and decuplet hadrons, charms, bottom and top quarks

7. **Nuclear Astrophysics**: Primordial nucleosynthesis, energy production in stars, pp chain, CNO cycle. Production of elements (qualitative discussion).

Paper PH 591 (50 Marks; 4 Credit)

Physics Lab IX

1. Molecular absorption spectroscopy (Iodine absorption)
2. Experiments with optical fiber
3. Saturation magnetization of ferromagnetic substance using hysteresis loop tracer
4. Measurement of velocity of light
5. Verification of Coulomb's Law (by method of image charge): Measurement of permittivity of air
6. Microwave diffraction
7. Measurement of magnetic susceptibility by Guoy's Method
8. Study of polarization of light

Paper PH 593 (50 Marks; 4 Credit)

GRAND VIVA

Semester-X

Paper PH 502 (50 Marks; 4 Credit) LECTURES 45 + 15 Tutorial

Material Physics I

1. **Physics of Nanostructures:** Reviews of quantum mechanics in reduced dimensions and solid state physics, Transport in low-D systems, Nano-scale phenomena and the related chemical, physical and transport properties, size effect and quantum mechanics, nano-thermodynamics optoelectronics of nanostructures, Nanotubes and nanowires, clusters and nano-crystallites.

2. **Nanostructured Materials and their Applications:** Physics of thin film deposition, adsorption, surface deposition, nucleation growth and structure development; Surface structure, role of surfaces in nanosciences; Epitaxial growth, lattice mismatch and strain, growth modes, self organization, self aligned nanostructures, heterostructures; Growth of quantum structures, Q-wells, Q-wires and Q-dots, Multilayer superlattice structures, single photon sources, Bulk nanostructured materials, porous silicon, Metal Nanoclusters, Semiconducting Chalcogenitde and oxide based nanocrystals and nanoparticles, nanowires, applications; Carbon clusters, Carbon nanotubes, applications; Polymers and polymer based composites, conducting polymers.

3. **Design and synthesis of nanostructure materials:** Physics of nanoscale engineering, nanofabrication, Processing of organic, inorganic and bio-based nano particles, nano composites. Common techniques for nano-structure fabrication, Top down and bottom up approach, Chemical process: Sol-gel method, plating, ion exchanged and reduction electro deposition technique, L-B technique; Physical process: vaporization, sputtering, chemical vapour deposition, molecular beam epitaxy and laser ablation and related theories and technology for thin film growth, condensation, nucleation, phase stability and basic modes of thin film growth, zone models for evaporated and sputtered coatings, factors on properties of thin films, columnar structure and epitaxial growth.

4. **Advanced Characterization Techniques for nano materials:** Microscopy: Compound microscopes, Electron microscopes, Scanning Electron microscope (SEM), Scanning Tunneling microscope (STM), Transmission Electron Microscope (TEM), Atomic force microscope (AFM).

5. **Spectroscopy:** UV- VIS- IR spectrophotometer, Fourier infrared Transform Spectrometer (FTIR) Raman spectrophotometer.

Or

Advanced Atomic and Laser physics

1. **Electron-atom collisions and atomic photoionization:** General features, elastic and inelastic electron-atom collisions at low energies, estimation of scattering amplitude and differential cross-section of electron collision with atomic hydrogen, Introduction of Feshbach projection operator formalism, S, T and K matrix, resonances, qualitative discussion on the relativistic effects for heavy atoms and ions, Elastic and inelastic electron-atom collisions at high energies, The Born series, Bethe-Born approximation, electron-impact ionization of atoms, Atomic photoionization, calculation of cross-section for one-electron atoms or ions, resonances in photoionization and photo-detachment

2. **Atom-atom collisions:** collision at very low energies, The semi-classical theory of atom-atom collision, rainbow scattering, Non-elastic collision between atoms, symmetrical resonance, state selectivity, atom-atom collision at high velocities, excitation and ionization, charge exchange

3. **Explicitly correlated methods for Few-body systems:** Configuration Interaction method (CI), Hylleraas method, Hylleraas-CI method and Hyperspherical method

4. **Coherent interaction of atomic system with LASER:**
   (a) Induced resonant transitions, decay phenomena, rotating wave approximation, exact Rabi solution in the strong field, Rabi flopping, dressed state picture.
   (b) Density matrix, rate equation for density matrix, optical Bloch equations, vector model of density matrix, Bloch sphere.

5. **Laser Spectroscopy**: Physical effects of strong fields on atomic matter: basic concepts of light-induced effects on atomic matter, Inclusion of phenomenological aspects of population and depopulation in a two-level system. A stationary two-level atom in a standing wave, A moving two-level atom in traveling wave, A moving two-level atom in a standing wave, Lamb dip, Saturation phenomena, Hole burning, physical significance, Three-level systems with two laser fields: pump-probe spectroscopy concepts and approach.

6. **Mechanical effect of LASER:** Dynamics of an atom in a LASER field, light forces on atoms, Radiation pressure forces, Dipole force, Optical potential

7. **Laser cooling, trapping and Bose-Einstein condensation:** Doppler cooling, cooling of an atomic beam, optical molasses, Doppler cooling limit, sub-Doppler cooling: Sisyphus cooling, recoil cooling limit, magneto-optic trap, magnetic trap, quadrupole trap, optical trap, experimental technique. Theoretical overview of Bose-Einstein condensate, experimental realization, evaporative cooling, observation of condensate.

Paper PH 504 (50 Marks; 4 Credit) **LECTURES 45 + 15 Tutorial**

Material Physics II

Electronic Structure of Materials

Basics: Electrons in periodic potentials: Bloch's theorem, Kronig Penney model, concept of energy bands, NFE model, TB model; Density of states:Green's function, Tridiagonal matrices & Continued fractions, Singularities in DOS; Reciprocal lattice & Brillouin zone: Special k points in BZ sampling

Electron Ion Problem: Adiabatic approximation (Born Oppenheimer); Classical nuclei approximation (Ehrenfest Theorem); Hellman Feynman force on nuclei.

Many Electron Problem: Hartree approximation, LCAO method**;** Hartree Fock approx: Slater determinantal wavefunction & its properties, Hartree Fock equation, Fock operator, Energy of the groundstate, Koopman's theorem; Going beyond Hartree Fock (introductory), absence of correlation in H F theory, Density Functional Theory, Energy as a functional of density : basic concepts,. Thomas Fermi theory, Hohenberg Kohn Theorem, Kohn Sham Eqn., LDA for the exchange correlation function

Advances in X-ray analysis for electronic and crystal structure

X-ray and Crystal structures: X-ray sources – synchrotron radiation – X-ray optics – monochromatization, collimation and focusing – X-ray detectors – point, linear and area detectors - physical and geometrical factors affecting X-ray intensities.

General theory of X-ray scattering and diffraction; Scattering by an electron, atom, atomic scattering factor, scattering by a conglomerate of atoms in regular order, scattering by a crystal, crystal structure factor, Reciprocal lattice, relations between reciprocal lattice and direct lattice vectors. Ewald's shere, Laue conditions, Bragg's Law, Laws of systemic absences from different crystal systems. Phase identification by Hanawalt's method. Quantitative estimation of different phases, some important applications.

Experimental approach: Basic concepts of small angle X-
ray scattering and its application in evaluation of shape and size of surface particles. X-ray reflectivity,

grazing incidence X-ray scattering. Dynamical theory of X-ray diffraction, X-ray microscopy, Fourier analysis of the diffraction profiles. Estimation of defect parameters from line shape analysis.

X-ray and electronic structures: Photoelectron spectroscopy and inverse photoelectron spectroscopy; Theory of Photoemission, Core-level and valence level photoemission, Three step consideration, Photoexcitation and photoionization, Core Levels (XPS) and Final States; Core-Level Binding Energies in Atoms and Molecules, The Equivalent-Core Approximation, Chemical Shifts, Koopman's theorem. Charge-Excitation Final States: Satellites, Continuous Satellites and Plasmon Satellites: XPS Photoemission in Nearly Free Electron Systems Valence Orbitals in Simple Molecules and Insulating Solids, UPS Spectra of Monatomic Gases, Photoelectron Spectra of Diatomic Molecules, Resonance photoemission spectroscopy.

X-ray Absorption; theory of inner shell excitation and X-ray absorption spectroscopy, near edge X-ray absorption.

Or

Advanced Nuclear and Particle Physics

Nuclear Reaction

- Nuclear reactions
  a) Introduction: Survey of reactions of nuclei: Strong, electromagnetic and weak processes, Types of reactions and Q-values, Threshold energy, Reaction mechanisms: Energy and time scales for direct and compound reactions, Experimental observables: Cross sections — definitions and units; Angular distributions, Excitation functions,
  b) Low energy behaviour and astrophysical S-factors, Maxwell-Boltzmann distribution of velocities, Thermal reaction rates and the Gamow peak.
  c) Neutron Physics
- Models for nuclear reactions
  a) Direct reactions: Optical Model: From Hamiltonian to cross sections for elastic scattering; partial waves, phase shifts, scattering amplitudes, **o**ptical potential.
  b) Nuclear Fission: Spontaneous fission, Mass energy distribution of fission fragments, Bohr-Wheeler theory, Fission isobars, Super-heavy nuclei.
  c) Compound nuclear reactions. Breit-Wigner one-level formula.
- Reactions involving exotic nuclei
- Nuclei far away from the stability valley: drip line, extremely neutron rich nuclei, superheavy nuclei.
- Basic Nuclear Reactors & Particle Accelerators

Particle Physics

- Preliminaries: Different types of symmetries and conservation laws. Noether's theorem.
- Symmetry groups and Quark model: SU(2) and SU(3): root and weight diagrams, Composite representation, Young's tableaux, quark model, colour, heavy quarks and their hadrons.
- Hadron structure: Elastic e-p scattering, electromagnetic form factors, electron-hadron DIS, structure functions, scaling,sum rules, neutrino production.
- Strong interactions: QCD, asymptotic freedom, gluons and jets in $e^+ e^- \rightarrow$ hadrons, Scaling violation.
- Low energy weak interactions: Fermi theory, calculation of decay widths of muon and π^+.
- Neutrino physics: Theory of two-flavour oscillation. Solar and atmospheric neutrino anomalies. Neutrino experiments.
- Flavour physics: Quark mixing, absence of tree-level FCNC in the Standard Model, the CKM matrix, oscillation in K and B systems, CP violation.
- HEP experiments: Relative merits and demerits of $e^+ e^-$ and hadronic colliders, LEP, LHC, B-factories.

Paper PH 507 (50 Marks; 4 Credit) **LECTURES 45 + 15 Tutorial**

General Theory of Relativity and Astrophysics

General Relativity

1. **Principles of relativity:** Overview of Special Relativity, Unit conversion between SI and GR units, space-time interval and Lorentz metric, proper time, action for free particle, relativistic dynamics, four vectors, electrodynamics in 4 dimensional language. Introduction to general relativity (GR), equivalence principle, gravitation as a manifestation of the curvature of space-time

2. **Geometrical framework of General Relativity:** Curved spaces, tensor algebra, Metric tensor, it's properties and affine connection, Geodesics, covariant derivatives and parallel transport, Curvature-Riemann tensor, Bianchi identities, Ricci tensor, Energy momentum tensors, Einstein's field equations

3. **Solutions to Einstein's equations and their properties:** Spherical symmetry, derivation of the Schwarzschild solution, test particle orbits for massive and massless particles. Inner most stable circular orbit (ISCO), Precession of the Perihelion, Schwarzschild Embedding Diagram, Deflection of Light, Gravitational lensing, Image Brightness

4. **Applications of GTR**

   Alternative co-ordinates: Event horizon, Tortoise co-ordinates, Eddington-Finkelstein co-ordinates, Kruskal-Szekeres metric

   Black holes: Kerr metric in Boyer-Lindquist co-ordinates, Energy extraction from a rotating black hole-Penrose process, Reissner-Nordstrom black hole, Kerr-Newmann blackhole (no derivation of the metric required), Blackhole thermodynamics

   Gravitational Waves: Linearized field equations - Gravitational Waves-polarization, he-licity, energy momentum; Generation of Gravitational waves; effect on a test particle; Binary pulsar; detection of gravitational radiation.

Astrophysics

Relativistic Hydrodynamic equilibrium, Tolman-Oppenheimer-Volkoff equation, Degeneracy of matter, Stellar models, Polytropic Stars, Lane-Emden equation, Chandrashekhar mass limit, Formation of White dwarfs, Neutron Stars and Black holes

Paper PH 592 (50 Marks; 4 Credit)

Advanced Physics Lab

Material Physics

1. Absorption / Transmission of thin films by using UV/Vis spectrophotometer.
2. Determination of susceptibility of paramagnetic solution (Ferric chloride and Manganese sulphate)
3. Dielectric and Curie temperature measurement of ferroelectric ceramic (Barium Titanate-$BaTiO_3$)
4. To measure the transition temperature of a high temperature superconductor and demonstrate the Meissner-Ochsenfeld effect
5. Photo-conductivity experiment
6. Preparation and V-I characterization of Thin film
7. Study of Dielectric Polarization and Dielectric spectroscopy

8. Preparation of Nano-particle

Advanced Atomic, Molecular and Nuclear Physics

1. Study of Zeeman effect
2. Study of Faraday effect
3. Study of Karr effect
4. Experiment with optical fiber
5. Characteristic study of a diode laser
6. Determination of the gamma and beta ray absorption coefficients by using a G.M. counter.

Paper PH 594 (100 Marks; 8 Credit)

Project work & Seminar presentation

RECOMMENDED BOOKS

Mathematical Physics

1. Mathematical Methods for Physics, Arfken & Weber (Elsevier)
2. Introduction to Mathematical Physics, C. Harper (Prentice-Hall of India)
3. Mathematical Methods, M. C. Potter and J. Goldberg (Prentice-Hall of India)
4. Vector Analysis, M. R. Spiegel, (Schaum's Outline Series) (Tata McGraw-Hill)
5. Mathematical Physics, P.K. Chattopadhyay (Wiley Eastern)
6. Tatwiya Padartha Bidyar Bhumika, S. Sengupta, Asok Ghosh and D. P. Roychaudhuri (West Bengal State Book Board)
7. Mathematical Physics, H. K. Dass, Dr. Rama Verma (S. Chand)
8. Mechanics & Mathematical Physics, R. Murugeshan (S. Chand)
9. Mathematical Physics, B. S. Rajput (Pragati)
10. Mathematical Methods, Morse & Feshbach
11. Mathematical Physics, B.D. Gupta (Vikas Pub)
12. Mathematical and Experimental Physics, S. Jayalakshmi, J. Arokiaraj & others (Narosa)
13. A Text book of Mathematical Physics, Suresh Chandra (Narosa)
14. Vector Spaces and Matrices in Physics, M.C.Jain (Narosa)

Classical Mechanics

1. Theoretical Mechanics, M. R. Spiegel, (Schaum's Outline Series) (McGraw-Hill)
2. Mechanics, K. R. Symon (Addison-Wesley)
3. Introduction to Classical Mechanics, R. G. Takwale and P. S. Puranik (Tata McGraw-Hill)
4. Classical Mechanics, N. C. Rana and P. S. Joag (Tata McGraw-Hill)
5. Mechanics and General Properties of Matter, D. P. Roychaudhuri and S. N. Maiti (Book Syndicate)
6. Padarther Dharma, D. P. Ray Chaudhuri (West Bengal State Book Board)
7. The Feynman Lectures on Physics, Vol I (Addison-Wesley)
8. An Introduction to Mechanics, D. Keppner and R.J. Kolenkow (Tata McGraw-Hill)
9. Mechanics, H. S. Hans and S. P. Puri (Tata McGraw-Hill)
10. Classical Mechanics, J. Goldstein (Narosa Publ. House)
11. Classical Mechanics, A. K. Roychaudhuri (O. U. P., Calcutta)
12. Berkeley Physics Course, Vol-I (Mechanics) (Mc Graw Hill)
13. Mechanics, D. S. Mathur, P.S. Hemne (S. Chand)
14. Classical Mechanics, Suresh Kr. Sinha (Narosa)
15. Classical Mechanics, N. Mukundo
16. Classical Mechanics, Sommerfeld

General Properties of Matter

1. Mechanics & General Properties of Mater, D. P. Roychowdhuri & S. N. Maiti
2. A Treatise on General Properties of Mater, Sengupta & Chatterjee (Central)

3. General Properties of Mater, A. B. Gupta
4. Advance Problems & Solutions in Physics, S. N. Goswami (Books & Allied Ltd.)
5. Properties of Matter, R. Murugeshan (S. Chand)
6. Properties of Matter and Acoustics for B.Sc., R. Murugeshan, Kiruthiga Sivaprasath (S. Chand)
7. Elements of Properties of Matter, D. S. Mathur (S. Chand)
8. Properties of Matter, Brij Lal (S. Chand)
9. Physics for Degree Students for B.Sc. Second year, C. L. Arora, P.S. Hemne (S. Chand)

Heat & Thermodynamics

1. Heat and thermodynamics, Zemansky and Ditman (Mc Graw Hill, Kugakusha)
2. Kinetic theory of gases, Loeb (Radha Publ. House)
3. Thermodynamics, F. Fermi (Dover)
4. Tapgatividya, Asoke Ghosh (West Bengal State Book Board)
5. A Treatise on Heat, Saha and Sribastava (The Indian Press Ltd)
6. Gaser Anabik Tattwa, Pratip Kumar Chaudhuri (West Bengal State Book Board)
7. Thermal Physics, S. Garg, R. M. Bansal, C. K. Ghosh (Tata Mc Graw Hill)
8. Heat and Thermodynamics, H. P. Roy and A. B. Gupta (New Central Book Agency)
9. Text Book of B. Sc. Physics (Thermodynamic & Optics), A. Kamal, R. B. Ramchander (S. Chand)
10. Thermal Physics, R. Murugeshan, K. Sivaprasath (S. Chand)
11. Heat, Thermodynamics and Statistical Physics, Dr. N. Subrahmanyam, Brij Lal, P.S. Hemne (S. Chand)
12. Basic Thermodynamics, E. Guha (Narosa)
13. Thermodynamics, Kinetic theory and statistical Thermodynamics, F. W. Sears, G.L. Salinger (Narosa)

Acoustics & Waves

1. Advanced Acoustics, D. P. Ray Chaudhuri (Chayan-Kolkata)
2. Waves and Oscillations, Rathin N. Chaudhury (New Age Publ.)
3. Waves, J R Crawford (Tata McGraw Hill)
4. A Text Book Oscillations, Waves & Acoustics, M. Ghosh, D. Bhattacharya (S. Chand)
5. Sound, K. Bhattacharyya (Shreedhar Prakashani)

Optics

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